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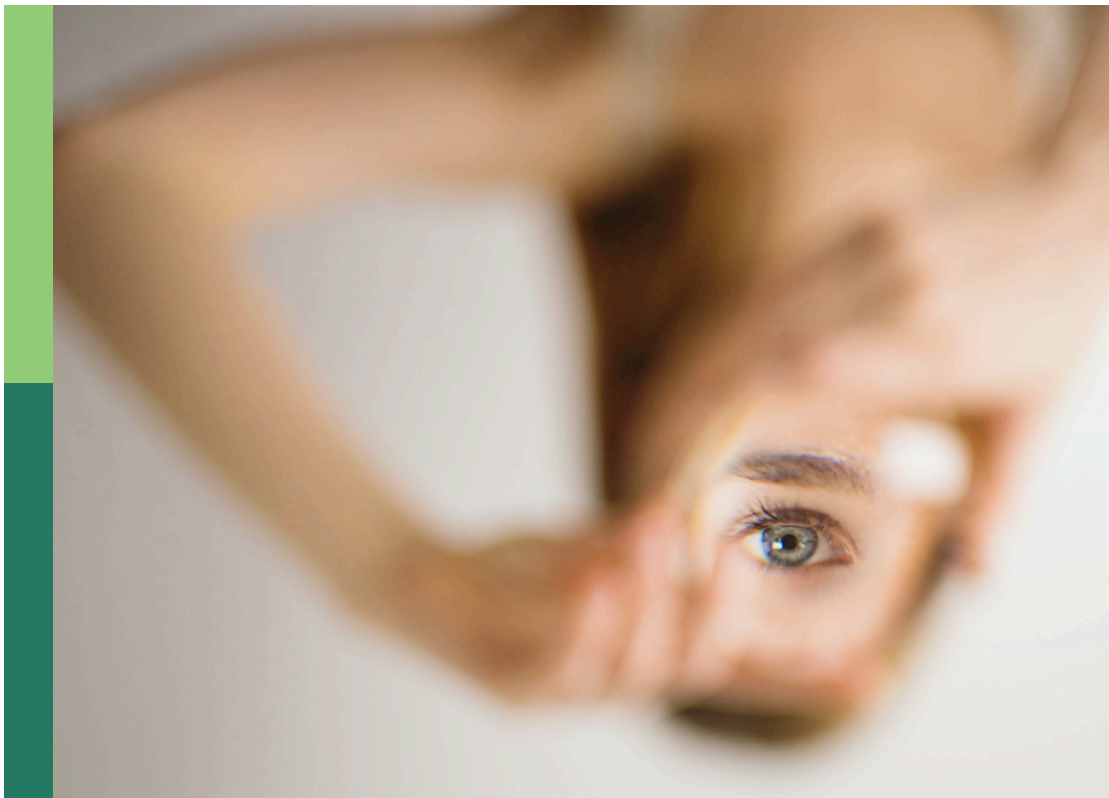

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Caring approaches to young, gifted music learners' education: a PRISMA scoping review

Guadalupe López-Íñiguez[1]* and Gary E. McPherson[2]

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This study reviews empirical research literature that deals with existing caring approaches to nurture and educate gifted children in music. The focus on the ethics of care stems from the need to expand notions of talent development in music from a purely behaviorist focus often associated with traumatic experiences, toward a perspective that addresses socio-emotional and cultural aspects of human development across the lifespan. We employed the Preferred Reporting Systems for Systematic Reviews and Meta-Analyses for Scoping Reviews method to review literature concerning caring approaches to the upbringing and education of children gifted for music. A total of 652 records dating from the 1930s and searched via both digital databases and manually in 41 relevant journals were retrieved from which 506 were examined using our inclusion criteria. A detailed analysis process allowed the authors to include 14 studies that were organized according to sampling location, methodologies, quality appraisal, and criteria-related topics. Eleven of the studies were qualitative with a majority of these employing semi-structured interviews for data collection, while the remaining meta strategy and quantitative studies typically employed questionnaires. Salient topics covered by the selected studies included: addressing inequalities in opportunity to access gifted programs; identifying socio-emotional needs of gifted (and twice-exceptional) students; offering a nurturing environment; focusing on intrinsic motivation; developing coping strategies for overall wellbeing; and cultivating healthy attitudes toward competitions through a spirit of peer collaboration and humility. These aspects were clustered into Francoy Gagné's Differentiated Model of Giftedness and Talent regarding natural abilities, environmental, intrapersonal, and developmental catalysts that are involved in nurturing talents in gifted children. Results suggest that the existing research on caring approaches to musically gifted children's learning and development are scarce and that current knowledge is based mostly on single one-off studies rather than systematic research, and on studies that examine a selection of aspects but not adopting a larger-scale theoretical framework. This review highlights the need for more systematic, multidisciplinary, and empirically robust studies on caring approaches to musically gifted children's learning and development, and for policy developments in educational settings where acceleration programs are offered for young, gifted music learners.

KEYWORDS

care ethics, giftedness and talent, music education, music performance, PRISMA-ScR, scoping review, socio-emotional development, special needs

1. Introduction

Ever since Seashore (1919) published *The Psychology of Musical Talent* in 1919, researchers have discussed various conceptions of musical ability and how musical talent can be developed during childhood (e.g., Hallam, 2010; McPherson et al., 2022) and later stages (MacNamara et al., 2006). A large focus has been placed on the environmental catalysts that enhance (e.g., Sloboda and Howe, 1999) or impede (Persson, 2000) musical development. Literature in this area has been considerably expanded across the past 25 years. Much of this literature is focused on evidence-based discourses that advocate an expansion of the focus on describing and explaining various forms of giftedness/talent (Preckel et al., 2020), or seeks to understand more precisely the most acute forms of giftedness that distinguishes musical prodigies (i.e., McPherson, 2016; and especially Gagné and McPherson, 2016).

Another important aspect in music research has focused on how to support students with special needs (e.g., Adamek and Darrow, 2010; Kivijärvi and Poutiainen, 2019) even though within this group of studies far less attention has been given to the socio-emotional needs of or specialized education provision for gifted children as compared, for example, to children who are autistic or have a physical or mental deficit that impacts on one or more aspects of their daily lives. Although approximations to the nurturing of twice-exceptional students in music (those with both high abilities and disabilities) have been theoretically discussed (e.g., Abramo, 2015; McCord, 2017), there is a gap in how special needs courses in higher music education often do not include content regarding gifted children. Such practices are often based on anti-elitist and anti-ableist unconscious bias regarding gifted students (e.g., Brown et al., 2005; Moltzen, 2009).

In light of this, the focus of this article is on research concerned with children who are highly gifted and, specifically, how their individual needs and expectations might be best served when they experience a musical education that is focused on their social and emotional needs, as well as their access and opportunity to undertake a highly specialized training program that develops their physical and mental skills as musicians in caring manners that safeguard their wellbeing and childhood rights. Within this understanding, Gagné's (2021) developed his Differentiated Model of Giftedness and Talent (DMGT) to define the range of natural abilities, environmental, intrapersonal, and developmental catalysts that play a part in the nurturing of young, gifted music learner's talents. In this model, it is assumed that children can be considered gifted for music when they display unusually precocious "intellectual, creative and/or physical maturity well before the majority of their peers" (Gagné, 2021, p. 77). Not only is Gagné's model used by researchers internationally as a guiding framework for research on multiple dimensions of giftedness and talent, but it also forms the basis of curricula and educational policies that are used in a number of school systems worldwide (VanTassel-Baska, 2022).

2. Expanding approaches to the education of young, gifted music learners

For nearly a century, the general conceptual landscape on giftedness and talent in music has been one of the most controversial and puzzling topics for scholars and practitioners alike. To date, much of the literature has focused either on the acquisition of skills or on exclusively environmental factors within selected contexts to define high abilities, as well as the intra- and inter- personal factors that explain the development of high levels of musical talent. Examples include the pioneering work of John Sloboda, Michael Howe, and Jane Davidson with students in specialist music schools in England during the 1990s. Overall, their set of studies (e.g., Howe et al., 1998; Sloboda and Howe, 1999) highlighted the importance of establishing specific quantities of practice, and also the role of environmental catalysts—and especially teachers and parents—in helping to stimulate and sustain the high levels of practice needed in order to acquire high levels of musical skill. Yet, their work did not cover the types of variation in individual achievement due to personal musical aptitudes (see Gagne, 1999) or the types of educational opportunities that would cater for the specific needs of individual learners (Davidson and McPherson, 2017).

In addition, the study of the acquisition of skills and the development of musical abilities in young children (e.g., Hallam, 2010), has been an important topic for some disciplines (psychology, neuroscience), but has often taken a behaviorist position oriented toward exclusively developing cognitive-motoric characteristics, or how to recognize giftedness at increasingly early stages. This has led to maximizing gifted children's potential through acceleration programs purely oriented toward skill acquisition and domain-specific expertise (e.g., Haroutounian, 2002). At the same time, most of these studies have taken a Global North-focus and narrow emphasis on either a biographical account of a single musician, collections of interview materials from a handful of selected individuals, narrative descriptions of the traumatic damage caused to them by abusive tutors/teachers, or by exposure to society at an early age (e.g., McPherson, 2016; Salasuo et al., 2017).

Because of neoliberal practice in professional education and the age of measurement we live in (e.g., Kohn, 1992; Biesta, 2010), conceptions of musical giftedness have rarely been connected to critical discourses about disadvantaged groups of learners with special needs, or the responsibilities of music schools, music universities, and music conservatories in 21st century societies toward their healthy, all-rounded development (besides and beyond the acquisition of talent at any cost). Typically, the education of young, gifted music learners has been based on widely spread reductionist and stereotypical beliefs concerning giftedness/talent, wherein the notion of childhood ethics is missing from the notion of gifted child (e.g., Beauvais and Higham, 2016). Thus, when a child demonstrates an exceptional ability in music—e.g., cognitive, creative, affective, sensorimotor—, the socioemotional troubles tend to be seen as an inevitable side effect

inherent to their persona (Gagné and McPherson, 2016). Such learners are typically conceived of as successful stars from elitist backgrounds who are capable of coping by themselves and for whom no additional support is needed (Brown et al., 2005; Moltzen, 2009).

Remarkably, and in distinct contrast to advances that have been made in defining and explaining the acquisition of musical and other forms of human accomplishment, only a few theoretical attempts have been made to envisage an inclusive education for the gifted (Slote, 2013). Apart from a few theoretical descriptions (Savage, 2006; Abramo and Natale-Abramo, 2020), little is known about the applicability of caring educational ecosystems in the nurturing of young, gifted music learners (e.g., Kenneson, 2002), and what kind of institutional changes are required to develop such ecosystems. Moreover, the contemporary reflective practitioner discourse has not fully recognized the need for such professional music education practice in which technical expert knowledge is not seen as the ultimate end but "the mediating means in the service of human good that needs to be guided by" what López-Íñiguez and Westerlund (in press) refer to, in the giftedness context, as "moral wisdom." In line with Smith (2006), the work of these music researchers in particular has identified several gaps in the existing literature on giftedness/talent that do not attend to the ecological agendas of human development in the 21st century (UNESCO, 2019; Barnett and Jackson, 2020) and can, therefore, jeopardize the ethics of care and moral values—ultimately compromising various socio-emotional, cultural, and educational aspects of the development of children gifted for music.

Our own view is that the professional education of gifted young music learners should be seen as a special case in terms of social justice and children's rights, requiring professional care and reflexivity from these children's music teachers, caregivers, educational institutions, and nations. Accordingly, a music education is most effective when it nurtures the wellbeing of the musically precocious child through a transformative politics of care in professional music education (López-Íñiguez and Westerlund, in press) where more specialist knowledge, socioemotional support (Manturzewska, 1992), and ethical empathic approaches to the educational process is provided (Smith, 2006). Such an approach follows the legal imperatives of the United Nations Convention on the Rights of the Child (brief version in UNICEF, 2010), where it is stated that children gifted for music ought to have a future as healthy and agentic individuals.

3. Purpose of the study

With the above in mind, a scoping literature review was undertaken to identify any existing gaps in knowledge, as well as to systematically map potential empirical research that has been completed in this area (on an international basis) that would support caring practices in the upbringing and education of young, gifted music learners. Thus, following exploratory research questions were formulated:

1. What is known from the literature about caring education approaches that have empowered and supported gifted and talented underage music students to live as agentic and healthy individuals while pursuing desirable educational outcomes?
2. Can this knowledge be organized systematically using Gagné's (2021) Differentiated Model of Giftedness and Talent (DMGT)?
3. Is this organization helpful in identifying potential research gaps in the care ethics area in relation to gifted education in music?

This knowledge was deemed important for promoting reflexive thinking in professional musicians and institutions for gifted education in music, so that technically oriented talent education embraces ethical professionalism through "an ethics of care" (Slote, 2013).

4. Method

4.1. Description of the process

For this study, we employed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR; see Tricco et al., 2018) method to review publications on caring approaches to gifted education in music. This type of literature review was chosen because the topic at hand had not been previously explored and the authors were aware that the amount of research identified would not be large, and not too heterogeneous methodologically, for which a systematic review would not be possible. Scoping reviews allow researchers to identify available evidence on a given topic, analyze knowledge gaps, as well as to clarify existing concepts and their key characteristics (e.g., Tricco et al., 2018; Peters et al., 2020).

Our *a priori* protocol was drafted using the Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocols (PRISMA-P; see Shamseer et al., 2015), which was revised by the research team across multiple meetings before undertaking the scoping review. The protocol attended to exclusion and inclusion criteria related to the research questions, as explained below. All stages of this scoping review, such as the final screening, data extraction, and critical appraisal were blinded and completed by two both authors independently.

We used relevant international databases in English and Spanish, with the first identified article in 1931 through to December 2022. We did not apply date boundaries for the searches in databases because there was no evidence indicating that studies concerning caring approaches to musically gifted students' education had been reported during a specific period. The search in digital databases was completed by the first author and a research assistant in December 2022 and yielded 532 records (Scopus: 81; ARSCA: 218; Eric: 132; PsycINFO: 70; Web of Science: 28; sCielo-Latindex: 3).

In addition, the first author manually checked all papers published in 41 specialist journals from the fields of music education, music psychology, and gifted education since 1990s when available. The manual searches of specialist journals took place in January 2023 and uncovered 120 records that were included for the screening (see Table 1 for details). After removing 146 duplicates, the titles, and abstracts of 506 records were screened. Of the screened records, 439 were removed as they were irrelevant (e.g., not related to music; not related to caring approaches to the education of students gifted for music;

TABLE 1 Terms, search dates, databases, and specialist research journals used in the literature search in English (EN) and in Spanish (ES).

Search Terms	music AND gifted* AND talent* AND care OR moral OR ethics OR "care ethics" OR empathy OR sympathy OR benevolence OR altruism OR "moral imagination" OR serving OR "ethic* sensitivity" OR holistic OR growth OR "moral sensitivity" OR "interpersonal sensitivity" OR "wellbeing" OR "well-being" OR development* OR "social" OR motivation* OR emotion* OR buoyancy OR resilience OR adaptability OR autonomy OR relatedness OR "mastery experience*" OR "self-efficacy" OR "self-esteem" OR "self-confidence" OR "mental health" OR "counseling" OR "counseling" OR "socializing" OR "socializing" OR preventing OR "social intelligence" OR "social interaction" OR equity OR inclusion OR rights OR "child' rights" OR "human rights" OR "safety" OR "freedom" OR "support* parent* style" OR "emotion* support" OR enjoy* OR "socioaffective development" OR nurtur* OR "student centered" OR "learner centered" OR "student centered" OR "student" OR "learner centered" OR "constructivism" OR support* OR teamwork OR collaboration
Databases and Dates of Searches	December 27th, 2022: • ERIC • PsycInfo • Scopus • Web of Science December 28th, 2022: • sCielo-Latindex January 16th, 2023: • ARSCA–Uniarts Helsinki Central Discovery Index database, which accessed following sources: ◇ Alexander Street Press (Music Online); ◇ CCC Get It Now (Alexander Street Press; Sage Journals Online; Springer; Taylor and Francis; Wiley Blackwell; Wolters Kluwer); ◇ DOAJ; ◇ EBSCOhost (Academic Search Elite; International Bibliography of Theater and Dance with Full Text; Free E-journals); ◇ JSTOR; ◇ Oxford University Press (Oxford Handbooks Online Music; Oxford Music Online); ◇ Project MUSE Premium Collection; ◇ ProQuest (Art, Design and Architecture Collection; Dissertation and Theses; Central; Music Periodicals Database; Performing Arts Periodicals Database; Publicly Available Content Database); ◇ PubMeb (Central; Open Access); ◇ SAGE Complete; and ◇ Taylor and Francis eBooks Complete
Specialist Research Journals and Dates of Searches*	January 3rd, 2023: 1. Action, Criticism, and Theory for Music Education (EN) 2. Australian Journal of Music Education (EN) 3. British Journal of Music Education (EN) 4. Bulletin of the Council for Research in Music Education (EN) 5. International Journal of Music Education (EN) 6. Journal of Music Teacher Education (EN) 7. Journal of Research in Music Education (EN) 8. Musicae Scientiae (EN) 9. Music and Science (EN) January 4th, 2023: 10. Frontiers in Psychology–Performance Science (EN) 11. Music Educators Journal (EN) 12. Music Education Research (EN) 13. Music Performance Research (EN) 14. Psychology of Music (EN) 15. Research Studies in Music Education (EN) 16. Visions of Research in Music Education (EN) January 7th, 2023: 17. British Journal of Ethnomusicology (EN) 18. Epistemus. Revista Científica sobre Estudios en Música, Cognición y Cultura (ES) 19. Ethnomusicology Journal (EN) 20. Faisca: Revista de Altas Capacidades (ES) 21. Finnish Journal of Music Education (EN) 22. Nordic Research in Music Education (EN) 23. Revista Complutense de Educación Musical (ES) 24. Revista Electrónica de Educación Musical (ES) 25. Revista Internacional de Educación Musical (ES) 26. Revista Latinoamericana de Educación Inclusiva (ES) 27. The Journal of Musicology (EN) 28. Update: Applications of Research in Music Education (EN) January 9th, 2023: 29. European Journal of High Ability (EN) 30. Exceptional Children (EN) 31. Gifted Child Quarterly (EN) 32. Gifted Child Today (EN) 33. Gifted Education International (EN) 34. High Ability Studies (EN) 35. Journal for the Education of the Gifted (EN) 36. Journal of Gifted Education and Creativity (EN) January 12th, 2023: 37. Australasian Journal of Gifted Education (EN) 38. Gifted and Talented International (EN) 39. Journal of Advanced Academics (EN) 40. Learning and Individual Differences (EN) 41. Roeper Review (EN)

*Manual searches since 1990s when available.

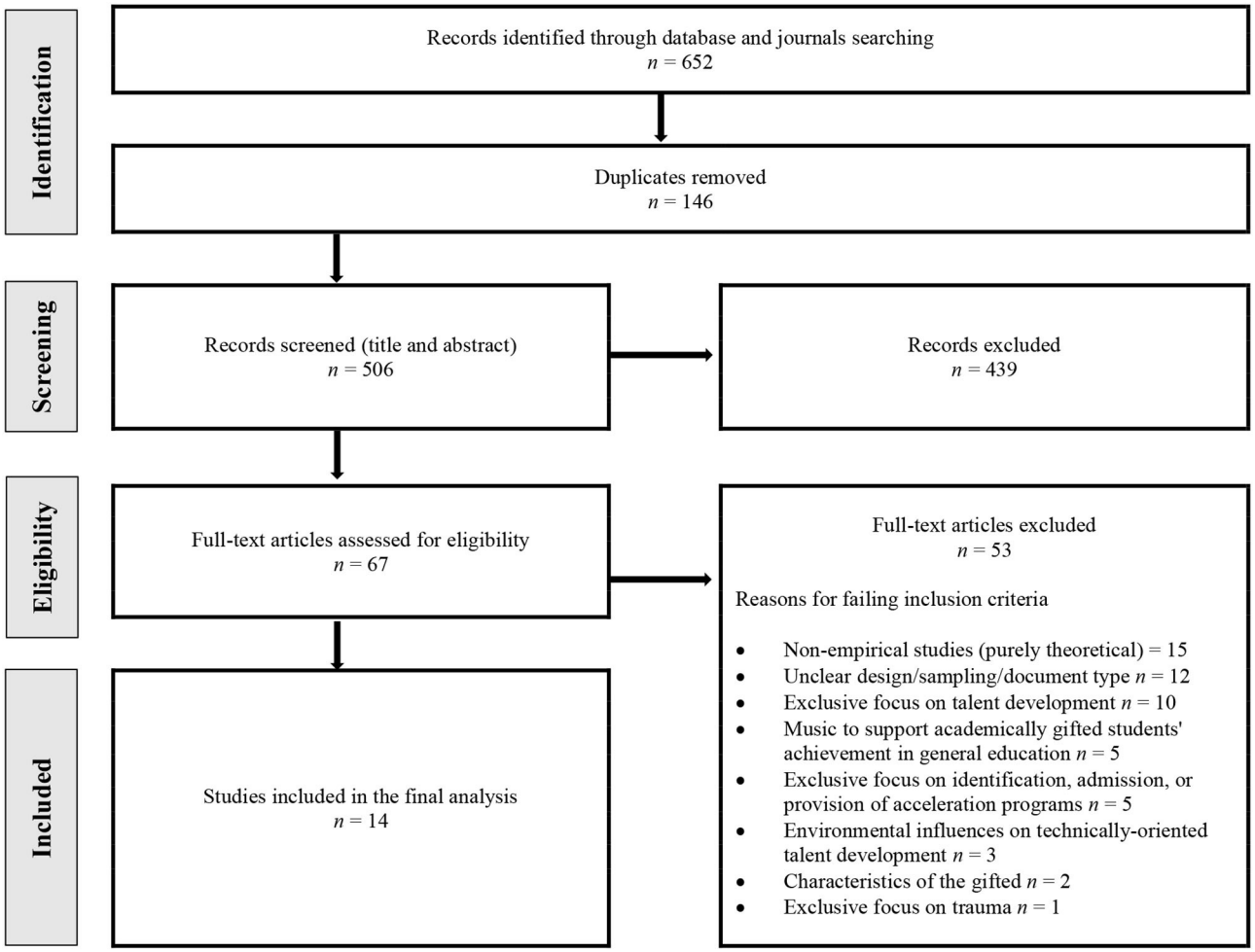

FIGURE 1
Process of selecting studies following the PRISMA flowchart (Moher et al., 2009).

book review, academic presentation slides, or commentary; full text unavailable).

Both authors retrieved the full texts of the remaining 67 records and independently examined these for their eligibility based on the following inclusion criteria: (1) full text was available and written in English or Spanish; (2) the publications included original research articles, data-driven book chapters, or doctoral dissertations; and (3) caring approaches to gifted education in connection to music was either the topic, a central element of the study, or a discussion point derived from the findings/results. Details of how the searches were conducted are shown in Table 1.

A total of 53 full-text studies were excluded due to the following reasons: (1) non-empirical studies (purely theoretical); (2) unclear or inadequate design, sampling, or document type; (3) exclusive focus on talent development; (4) utilizing music for the overall learning and development of academically gifted students in general education settings; (5) exclusive focus on identification, admission, and provision of acceleration programs; (6) describing environmental influences on technically-oriented talent development; (7) defining gifted people's characteristics; and (8) exclusive focus on describing trauma without offering solutions. Findings of the 14 studies included in the final analysis are described in the Findings section.

4.2. Analytical approach

The research topic was defined based on existing gaps in a preliminary literature search. This was followed by the selection of relevant studies using the PRISMA flowchart (see Figure 1). Within this phase, we undertook a scoping review of relevant literature and drew up eligibility criteria for selecting the studies to be reviewed. For this, we used English and Spanish variations of the search terms *music*, *gifted** and *talent* in combination with relevant keywords (see Table 1 for details).

The 67 results of the search that were eventually included in the first screening stage concerned caring aspects within music education. With the screening process in Covidence, the second author blindly checked 100% of the full-text articles assessed for eligibility, and 6 inconsistencies against the selection criteria for excluded papers were found, which helped refine the criteria. After this, we read the studies to be included in the review and extracted

the data by appraising the quality of their research questions and methods using the Mixed Methods Appraisal Tool (Hong et al., 2018). We also conducted a thematic content analysis to identify codes across the 14 studies that are presented in the next section.

5. Findings

5.1. Overall publication trends

The 14 studies included in this review were conducted in Singapore ($n = 3$), the United States ($n = 2$), and in Australia, Estonia, France, Germany, Finland, Norway, Poland, Romania, Taiwan, and the United Kingdom ($n = 1$). A total of 1,944 participants took part in the 14 studies, of whom over 1,200 were music students (estimate, as the sampling information in some studies was insufficient to make an exact calculation). The remaining participants included music teachers, ceased or alive professional performing musicians, parents, band directors, or students of other arts or academic disciplines.

Most of the studies were qualitative ($n = 11$), with the remainder either quantitative ($n = 3$), or mixed methods ($n = 1$). Data were collected via surveys (2 studies), semi-structure and standardized questionnaires ($n = 7$), interviews (8 studies), case studies of diverse nature (11 studies), observations (3 studies), designs with control groups (2 studies), essays (1 study), and other means such as phone conversations and email correspondence, review of documents and blog entries, or photographs ($n = 2$).

The selected studies were published in journals related to gifted education ($n = 7$), music education ($n = 3$), music psychology ($n = 2$), and the learning sciences ($n = 2$) between the years 2000 and 2020. Using the quality appraisal categories developed by Dixon-Woods et al. (2007), we did not find any paper deemed flawed or irrelevant. However, one (1) of the articles was appraised as a key paper, seven (7) of the studies were assessed as being of satisfactory quality, and the remaining six (6) papers' relevance was unclear. All the information can be seen in Table 2.

5.2. Grouping of the selected studies and identification of topics

Each of the 14 articles covered different facets and often multiple dimensions that are directly or indirectly associated with our central concern of caring for young, gifted music learners. These included: humility, collaboration and egalitarian practices, gifted education provision for disadvantaged children, artistic sensibility, personal connectedness, childrearing (parental styles and practices), coping and wellbeing (health and pain prevention), self-determined motivation (focus on intrinsic motivation), twice exceptionality, nurturing teachers, holistic approach to nurturing children gifted for music, cultivating healthy attitudes toward competitions (psychosocial coaching), psychological/emotional training, and socioemotional needs and development.

These 14 identified caring approaches have a higher level of abstraction and represent the themes that were derived from the coding process. The initial level of coding in our narrative analysis included broader codes such as childrearing values, supportive and nurturing parents, developmental care and readiness, learner-centeredness and intrinsic motivation, or brief discussion on a holistic approach to nurturing children gifted for music. These led to the 14 themes enumerated above in a second analysis stage. Table 3 shows how these themes clustered into the natural abilities and environmental, intrapersonal, and developmental catalysts depicted in Gagné's (2021) Differentiated Model of Giftedness and Talent (DMGT).

5.3. Synthesis of the studies

Following PRISMA-ScR guidelines, the selected studies of this research did not allow for quantitative synthesis. Thus, an outline of the main emphasis and findings of each of these studies is presented briefly in the following sub-sections. The studies are presented in alphabetical order.

5.3.1. Study 1: "musical humility: an ethnographic case study of a competitive high school jazz band"

The case study presented by Coppola (2019) examines the role of humility within a competitive high school jazz band in the United States. Musical humility was theorized to encompass: "(a) purposeful musical engagement and collaboration, (b) lack of superiority, (c) acknowledgment of shortcomings and learnability, (d) other-orientedness, and (e) healthy pride" (p. 9). Two implications arising from the research suggest that teachers might embrace this framework for fulfilling two sociomusical imperatives in their teaching. First, as a means of practicing humility within their musical interactions more broadly, and second as a by-product of egalitarian participation in and through music more generally. For the author, "this nascent construct could come to simultaneously illustrate how humility might improve musical experiences and how musical participation might be harnessed to promote humility in turn" (p. 22).

5.3.2. Study 2: "children's talent in fine art and music–England"

The study by gifted education scholar Joan Freeman (2000) examines outstanding talent in children in music and fine art. It incorporates measures to provide evidence that aesthetic perceptual development begins at birth, then becomes habitual, and subsequently shapes future interest and participation. Home environment was particularly important even when the child is exposed to high level provisions at school. In addition, Freeman concluded that some of the schools failed to produce any children of assessable talent and that huge discrepancies existed between the provisions provided for artistic development across schools. This led her to express difficulty in accepting that instances of exceptional talent are definable by school catchment. Importantly, this research stresses the need for future research to focus on contexts, most important of which are the wider social implications of how communities value the arts more generally and understand through their actions the important role of the arts for transmitting cultural values, developing a child's perceptual and analytical abilities, and nurturing the types of creativity and imagination required for innovative thinking and high-level problem solving.

TABLE 2 Reading the studies to be included in the review and extracting the data.

No.	Author(s) (year), journal	Title of study	Design	Country	Participants	Sample	Data collection	Quality appraisal	Caring approach
1	Coppola (2019) *Bulletin of the Council for Research in Music Education*	Musical humility: An ethnographic case study of a competitive high school jazz band	Qualitative	United States	High school students (11) and band director (1)	12	Ethnographic case study, semi-structured interviews, observations	Satisfactory	Humility Collaboration, and egalitarian practices
2	Freeman (2000) *Roeper Review*	Children's talent in fine art and music – England	Mixed methods	United Kingdom	Primary school students (12 from music)	72	Experimental design (including 2 control groups), questionnaires	Satisfactory	*Gifted Education Provision for Disdvantaged Children*
3	Garces-Bascal et al. (2011) *Gifted Child Quarterly*	Soul behind the skill, heart behind the technique: Experiences of flow among artistically talented students in Singapore	Qualitative	Singapore	Specialized-arts secondary school students (3 from music)	14	Case studies, interviews, semi-structured questionnaire	Unclear relevance	*Artistic Sensibility Personal Connectedness*
4	Garces-Bascal (2013) *Roeper Review*	Perceived family influences in talent development among artistically talented teenagers in Singapore	Qualitative	Singapore	Specialized-arts secondary school students (3 from music)	14	Case studies, interviews, semi-structured questionnaire	Unclear relevance	*Childrearing* (parental styles and practices)
5	Gembris et al. (2020) *Frontiers in Psychology–Performance Science*	High-performing young musicians' playing-related pain. Results of a large-scale survey	Quantitative	Germany	Underage and adult musicians participating at the national level of the "Jugend musiziert" contest	1.143	Exploratory design, survey including open-ended questions, standardized questionnaires	Satisfactory	Coping and wellbeing (health and pain prevention)
6	Haraldsen et al. (2020) *Roeper Review*	Thriving, striving, or just surviving? TD learning conditions, motivational processes and well-being among Norwegian elite performers in music, ballet, and sport	Qualitative	Norway	Former students at the Norwegian talent development schools (pre-college level; 3 from music)	9	Narrative design, lifespan perspective, semi-structured interviews	Unclear relevance	Self-determined motivation (focus on intrinsic motivation)
7	Hendricks and McPherson (2010) *International Journal of Music Education*	Early stages of musical development: Relationships between sensory integration dysfunction, parental influence, and musical disposition of a 3-year-old "maestro"	Qualitative	United States and Australia	Preschool child (1) and parents (2)	3	Case study, interviews, observations, questionnaires, journal, and blog entries, photographs, email correspondence	Satisfactory	*Childrearing* (parental styles and practices) *Twice Exceptionality*
8	Ho and Chong (2010) *International Journal of Music Education*	The talent development of a musically gifted adolescent in Singapore	Qualitative	Singapore	Gifted education programme and music conservatory student (1), parents (2), and music teachers (2)	5	Case study, lifespan perspective, survey, and interviews	Key paper	*Childrearing* (parental styles and practices) *Nurturing teachers*

(Continued)

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TABLE 2 (Continued)

No.	Author(s) (year), journal	Title of study	Design	Country	Participants	Sample	Data collection	Quality appraisal	Caring approach
9	Jung (2015) *The Australasian Journal of Gifted Education*	Unfulfilled potential: The adult careers of former musical prodigies Ervin Nyiregyházi, Fanny Mendelssohn Hensel, and David Helfgott	Qualitative	Australia	Ceased musical prodigies	3	Biographical case studies	Unclear relevance	Holistic approach to nurturing children gifted for music
10	Kao (2011) *High Ability Studies*	The dilemma of competition encountered by musically gifted Asian male students: An exploration from the perspective of gifted education	Qualitative	Taiwan	Junior high school students participating in gifted music programs (7), their mothers (7) and music teachers (7)	21	Multiple-case study, semi-structured interviews, observations, phone conversations, and review of documents	Satisfactory	*Cultivating healthy attitudes toward competitions (psychosocial coaching)*
11	Nogaj (2017) *Polish Psychological Bulletin*	Locus of control and styles of coping with stress in students educated at Polish music and visual arts schools–a cross-sectional study	Quantitative	Poland	Students from schools with professional arts programs (*n* for music unknown)	354	Cross-sectional study (including 1 control group), standardized questionnaires	Unclear relevance	*Coping and wellbeing*
12	Rucsanda et al. (2020) *Psychology of Music*	Musical performance and emotions in children: The case of musical competitions	Quantitative	Romania	Children and teenagers participating in international music competitions for young musicians	146	Correlational study, standarized questionnaire	Satisfactory	Cultivating healthy attitudes toward competitions (psychosocial coaching) *Psychological/emotional training*
13	Ruokonen et al. (2011) *Procedia-Social and Behavioral Sciences*	"They have always supported my choices." Creative catalysts in university students' learning environments	Qualitative	Finland and Estonia	Estonian and Finnish university students especially talented in music or other arts	115	Comparative, phenomenographic multiple-case study, lifespan essays	Unclear relevance	*Childrearing* (parental styles and practices) Self-determined motivation (focus on intrinsic motivation) *Nurturing teachers*
14	Tordjman et al. (2020) *Journal for the Education of the Gifted*	Rethinking human potential in terms of strength and fragility: A case study of Michael Jackson	Qualitative	France	Ceased musical prodigy	1	Biographical case study	Unclear relevance	*Socioemotional needs and development*

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TABLE 3 Comparison between the aspects of development comprised in Gagné's (2021) DMGT model and the identified topics found in the selected studies.

Gagné's model	Main dimensions of the model	Articles that relate to these dimensions of development
Natural abilities	Mental–intellectual, creative, social, perceptual Physical–muscular, motor control	Twice exceptionality (Hendricks and McPherson, 2010) Artistic sensibility (Garces-Bascal et al., 2011)
Environmental catalysts	Milieu–social, familial, environment (support mechanisms to reinforce familiarity, comfort, satisfaction with living and musical environment) Individuals and others–influence of parents, family, peers, teachers, mentors Provisions–enrichment programs provided, curriculum, form of pedagogy, pacing/pushing, acceleration, catering for needs	Gifted education provision for disadvantaged gifted children (Freeman, 2000) Childrearing (parental styles and practices) (Hendricks and McPherson, 2010; Ho and Chong, 2010; Ruokonen et al., 2011; Garces-Bascal, 2013) Nurturing teachers (Ho and Chong, 2010; Ruokonen et al., 2011) Holistic approach to nurturing children gifted for music (Jung, 2015) Collaboration and egalitarian practices (Coppola, 2019) Socioemotional needs and development (Tordjman et al., 2020)
Intrapersonal catalysts	Physical–appearance, handicaps, health Mental–temperament, personality, resilience Awareness–self and others, strengths, and weaknesses Motivation–values, needs, interests, passions Volition–autonomy, effort, perseverance, buoyancy, adaptability	Coping and wellbeing (health and pain prevention) (Nogaj, 2017; Gembris et al., 2020) Self-determined motivation (focus on intrinsic motivation) (Ruokonen et al., 2011; Haraldsen et al., 2020) Humility (Coppola, 2019) Personal connectedness (Garces-Bascal et al., 2011) Psychological/emotional training (Rucsanda et al., 2020)
Developmental process	Activities, including access, content, formal/informal Investment, including time, energy, money Progress, including stages, pacing, and turning points (special events that provide mastery experiences)	Cultivating healthy attitudes toward competitions (psychosocial coaching) (Kao, 2011; Rucsanda et al., 2020)

5.3.3. Study 3: "soul behind the skill, heart behind the technique: experiences of flow among artistically talented students in Singapore"

Garces-Bascal et al. (2011) present case studies of 14 Singaporean students enrolled in a specialized secondary school who were asked about their experiences of flow as they undertook training in visual arts, dance, music, and theater. Results reveal that the learners experienced certain forms of flow through establishing clear goals for themselves, experiencing intense concentration, enjoyment and loss of self-consciousness, and transformation of time. Implications for teaching were grouped around five themes:

> "(1) the significance of investing a sense of personal connectedness with the students as they engage in their training, (2) the importance of immediate feedback as they progress in their respective fields, (3) the inspiration that is derived from seeing the students' own mentors perform or, at the very least, having a firsthand knowledge of what it means to be in that domain or the transfer of tacit knowledge and insider information [...], (4) the sense of kinship that is fostered in a school that allows one a measure of safety to express one's artistic sensibilities, and (5) the balance between "fun" and rigor that engages and captures the students' attention" (p. 205).

5.3.4. Study 4: "perceived family influences in talent development among artistically talented teenagers in Singapore"

Using the same participants and in the previous study, Garces-Bascal (2013) examines how Singaporean families promote literacy and instill values in academic excellence within the home environment. Results show how families influence the talent development process and their involvement in their child's interest and involvement in the arts activity in which they are specializing. Parents' style and practices are shaped by their occupational backgrounds and reflect patterns of childrearing that are common within Asian contexts.

5.3.5. Study 5: "high-performing young musicians' playing-related pain. Results of a large-scale survey"

The recent publication by Gembris et al. (2020) presents a large sample study that deals with how playing-related pain (PRP) impacts on the development of highly talented young musicians by addressing how they cope, behave, and communicate about PRP with other young musicians, their teachers, their parents, and others, including their peers. Results show that around three quarters of the sample reported that PRP impacted on their development and that females were significantly more affected than their male counterparts. Importantly, duration of practice and prevalence of PRP were closely associated. Just over half of the young musicians reported being taken seriously about their PRP, but alarmingly around 44% felt that their complaints were not taken seriously enough or ignored. The study confirms that around three quarters *(75%)* of highly talented young music learners will be typically impacted by PRP and recommends ways of counteracting this problem through teaching more adequate practicing techniques that might involve, for example, warm-up and cool-down activities, breaks, correcting incorrect posture, and self-observation while practicing. The researchers cite alarming evidence showing that some parents believe that PRP is an inevitable problem that talented young musician must endure. The authors therefore assert that these types of opinions need to be confronted and should not be

accepted. One way of achieving this is for the teacher to include information about health and prevention in all lessons. For these researchers, better communication between learner, teacher, and parents is fundamental to avoiding PRP in talented young musicians.

5.3.6. Study 6: "thriving, striving, or just surviving? TD learning conditions, motivational processes and well-being among Norwegian elite performers in music, ballet, and sport"

Haraldsen et al. (2020) interview nine elite performers in ballet, music, and swimming to examine their motivational orientation at Norwegian talent development (TD) schools to understand how the performers' development was shaped by egalitarian values, high-performance deliberate practice, and controlling conditions. Results reveal multifaceted motivational profiles, ranging from predominantly self-determined to predominantly be controlled. Performers regulated by self-determined motivation experienced more joyful, robust, and healthy development that was characterized by self-realization, flow, self-esteem, and vitality. They were also less dependence on their TD learning conditions. Performers who experienced a more controlling learning environment reported higher vulnerability, and ill-being that was evident in low self-esteem, perfectionism tendencies, obsessiveness, stress, negative affect, and exhaustion. In contrast to other literature this study reports that many of the performers did not possess an original intrinsic motivation with only two of the nine performers displaying a predominantly autonomous engagement. Based on the findings, the authors assert that some of the negative aspects of the performers' TD include over-striving to compensate for low levels of self-worth, and perfectionism in the form of striving to become an "ideal-self." They also pointedly remark that "In a debilitative circle of negative emotion (frustration, negative affect, and stress), cognition (guild, shame, and performance anxiety), and behavior (rigidity, obsession, and eating disorders), the performers' self seemingly will become diminished" (p. 121). To alleviate these tendencies the authors warn that TD programs must guard against the negative consequences of controlling environments, and strive to reinforce and enhance the performers' autonomous motivation and their self-determined psychological needs of relatedness, competence, and especially autonomy.

5.3.7. Study 7: "early stages of musical development: relationships between sensory integration dysfunction, parental influence, and musical disposition of a 3-year-old 'maestro"'

The article by Hendricks and McPherson (2010) presents a case study of a 3-year-old boy with neurological disorder (Sensory Integration Dysfunction) and the parent-child interactions that facilitated his involvement in music from an early age. Stressed is the high level of attention and support the child is provided with from his parents, in terms of an elongated period of "communicative musicality" that is characteristic of mother-infant bonding processes during infancy. Specifically, interactions involving both child and parents resulted in all participants developing competence, connectedness, and their sense of musical identity through "organic synchronous and reciprocal interactions […] in freely creative settings" (Custodero, 2009; p. 514). The study concludes that important work is yet to be undertaken on how these interactions might help with our understandings of the acquisition of precocious musical involvement during infancy and early childhood.

5.3.8. Study 8: "the talent development of a musically gifted adolescent in Singapore"

The study by Ho and Chong (2010)—which was the only one assessed as a key paper for this literature review—applies Gagné's model to examine aspects of natural ability and environmental catalysts that related to talent development within the Singaporean context. Citing Sternberg (2007), the authors suggest that "giftedness represents a set of cultural values" (p. 57) and that differing values, customs, and beliefs related to notions of giftedness need to be recognized. In this study, the home environment of the gifted learners studied typically offered opportunities for exposure to multiple rigorous and challenging forms of musical engagement at each age that greatly enhanced their musical development. Consequently, one of the significant findings that emerged is the wealth of cultural knowledge and resources that are available in the homes of the musically gifted young Singaporean musician through their interactions with others, particularly their parents. The authors show how musicians can access cultural knowledge and values of a type that are invaluable for improving young musicians' motivation to participate in and develop their musical potential. Stressed is the need for music educators to consider home-school relationships in their quest for fostering links between their own teaching strategies and the lived experiences of their students.

5.3.9. Study 9: "unfulfilled potential: the adult careers of former musical prodigies Ervin Nyiregyházi, Fanny Mendelssohn Hensel, and David Helfgott"

The study of Jung (2015) draws on the lives of three notable musical prodigies (Ervin Nyiregyházi, Fanny Mendelssohn Hensel, David Helfgott) who sought out musical careers but did not experience adult success despite their extraordinary musical potential. Interestingly, none of the reason their adult careers floundered relate to their musical abilities but rather a less than optimal level of psychosocial skill (Nyiregyházi), a restrictive societal and family environment (Hensel), and mental illness (Helfgott). This study is important because it highlights how exceptional natural musical abilities interact with and compliment various non-musical attributes. Examples would include access to high quality music teachers, consistent family support, participation in a community or culture that supports the transition from musical potential to talent, and the possession of personal qualities related to perseverance and discipline, in addition to sound interpersonal skills. Also important are access and opportunities to take advantage of chances that will facilitate a career, freedom from issues (e.g., health) that might impact on

future commitment to succeed, in addition to a multitude of other non-musical factors that have not yet been identified and described because of a limited research base.

5.3.10. Study 10: "the dilemma of competition encountered by musically gifted Asian male students: an exploration from the perspective of gifted education"

Kao (2011) examines competitiveness in musically gifted students across the daily experiences of seven musically gifted Taiwanese adolescent males who were participating in a competitive music class. Five themes emerged from the study: (1) tacit student competition and rivalry; (2) a tendency for students not to discuss music between themselves; (3) utilitarian training where the music students spent most of their time practicing very few pieces of difficult repertoire to acquire a competitive edge for "big occasions"; (4) for some students, feelings of inadequacy due to lower levels of mental maturity and self-discipline, or denial of natural giftedness by other classmates; and (5) and critical comparisons made by parents and teachers who pushed their child or students to achieve at a higher level through ongoing comparisons with others. The author concludes that gifted students would benefit from psychosocial coaching to activate their intrinsic motivation.

5.3.11. Study 11: "locus of control and styles of coping with stress in students educated at polish music and visual arts schools–a cross-sectional study"

Using a sample of music schools in Poland and Serbia the study by Nogaj (2017) provides an overview of stages of development related to musically talented children and youth. Despite cultural differences between the two countries, both share similar models for educating students in their music schools. The authors suggest that during preschool, informal and spontaneous activities should form the basis of preparing the young children for participation in more specialist instrumental/vocal training later, and that talent identification mainly occurs within the family. A "romance or from abilities to competence" (p. 156; see also Subotnik and Jarvin, 2005) which occurs when children enter Elementary school offers opportunities to learn how to play an instrument and gain tuition. Children's progression will not only depend on their individual abilities but also the forms of parental and teacher support or pressure they received in the form of external rewards and recognition. When these young learners enter high school, they move to a period in which they are developmental ready to aim for precision and perfection in their mastery of an instrument. It is also a period in which social support from parents and peers is particularly important so that the adolescent musician can cope with the pressures of learning at a high level. For those who choose higher music education, coping with pressure is dependent on integration of the musical, personal, social, and environmental influences experienced during earlier periods.

5.3.12. Study 12: "musical performance and emotions in children: the case of musical competitions"

The recent study of Rucsanda et al. (2020) investigates 146 young singers who participate in music competitions to compare the emotions of those who obtained prizes with those who did not. The researchers found that lower performance quality was related to negative emotions while higher performance quality was linked to positive emotions, low arousal, and increased dominance. More experienced singers demonstrated more positive emotions, lower arousal, and high dominance. Consequently, experience in music competitions was theorized to mediate emotions and the quality of music performance in competitions. The researchers draw on evidence showing that young people become more self-critical, experience increasing levels of performance-related emotions and are increasingly capable of evaluating themselves compared to others as they progress through childhood to adolescence. Psychological and emotional training is therefore recommended to support the wellbeing of young singers so that they are more capable of understanding, expressing, and managing their emotions when preparing for and participating in music competitions.

5.3.13. Study 13: "'they have always supported my choices.' Creative catalysts in university students' learning environments"

The study by Ruokonen et al. (2011) describes important environment catalysts of Estonian and Finnish university students that have contributed to their artistic giftedness and creative products or presentations. Ruokonen et al. stress the importance of home and school environments, cultural communities, and informal learning opportunities, and draw the conclusion that to aid in early development, children should be exposed to both formal and informal aspects and various environmental catalysts that connect to their intrinsic motivation and the development of their creativity and giftedness.

5.3.14. Study 14: "rethinking human potential in terms of strength and fragility: a case study of Michael Jackson"

The final selected study by Tordjman et al. (2020) presents a case study of Michael Jackson's high potential, talent, and precocity that stresses the usefulness of a multidimensional approach to examining human potential. Highlighted are the asynchronies evident in extreme talent and the impaired socio-affective development and interplay between strength and fragility in a case where cognitive functioning is not able to be separated from emotional functioning. The authors show—using the case of Jackson—how exceptional qualities as a musician can be accompanied by extreme fragility that can "freeze an individual in a youthful state that may result in serious developmental maladjustments" (p. 74). Publicly recognized and admired precocity, therefore, can lead to a host of identity problems, immaturity, and socioemotional difficulties. These might result in a highly gifted child and then adolescent displaying symptoms of depression, together with a fading precocity and decrease in precociousness—which the authors believe is the result of a freeze

in emotional development. Consequently, schools, society, and individual families need to ors into considerations so that children are not defined exclusively through their gift for music or other high-level form of achievement.

6. Discussion

6.1. Summary of evidence

The primary purpose of this scoping PRISMA literature review was to identify international research that reflects existing caring education approaches that can be used to empower and support gifted and talented underage music learners to live as agentic and healthy individuals while pursuing desirable educational outcomes. Our analysis of the literature reveals that there is only a superficial coverage of research on this topic, with only 14 research articles identified in our search. Close examination of the content of these 14 studies shows that they are only loosely related to aspects of "care" and minimally aligned with the natural abilities, environmental and intrapersonal catalysts, and developmental processes described within the holistic DMGT model proposed by Gagné (2021). The most important finding of this review, therefore, is a serious lack of systematic research on caring approaches to educating young, gifted musicians.

The 14 identified studies largely consist of single studies on the topic or multiple write ups using the same sample of participants as in the case of Garces-Bascal (2013) and her colleagues (Garces-Bascal et al., 2011) that cover differing aspects related to the development of 14 gifted Singaporean youth. Among the most impressive work is that by Freeman (2000) who studied highly talented English students for much of her professional life. Her studies have expanded views across the past 30 years on work undertaken in specialist English schools and the influences within the home environment that facilitate talent development. Other rigorous research has been undertaken recently by Gembris et al. (2020) on pain related problems with young musicians, as well as studies led by Rucsanda et al. (2020) and Haraldsen et al. (2020) who focus on motivational aspects related to extrinsic motivation—such as those experienced in competitions or high stakes "hot bed" learning environments. In addition, Jung (2015) details the lives of three notable prodigies who experienced a less than optimal level of psychosocial skill, a restrictive societal and family environment, or mental illness.

As is evident from the information outlined above, the existing literature provides only a superficial coverage of the multiple facets that relate to caring approaches to developing gifted young music learners' education or personal development—with no single study or set of studies specifically focused on the aspect of "caring environments" for young, gifted music learners. In this context, engaging with a caring approach would require "empathetic behaviors in both the public and domestic spaces surrounding [musically gifted] children," and confronting "the still common patriarchal and elitist ethos of the education of [these children], while seriously considering alternative, mutually negotiated educational paths for serving the[ir] wellbeing" (López-Íñiguez and Westerlund, in press).

Of equal concern is that few of the studies identified employed a strong theoretical framework for examining issues examined in their studies. From the selected studies, the exception was the study by Ho and Chong (2010) which—using Gagné's model in their analysis, and being the only article appraised as a key paper for the purposes of our scoping literature review—tackled the ways a musically gifted child could be nurtured and socialized to thrive in the music world (Ho and Chong, 2010). In that line, an added ecological dimension to our study includes extending theory to include much broader human perspectives such as care ethics, justice, and democracy for the gifted—so that a more inclusive education for the gifted, and less imposed futures can be envisaged (e.g., Slote, 2013). This, in turn, calls for educational reforms that recognize childhood rights, by allowing gifted children to become agentic in their decisions regarding their minds and bodies, as well as empowered to realize their potential to become social agents (e.g., Wyness et al., 2004).

Although two studies dealt specifically with how music students could better navigate the competitive performing world (Kao, 2011; Coppola, 2019), a related, relevant point concerns how a young gifted child copes with success. Because the bar for outstanding performances is continuously being raised, young, gifted music students (and those who are gifted in other pursuits) need to be adaptable to cope with the "seemingly limitless extent of human performance possibilities" (Subotnik et al., 2011; pp. 12). To facilitate this adaptability, young, gifted music learner's education needs to be flexible and to feature the types of socio-emotional development components that go well beyond traditional conceptions of talent development that rely (often exclusively) on repetitive practice of a small repertoire of music literature. In this line, teachers and parents need to be more mindful about systems of rewards/punishments (see Kohn, 1992), about understanding giftedness as a synonym for "success," and about realizing the role of chance and the environment for supporting or alternatively preventing individuals from reaching their potential in healthy or unhealthy ways (see Gagné, 2021).

In line with the above comments, we were pleased to find the Garces-Bascal et al. (2011) study that deals with artistic sensibility. However, apart from this study there is a complete lack of other research dealing with the critical pedagogical approach of linking high level performance skills with the types of creativity and innovation needed for a young, gifted music learner to perform in an original and uniquely artistic manner that goes beyond the reproductive and technical skills mentioned above. In our view, creativity and innovation are fundamental to higher levels of music performance but as is evident in this review, have received virtually no research attention regarding the development of young, gifted music learners. Unfortunately, the conservatoire tradition—which often unduly emphasizes technique and rigidity in learning—does not always lead to autonomous and artistically agentic learners (e.g., Pozo et al., 2022) nor does it promote reflexive thinking in ways that can embrace ethical professionalism through an ethics of care (Slote, 2013).

Regarding the various studies on nurturing parents/teachers, it also became clear that there are key agents in the development of these children, but no study addressed the issue of caring for young, gifted music learners who might be placed in

dysfunctional environments, or who might have experienced trauma and abuse. In this case, further research would be needed to identify and better support such students to safeguard their rights. In addition, parents and teachers contribute to eminence achievement, yet encouragement and stimulation are not always necessarily accompanied by emotional support. To address this deficiency, we recommend that music education institutions should provide training for both practitioners and for families.

Although gifted young learners might be exceptional at playing music, there is a need to better assess the extent to which they engage in music due to their intrinsic motivation for making music (i.e., their passion for music making), or because of various extrinsic motivations related to external reinforcement of a type that supports (but may also push or coerce) them into maintaining their involvement in music at a high level. The delicate balance between intrinsic motivation and external forms of coercion and control needs much more research attention in the population of young, highly gifted music learners, particularly given the many reports of prodigies and gifted individuals who acknowledge being harmed by the pressures of competitions, demanding parents, uncompromising teachers, or a constant feeling of needing to excel at a level that is higher than any of their peers.

Two studies tackled the provision of gifted education for disadvantaged children, as well as caring for those students who fall under the twice-exceptionality spectrum (Freeman, 2000; Hendricks and McPherson, 2010, respectively). However, we need more nuanced studies that address inequalities in opportunity to study in gifted music programs especially in relation to minorities, underage women, and students coming from less affluent families or who live in rural contexts with less access to specialized music education for the gifted.

Finally, several key concepts related to caring are being studied in educational psychology that deserve to be applied in research on young, gifted music learners. Among the most important is work by self-determination theorists (e.g., Evans and Ryan, 2022) dealing with conditions that can undermine enjoyment and be detrimental to motivation and wellbeing, particularly when a young, gifted music learner's basic psychological needs (i.e., relatedness, competence and autonomy) are not met. Another is the framework devised by Martin and colleagues (e.g., Martin and Evans, 2022) that outlines how buoyancy, resilience, and adaptability can be conceptualized as asset-oriented or strengths-based attributes that can shape a young, gifted music learners' responses to adversity, change, and uncertainty. Two other dimension relevant to talent development during childhood and adolescence would be work in positive psychology where the "broaden and build" theory of positive emotions (Fredrickson, 2001; Martin, 2004) could be adapted to expand the behavior of young, gifted musicians when they experience high levels of stress and change, in addition to conceptions related to mental wellbeing in the absence of mental illness that would allow a young musician to "flourish" (Keyes, 2007).

From the abovementioned gaps, several are considered systemic issues surrounding the music education of gifted children (see López-Íñiguez and Westerlund, in press). One of these systemic, pressing issues that was completely missing from our searches—and that explains in part why so few scholars have dealt with caring approaches to gifted education in music—is the much-needed confrontation of misconceptions that sustain narrow views that lead to the stereotyping of highly gifted children. As we mentioned at the beginning of this article, these include elitist and anti-ableists positions that refer to young, gifted music learners as if "they will survive regardless of the pressure and hardship of their training," and conceptions that center around the outdated idea that "innate abilities do not exist and any kind of outstanding success in children can be entirely explained through their highly supportive environments" (see Brown et al., 2005; Moltzen, 2009).

6.2. Delimitations

The study was limited to literature published in English and Spanish, given the two authors expertise and familiarity with research paradigms in both languages. Studies published in these languages included samples of children from Europe, North America, and the Asia-Pacific. We restricted our focus to identifying caring approaches to the education of young, gifted music learners. The study results provide a framework for future efforts to devised evidence-based pedagogical models that can be used in interventions and policies aimed at catering for the needs of children gifted for music.

7. Conclusions

This study is among the first to critically examine existing literature concerned with caring approaches to the development and education of gifted young music learners. A scoping PRISMA review of all uncovered studies found that there is currently only a small handful of studies related to the topic of caring in music education. Of particular concern is the lack of systematic research that directly impacts on what is currently known regarding this important topic.

The article highlights the need for further research that is built on theoretical frameworks that can compare and contrast what is evident in studies of gifted young musicians with other highly demanding forms of specialization, together with a much broader approach that links this knowledge with broader national and international concerns such as human rights, ethics of care, and responsibility and laws that might protect highly gifted youth who are vulnerable due to external pressures. For instance, multidisciplinary studies are recommended to understand the complete ecosystem surrounding young, gifted music learners at micro-macro-meso levels and the role that multiple stakeholders (e.g., parents, teachers, peers, industry representatives), contexts (e.g., home, school, community, performing arenas), and variables (e.g., motivation, learning mindset, stage of development) play in it.

In conclusion, the findings of this study reaffirm the view that music education research and practice need to nurture the wellbeing of musically precocious children more adequately by expanding conceptions of talent development within an environment that takes on board (and cares for) the needs of vulnerable young music learners. This has potential to inform music education aimed at professionalism where more specialist knowledge and ethical empathic approaches to these children's education is provided (Smith, 2006; López-Íñiguez

and Westerlund, in press). Such an approach follows the legal imperatives of the United Nations Convention on the Rights of the Child (brief version in UNICEF, 2010), which clearly states that gifted children in any domain deserve to have a future as healthy and agentic individuals.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

GL-Í conceived the original idea of the research, did the manual searches in 41 specialist research journals as well as in ARSCA and sCielo–Latindex databases, checked the searches done by a research assistant in ERIC, Scopus, Web of Science, and PsycInfo databases, and screened the eligible 506 documents in Covidence after duplicates were removed. GL-Í and GM independently screened the 67 full-text studies assessed for eligibility, formulated the conceptual ideas adapted in the manuscript, defined the search terms for the study, defined the selection/exclusion criteria for studies, and discussed about the disagreements in the final stages of screening, and provided critical feedback at all phases, discussed, and contributed to the interpretation of the results and writing of the manuscript, and approved the submitted version of the article.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Focus of attention in musical learning and music performance: a systematic review and discussion of focus instructions and outcome measures

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The topic of attentional focus (focus of attention, FOA) in musical learning and performance has recently received increasing interest, as the growing number of empirical studies inspired by the established FOA paradigm in sports by Wulf and colleagues in 1998. The current systematical review aims at collecting, abstracting, and categorizing relevant data to show which kinds of FOA instructions were applied in experimental designs and what kinds of dependent variables were used to measure the effects of FOA instruction on musical performance. The three main inclusion criteria in the selection process were experimental design, detailed descriptions of FOA instructions, and outcome measures (OMs). A systematic search was conducted with a complex search term in four scientific databases in March 2023. For presenting and synthesizing results, we used data collection and an inductive-deductive data categorization. Fifteen studies with a total sample size of 401 participants were included out of 387 records initially identified. We collected 53 different FOA instruction citations from the 15 studies and classified them into 9 FOA subcategories, of which the most applied were *bodily focus* (21%), *sound focus* (15%), and *visual focus* (14%). Selected studies used 63 OMs that were abstracted to 10 different OM categories with *expert ratings* (27%) and *acoustical analysis* (22%) as the most applied dependent variables. Data categorization and abstraction of additional study information show multiple combinations of FOA instructions, OMs, participants' instruments and expertise, and musical tasks. Finally, studies show no consistent results of superiority of either external or internal or otherwise different FOA considering positive effects on musical performance. Limitations of the review lie in the small study sample, possible criticism of applied eligibility criteria, and subjectivity of data categorization. We propose a research agenda with a more exploratory approach that comprehensively and qualitatively examines the dimensions of musical goals to create a database that could provide a foundation for developing a music-specific FOA model.

KEYWORDS

attentional focus, motor learning, musical performance, focus instruction, outcome measures, systematic review

1 Introduction

The general questions of how we locate our attention while we perform and why we do so play a crucial role in physiological and psychological processes in performances of various everyday life areas as well as in many professional, high-performance domains (e.g., sports, music, dance, etc.). Considering these performance areas in which motor control and motor learning are highly important, we can add many questions that are of special interest to certain research fields, performers, trainers, and educators. Assuming there is a performance effect based on attentional mechanisms, questions arise as to how these processes manifest in different learning or performing situations. What degree of influence does the type of movement, movement task, expertise, pressure, anxiety, state of consciousness, and, finally, instructions have on performance quality and how can we measure it in a domain-specific way? The current systematic review aims to shed light upon some open challenges of focus of attention (FOA) research in general in the music domain by systematically collecting and abstracting data on the two much-discussed aspects of instruction and outcome measures (OMs).

The idea that attentional processes could affect motor performances is not new, nor is it the scientific discourse on it that began at the end of the 19th century and continues today. James (1890, p. 520) describes in chapter XXVI of his book *The Principles about the production of movement* "[…] that we fail of accuracy and certainty in our attainment of the end whenever we are preoccupied with much ideal consciousness of the means." Moreover, Bliss (1895, p. 55) said in the last sentence of his report, *Investigations in reaction-time and attention,* that it is "[…] a well-known fact that we can perform numerous actions much better when only half attending to them." From the 1960s, movement and sports research shaped the debate about positive or negative attentional effects on performance from the motor learning perspective. Many of the well-established motor learning theories and concepts refer to development from conscious and highly controlled movements or actions at the beginning of the acquisition of motor skill to a more unconscious and highly free, automatic performance of movements at an expert stage. Meinel (1960) defined this stage as *Variable Verfügbarkeit* (variable availability), in which a performer can detach from movement execution and focus on movement expression (for the role of variability in this regard, see also Bernstein, 1967). Other phase concepts described this as the *autonomous phase* (Fitts and Posner, 1967) that contains automatic mechanisms and the ruggedness of movement execution against external resistances.

1.1 Attention under pressure: explicit monitoring and distraction theories

Following this tradition, experimental psychologists of the 1970s and 1980s started to ask and examine whether self-awareness, self-consciousness, and certain attentional processes could aid or detract from performance success (Martens and Landers, 1972; Langer and Imber, 1979), especially in contexts, in which performers are under pressure (Baumeister, 1984; see also Masters, 1992). Later, Beilock and Carr (2001) subsume the explanations for this phenomenon as *explicit monitoring theory* (EMT). The terms *execution focus theory* (see also Beilock and Carr, 2001) and *conscious processing hypothesis* (CPH; Mullen and Hardy, 2000; Wilson et al., 2007) are in line with EMT and highlight that a step-by-step focus on execution degrades performance and this control or self-control disrupts fluency as well as automaticity of movement on the expert level. Although Baumeister (1984) also emphasized the role of anxiety in his concept, other theories put the fear of failing in situations under pressure at the center of their arguments (Wine, 1971; Eysenck, 1979). This *distraction theory* describes processes of involuntary shifts of attention to task-irrelevant information. Another attempt by Eysenck and Calvo (1992) claims that anxiety does not directly impair performance effectiveness but negatively impacts the efficiency of the on-task effort—and further leads to a reduction of processing capacity that results in performance degrading (*processing efficiency theory*, see also Smith et al., 2001; Murray and Janelle, 2003). The first comparative experimental studies from the music and sports domains show that EMT or CPH seems to be a more useful explanation theory for *choking under pressure* processes than the distraction or processing efficiency attempts (Wan and Huon, 2005; Wilson et al., 2007). However, more recent results tended to contradict those insights (Lee and Grafton, 2015; Buchanan et al., 2018; Furuya et al., 2021), whereas other studies seemed to confirm it (Reeves et al., 2007; Gray et al., 2013; Carson and Collins, 2016)—the discussion and research on this topic is ongoing (see also Saikley and Haroush, 2021).

1.2 Attentional focus in motor learning and motor performance

In 1998, Gabriele Wulf and colleagues published the results of an experimental study that has received much attention in the last two decades up to the current discourse. Referring to the abovementioned concepts of Baumeister (1984) and Masters (1992), explaining performance degrading under pressure, Wulf et al. (1998) developed an experimental paradigm to examine the effects of different attentional focus instructions on motor learning, independent from the existence of high-pressure situations or anxiety processes. In the first experiment, participants should perform a repetitive skiing-like movement task multiple times with a ski-simulator. The instruction was either "[…] to try to exert force on the outer foot (e. g., the right foot) as long as the platform moved in the respective direction (e. g., to the right side)" (*internal-focus group*) or "to try to exert force on the outer wheels as long as the platform moved in the respective direction" (*external-focus group*; Wulf et al., 1998, p. 172). The results show significantly higher mean amplitude (derived from the platform position data) of movements of the external-focus group compared to the internal-focus group (and a control group that got no specific instruction) in both practice trials and retention tests. A second experiment containing a balance task somehow confirmed these results by showing fewer balance errors in the external-focus group than in the internal-focus group during a retention test after 2 days of practice, in which no further instructions were given. Although a concrete theoretical foundation of that outcome could not be found by the authors at that time, the *common-coding theory* (Prinz, 1997)—describing a common representation of perception and action in the brain—serves as a theoretical framework due to its link to distal events in the form of perception–action coupling mechanisms (an external FOA is a "distal event"). Wulf herself later interpreted that link as insufficient: "Yet, because the theory is rather abstract, it does not

specifically predict the differential learning effects of external versus internal attentional foci. It also does not explain any underlying mechanisms of this effect" (Wulf, 2013, p. 91).

Due to the promising results, and despite missing adequate theoretical constructs, Wulf and other researchers applied the paradigm to other movement tasks and could confirm the claimed benefit of an external FOA for motor learning (e.g., Shea and Wulf, 1999; McNevin et al., 2000; Wulf et al., 2000) before formulating the *constrained action hypothesis* (CAH; Wulf et al., 2001a,b). The CAH describes a negative effect chain from (1) focusing consciously on body movement execution or trying to control it, (2) interfering with automatic control motor processes, to (3) a performance degrading or action constraining effect. In addition, or as an expansion, a less beneficial focus on the *self* through an over-evaluation of one's own actions could enhance the interference effect (*self-invoking trigger hypothesis*, Wulf and Lewthwaite, 2010; McKay et al., 2015). Turning the CAH—which focuses on disadvantageous processes—into an assumption, what kind of FOA could be beneficial for supporting the motor system to be automatic and self-organized, Wulf and colleagues formulate the general instruction advice to focus "[…] on the intended movement effect or task goal" (Wulf and Lewthwaite, 2016, p. 1402). Another hypothesis describes the importance of distance in this regard. The further away a goal appears that refers to external FOA instructions, the greater the effect on motor learning and performance (*distal foci effect hypothesis*; Bell and Hardy, 2009; Duke et al., 2011; McKay and Wulf, 2012; Stambaugh, 2017). Current results from a meta-analysis confirmed the hypothesis that distal-external foci instructions have a more positive impact on motor learning than proximal-external foci instructions (Chua et al., 2021).

An impressive number of experimental studies demonstrate the superiority of the effects of external FOA instructions on motor learning and motor performance. However, there are critical discussions on some aspects of the big picture, e.g., regarding various theoretical issues (Ehrlenspiel and Maurer, 2007; Oudejans et al., 2007; Poolton et al., 2007; Raab, 2007; Peh et al., 2011), methodical questions (Mullen, 2007), and the missing of a theoretical construct that could explain learning benefits of an external FOA (Maurer and Zentgraf, 2007; for an overview, collection of critical commentaries, and responses by Wulf, see the special issue of *Bewegung und Training* [Movement and Training], 2007).

1.3 Focus of attention in music

Madsen and Geringer (1990), Geringer and Madsen (1996), Madsen (1997) started a series of studies investigating the focus of attention on different musical elements of musicians and non-musicians while listening to music. Whereas this research is not in line with the attentional effects of focus instructions on motor learning, the results show how different the attentional focus on diverse musical parameters can be in relation to musical expertise or musical stimuli. Wulf and Mornell (2008, see also Mornell, 2007) were the first to investigate the transfer and adaptation of FOA findings from sports to music and dance (see also Guss-West and Wulf, 2016; Mornell and Wulf, 2019). This was followed by an experimental study by Duke et al. (2011) on the effects of attentional instructions on various aspects of solving a short piano task. In their study, participants focused on the fingers, the keys, the hammers, and the sound of the music while playing as part of a repeated measures design. The authors investigated the effect of different FOAs on the evenness of playing movements and showed that non-experts play significantly more consistently in the transfer test when focusing on the hammers and the sound of the music.

Following these results, the FOA paradigm of Wulf et al. (1998), and different explanatory hypotheses (e.g., CAH), some music-related experimental and exploratory studies have been conducted, e.g., in singing (Atkins and Duke, 2013; Atkins, 2017, 2018; Treinkman, 2022a), on the effect in piano playing (Cheng et al., 2011; Lipke-Perry et al., 2022; Jentzsch and Braun, 2023), violin playing (Allingham et al., 2021; Allingham and Wöllner, 2022), wind instrument playing (Stambaugh, 2017, 2019; Williams et al., 2023), or in music education settings (Silvey and Montemayor, 2014; Montemayor et al., 2016; Parsons and Simmons, 2021). The results of these studies vary widely, with some evidence of a positive effect of an external FOA on certain aspects of musical learning and musical performances and some results showing no significant differences between different FOA instructions.

Most of the studies investigating FOA in music predominantly used motor learning and *performance under pressure* models as theoretical underpinnings and transferred those to create an experimental paradigm with a musical task (e.g., Duke et al., 2011; Atkins and Duke, 2013; Atkins, 2017; Stambaugh, 2017; Mornell and Wulf, 2019). Allingham et al. (2021) used an additional music-specific theoretical framework by Jensenius (2007) that presents an *action-sound chain* describing the process from neurological activity in the brain at the start to the production of sound at the end. In more detail, he outlined a paired connection mechanism between the involved performance part and its location area (Brain–Neurological, Muscle–Physiological, Limb–Physical, Instrument–Mechanical, Sound–Acoustical; see Jensenius, 2007, p. 24). In all these parts of the process, a multimodal feedback-loop takes place. This model could be used as an explanation for sound as an external FOA because, at least in the dimension of time, it is the furthest point. Williams et al. (2023, p. 3) provided an attentional focus continuum model for musicians, classifying focus instructions into four main categories from proximal to distal, namely *internal focus*, *external focus*, *distal external focus,* and *very distal external focus*. It is a movement-oriented approach that subsumes insights from the motor learning and music research field but lacks precise sources and theoretical underpinnings regarding what dimension the continuum is grounded on—it could be time, room, and mental capacity. There are only very few approaches to investigating the attention processes of musicians in an explorative and qualitative manner to discover which music-specific aspects condition the direction of an attentional focus. Buma et al. (2015) used a collection of statements from experienced professional musicians to examine different thoughts before and during a performance situation under pressure. The various statements were categorized using cluster analysis and inductively assigned to six focus categories. The individual statements were then evaluated by musicians for their importance and frequency of occurrence during stage performances. The results show that a *musical focus* is mentioned most frequently, but the relevance and application of a musical focus are not considered as important as that of a *focus on physical aspects*. A study by Oudejans et al. (2017), which builds on this, deals with the focus shortly before and after moments of *choking under pressure* and assigns an important significance to a focus on musical aspects here. Another qualitative

approach was made by Treinkman (2022a), who examines attentional focus processes in singing by asking more than 200 singers about their foci while practicing and performing. The deductive assignment of the singer's open statements, where they direct their attention to Wulf's paradigm of internal vs. external FOA, showed no convincing results regarding which kind of foci were preferred, used, or useful in singing. A qualitative thematic analysis of open-format questionnaires with string players conducted by Lubert et al. (2023) shows four main themes of reported attentional foci during music performance under pressure, that is, navigation of music-related aspects, physical and emotional performance experience, critical thoughts and attempts and control, and quality and dynamic of focus. These explorative studies and inductively performed qualitative analyses are very important for the field due to the differentiated perspective on attentional foci in various musical situations.

1.4 Challenges of attentional focus instruction and outcome measures in music

A critical aspect in assessing the effect of attentional instructions in music is the heterogeneity in terms of participants (amateur and professional musicians), instruments (vocals, strings, winds, etc.), and musical tasks or tests (high internal validity and low ecological validity or very application-oriented tasks or music practice interventions). However, the variety of reported verbal attentional instructions and their mainly deductive classification to the internal vs. external FOA categorization by Wulf et al. (1998) lead to difficulties in the interpretation of effects as well as study results. There are some limitations of a dichotomous assignment of instructions for executing a musical task into categories of internal and external FOA (or complementarily possibly far-external and proximal-external FOA). Instructions used in the experiments do not exclusively refer to one movement execution (internal FOA) or one (near or far) movement target (external FOA) as Wulf and colleagues' paradigm purports (Wulf et al., 1998; see also Wulf, 2013; Wulf and Lewthwaite, 2016). They refer to many different aspects that play a role in making music—namely, body movements, breathing, sound, visual orientation, consistency, communication, visual and auditory imagination, metaphors, musical instruments, physical resistance, creativity, expressivity, musical articulation, etc.—and a music-specific theoretical FOA model that could explain, connect, or differentiate these aspects from another is missing. Recently, Herrebrøden (2023) argued in his critical review that the superiority of external FOA instructions in motor learning experiments in the sports and music domains could alternatively be explained with the direction of instructions on task-relevant information—whereas internal foci instruction often refers to task-irrelevant information.

Finally, the measurement methods used in the experiments are as heterogenic as the various aspects mentioned before. Measuring musical performance is a fundamental problem that plays a major role in a transfer or commonality of sports and musical performance models ("First, we have the problem of measurement," Schmidt and Lee, 2012, p. 17). In sports and movement research, there is no discussion of the outcomes of gross movement tasks or specific types of sports scoring systems. We can easily measure how high we jump, and we can count baskets, holes, bull's eyes, or detect errors while trying to reach a task goal (for an overview of outcome measures in the FOA motor learning field, see Chua et al., 2021, p. 622, footnote 2 and Appendix). One of the few exceptions in the FOA research field is expert ratings in gymnastics (Lawrence et al., 2011). In music performance research, the discussion of how to assess musical performances validly and reliably has a long tradition (Saunders, 1993; McPherson and Thompson, 1998; Thompson and Williamon, 2003) and is still up to date (Wesolowski and Wind, 2019a,b; for an overview of different perspectives on the issue from education and research see Brophy, 2019).

1.5 Review aims and research questions

Although there was no empirical research on the effects of FOA in music at the time of Wulf and Mornell's (2008) contribution, the authors formulated implications for music education based on the findings from the field of motor learning: "Teachers will ideally look for verbal instructions that direct attention away from small muscle movements or body, so that automatic motor programs are not disrupted by cognitive interference" (p. 14). Similar deductions are also made based on other results, although the study situation and less evidence do not (yet) provide clear pedagogical or didactical implications for musicians and singers while they practice or perform on stage.

Thus, this review first aims to contribute to a broader discourse in the FOA field by systematically displaying the genesis and actual research situation, mainly in the sports and music domains. Second, we intend to highlight theoretical and methodical challenges and examine to what extent a movement-based model can be transferred to the specifics of musical skill acquisition and music performance. Two of the main questions in this context serve as a framework for the current review and future directions of examining FOA effects in music: What should we focus on and how can we measure it? In more detail and in the context of the present review, we have the following three research questions:

(1) How many experimental studies investigate the effects of different attentional focus instructions on learning and performance in the music domain?
(2) What kind of FOA instructions, outcome measures, and classifications do they use?
(3) Which concrete aspects of FOA research in music should be discussed in the field in the future, and what directions of an application-oriented agenda could there be in music performance research?

2 Methods

The present systematical analysis and its methods are strongly oriented to the *PRISMA statement* (Moher et al., 2009) and the updated guidelines for reporting a systematic review (Page et al., 2021). The abstract was written in line with the *PRISMA 2020 for Abstracts checklist* (Page et al., 2021, p. 185). The application of the *PRISMA guidelines* in this systematic review lies in both the methodological process and the structure of illustration by

continuously following the *PRISMA 2020 item checklist* (see Page et al., 2021, pp. 183–184). Due to the research topic and main research aims of reviewing FOA instructions and outcome measures, and not effects, the current study did not consider items from the checklist related to meta-analysis recommendations (*11. Study risk of biases*; *12. Effect measures*; *13. Synthesis methods*; *14. Reporting risk of bias*; *15. Certainty assessment*; *18. Risk of bias in studies*; *20. Results of syntheses*; *21. Reporting biases*; *22. Certainty of evidence*, see Page et al., 2021).

A detailed and comprehensive *review protocol*, which can be found in the Supplementary material (Review protocol), contains different tables of datasets to understand the review process better. However, important outcomes referring to the research questions of the current study and additional findings are implemented in the text.

2.1 General eligibility criteria

Regarding the whole study selection process recommended by Moher et al. (2009), the eligibility check of reports contains three main levels, i.e., *identification* of records, *screening* of records, and a final, full-text *eligibility* check that includes data collection as well as data abstraction. Beyond singular methodical steps, we defined eight eligibility criteria, which have been reviewed throughout different stages of the selection process. Included studies should meet the following criteria:

(a) Be published in the English language.
(b) Be published between February 1998 and March 2023 (due to the first publication of Wulf et al. (1998) presenting the FOA paradigm in movement science).
(c) Be published in a peer-reviewed journal.
(d) Refer to the research topic *focus of attention on music* in a broad sense.
(e) Apply an experimental paradigm referring to Wulf et al. (1998).
(f) Address the processes of learning or performing a musical skill.
(g) Contain a precise description of FOA instructions.
(h) Contain a precise description of outcome measures.

Considering the study selection flow, the first four criteria (a–d) were reviewed in the *screening* phase, whereas the latter four (e–h) were examined during the full-text *eligibility* check.

2.2 Information sources and search strategy

To find appropriate reports referring to *FOA in music* as much as possible and guarantee a high degree of transparency, we defined a search term suitable for various scientific search engines and databases. It contains keywords, Boolean operators, truncations, quotation marks, and parentheses. The search with the term *("focus of attention" OR "attentional focus" OR "external focus" OR "internal focus") AND (music* OR music OR singer OR singing OR voice)* was performed using a title/abstract filter in *PubMed*, *SAGE journals*, *Taylor & Francis Online,* and *Web of Science*. In addition, we conducted an open search with the term *"focus of attention" music* in *Google Scholar* and examined the first 300 records (as recommended by Haddaway et al., 2015, who analyzed the procedure, usefulness, and weaknesses of Google Scholar for systematic scientific literature searches in detail). Finally, we scanned the reference lists of representative articles in the field. All actions regarding the systematic search of records were performed by the first author (JH). The search was conducted on 30 March 2023.

2.3 Study selection process

After the identification of records and exclusion of duplicates, two reviewers (JH and AI) independently scanned the publishing date, publication type, journal name, record title, and abstract under consideration of the first four eligibility criteria (a–d). If the record did not meet one of the four criteria, it was rated with [EC] for exclusion; otherwise, we assigned the code [TM] for transmission to the next level. In the case of a mismatch rating (a record was rated with [TM] by the first reviewer, but the second reviewer assigned [EC] or vice versa), the records in question were looked at together again and discussed before a decision was made (see the *Review protocol* for review methods, code explanation, and contents of the screening categories, Supplementary material).

Records that met the criteria were transmitted to the final eligibility check, performed by two reviewers (JH and AI) together. At the beginning of this stage, we collected additional basic information about the reports (e.g., *Authors*, *APA citation*, and *DOI*). One report could contain two or more studies (experiments); in such cases, both studies were reviewed. There were no studies published twice, so we did not exclude double-published contributions. Subsequently, we performed a first collection of relevant data in line with the research aim of this review to check the studies under consideration of the latter four eligibility criteria (e–h) and finally, to decide on inclusion or exclusion. Therefore, we created six main data abstraction variables, which are important for the eligibility check, i.e., *type of report*, *research approach*, *research design* (each of these was filled with data by JH and AI, who followed a variable-specific categorization system; see Supplementary material), *FOA instruction description*, *musical task description*, *outcome measure description* (each of these was filled by JH and AI with either [YS] for *reported* or [NO] for *not reported*). In the next step, we checked the four criteria (e–h) for eligibility and finally decided on the inclusion [IC] or exclusion [EC] of the study. In two cases, the decision for selection was made after intensive discussion. Furthermore, the decision about the criteria being fulfilled or missing was distinct.

2.4 Data collection, data abstraction, data categorization, and frequency analysis

The included studies were reviewed in more detail with the help of a complex dataset that was divided into five major sections, namely *design*, *participants*, *focus of attention*, *outcome measures,* and *results*. In each of the sections, we created different variables and deductively developed various information categories and an associated code system. The dataset contains four types of variables, namely dichotomous variables (with the codes [YS] for *reported* or [NO] for *not reported*), categorization variables (either with a category system created by us or by the authors of the reviewed studies), and citation variables (with relevant original content from the reviewed studies) or

quantitative variables (e.g., sample size). First, this structure provides the basis for an overview of the objective, methods, and outcomes, and second, it lets us focus on the important data to answer the research questions, i.e., (1) the precise wording of FOA instructions and (2) the type of outcome measures trying to assess the effect of those instructions. We either collected FOA instruction classifications (as assigned by the authors of the reviewed studies) or categorized instructions inductive-deductively to give an overview of the field in this regard. Furthermore, we conducted an inductive-deductive categorization of outcome measures, aiming to overview which dependent variables were used in the studies. To display the actual research situation as comprehensively as possible, we finally ran frequency analyses of the most relevant variables in relation to the research questions of this review and displayed percentage distributions accordingly.

3 Results

The systematic search identified 387 records, of which 163 were duplicates and thus sorted out. The *publishing date*, *title of the journal*, *record title,* and *abstract* of the remaining 224 records were screened by the two reviewers independently. The decision for *exclusion* [EC] or *transmission* [TM] was made with a total agreement rate of 91% (see review protocol, Tab. III, Supplementary material). After discussing critical records and a final agreement about the decision, 185 records (79%) were not transmitted to the final eligibility check. Most records (75%, $n = 139$) were excluded since the contribution did not refer to the research topic FOA in music at all (criteria d), and 4% ($n = 7$) were sorted out because the report was not published in a peer-reviewed journal (c). Five records (3%) were not published between February 1998 and March 2023 (b). The remaining 18% of records ($n = 34$) were not transmitted due to a failure of more than one eligibility criteria (see Figure 1 and Tab. III, Review protocol, Supplementary material). Finally, 39 records passed the screening criteria and were reviewed in detail in the next step.

Within the final full-text eligibility check, we reviewed 39 reports on 41 studies by proofing relevant data in the manuscripts, and we discussed important criteria to decide on study inclusion or exclusion. Finally, 14 reports (36%) with 15 studies were included in the review. One report (Mornell and Wulf, 2019) contains two experiments that should be interpreted as two *studies* following the *Glossary of terms* of the *PRISMA 2020 statement* (see Page et al., 2021, p. 181). Almost all reports ($n = 25$, 96%) were excluded due to the failing of more than one of the four eligibility criteria (e–h). For an overview of the study selection flow, see Figure 1.

After collecting and abstracting relevant data from the studies for the eligibility check, we did another data collection, abstraction, and categorization step for the 15 studies included in the review (see Review protocol, Tab. V, Supplementary material). Many variables containing citations of aims and hypotheses, participant information (e.g., sample size, participants' instrument, and participants' expertise), descriptions of musical tasks and material, and detailed information about the results (e.g., post-hoc results) were added to the protocol. Finally, we collected and categorized the important data to answer the review research questions, that is, the correct citations of FOA instructions within the 15 studies and all outcome measures used to measure the effects of experimentally manipulated attentional focus instructions in different experiments. Furthermore, we collected the classifications of FOA instructions by the authors of the original studies and inductive-deductively developed a code system that helps to categorize all focus instructions and assign these categories to the two main FOA classifications by Wulf et al. (1998), that is, *internal* and *external*. The coding and categorization process of dependent variables was conducted with an inductive-deductive attempt to cluster outcome measures into 10 categories (e.g., expert rating, acoustical analysis, and self-evaluation rating).

3.1 Attentional focus instruction in music

In total, we collected 53 different experimental FOA instructions. On the first abstraction level, we assigned these instructions to 9 different FOA subcategories inductive-deductively, i.e., either the category is strongly oriented to the original instruction citation or it was assigned by the authors of this review by abstracting on a broader aspect of the FOA field. Fourteen out of 15 included studies designed an experimental paradigm that contains—albeit in different ways—a comparison of different movement (or playing or teaching) instructions made by the experimenter, which refer at least to one *external* and one *internal* aspect of the required task. This fact can be seen as a minimal match across all studies. The study by Williams et al. (2023) serves as an exception due to comparing a practice program that contains external foci with a control group without any FOA instruction. However, the collection, abstraction, and categorization of instruction data show a wide variety of attentional focus instructions with reference to many different goals (see Tables 1, 2).

The most frequently used instructions refer to an attentional focus on the body ($n = 12$, 21%), a FOA on sound ($n = 9$, 16%), and a control condition or control group, in which generally no specific focus instructions were given ($n = 9$, 16%). Instructions referring to a visual focus were solely used in studies with singers and investigating FOA instructions on different singing tasks (Atkins and Duke, 2013; Atkins, 2017, 2018). The reason for this specificity lies in the behavior that singers do not have naturally to visually focus their instruments, as they are hidden inside the body, so they can adopt an attentional focus while visualizing different focal points in their environment. An instrumental focus was instructed in 4 of the 15 studies reviewed. Furthermore, there are a few experimental FOA instructions that we could not assign reasonably to one of the other 9 subcategories because they were part of a whole practice (Williams et al., 2023) or education program (Silvey and Montemayor, 2014; Montemayor et al., 2016) and their content between and within the program was very different. That is why they were subsumed in the category *Other focus* (see Table 2).

Those 10 subcategories were assigned to three main categories of a category system that is oriented on the original experimental paradigm of Wulf et al. (1998); see also (Wulf, 2013) consisting of FOA instructions either as internal, external, neutral, or with no specific focus. In the current review, we abstracted each of the FOA instructions used and 10 subcategories to one of these three main categories based on either a note for a link in the original manuscript of the study or due to an interpretation of the original group/condition classification in terms of Wulf's definitions of an external focus (to focus "[…] on the intended movement effect or task goal," Wulf and

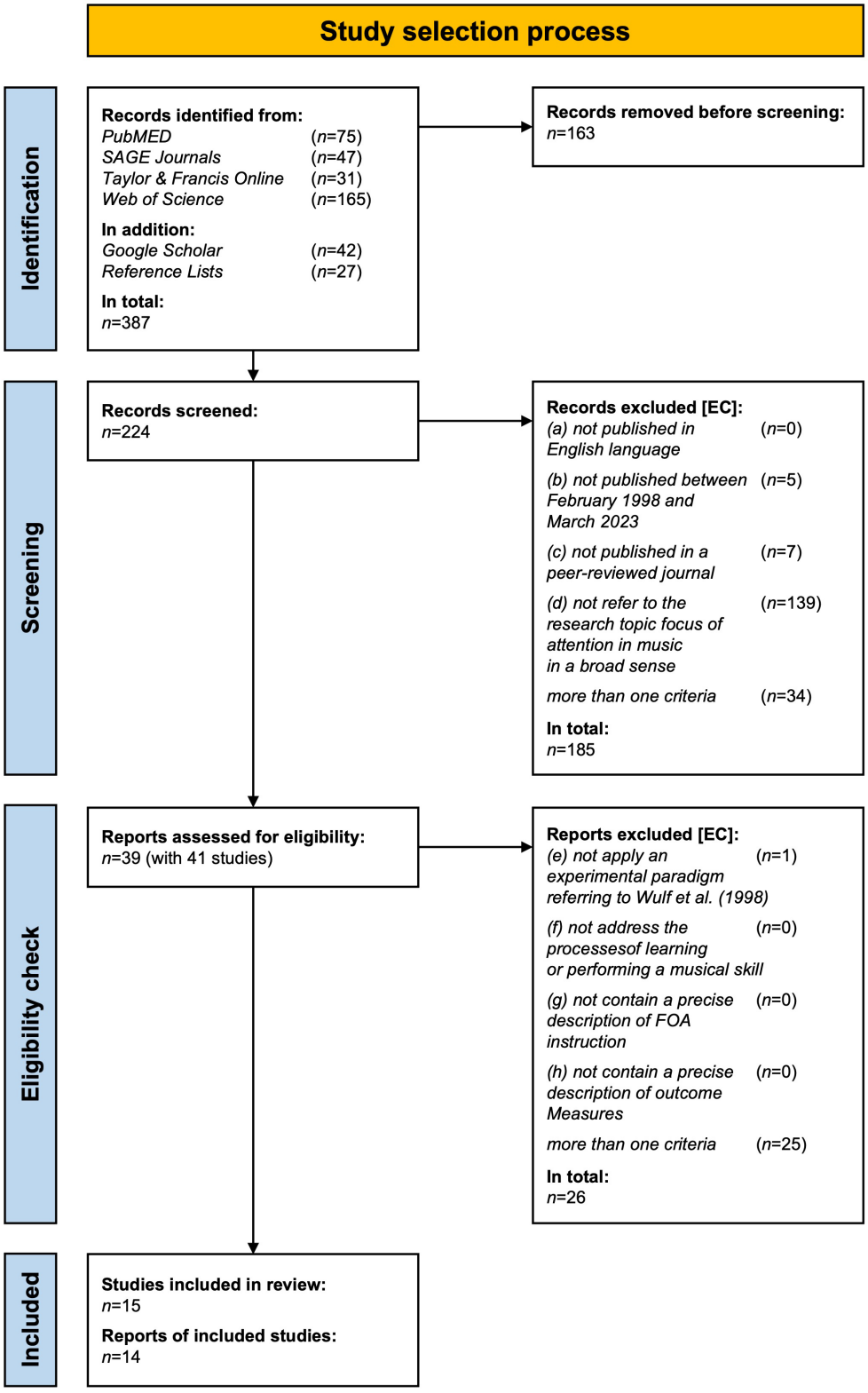

FIGURE 1
Flow diagram of the study selection process.

Lewthwaite, 2016, p. 1,402) and an internal focus ("[…] concentration on body movements," Chua et al., 2021, p. 619). Within the 15 studies reviewed, 27 (51%) external foci have been used, 32% of all FOA instructions refer to internal attentional processes ($n = 17$), and 9 instructions had no special focus and served as control or baseline conditions (17%, see Table 3).

TABLE 1 Participant information and attentional focus (FOA) instructions of included studies.

Study	Author(s)	Sample size[a]	Expertise	Instrument	Foa instruction[b] (page)	FOA categorization	
No.	(Year, Experiment)	*N*	Category	Category	Citation	Subcategory[c]	Main category[d]
1	Allingham et al. (2021, Exp I[e])	32	Both[f]	String	"Focus your attention on the movement in your right arm" (see Table 1, Allingham et al. (2021)	Bodily focus	Internal focus
					"Focus your attention on the sound you produce"	Sound focus	External focus
					"Focus your attention on the resistance of the bow against the string"	Instrumental focus	External focus
2	Allingham and Wöllner (2022, Exp II[e])	33	Both	String	"Focus your attention on the movement in your right arm" (p. 176)	Bodily focus	Internal focus
					"Focus your attention on the sound you produce"	Sound focus	External focus
					"Focus your attention on the resistance of the bow against the string"	Instrumental focus	External focus
3	Atkins (2017)	22	Experts	Voice	"Focusing their attention to the position of their soft palate" (p. 425)	Bodily focus	Internal focus
					"Focusing their attention on keeping their vibrato steady and consistent"	Technical focus	Internal focus
					"Directing their sound to the top of a tripod placed 18 inches in front of them at mouth height"	Visual focus	External focus
					"Directing their sound to a chair in the center of the performance hall, approximately 24 feet directly in front of the singer and marked with a piece of paper"	Visual focus	External focus
					"Directing their sound to a piece of paper on the back wall of the performance hall approximately 40 feet from the singer and approximately 8 feet above the level of the microphone"	Visual focus	External focus
					"Thinking about filling the room with their sound"	Sound focus	External focus
					"No focus of attention instructions"	Baseline/control	No focus
4	Atkins (2017)	12	Experts	Voice	"Positioning the soft palate" (p. 7)	Bodily focus	Internal focus
					"Keeping their vibrato steady"	Technical focus	Internal focus
					"Directing their sound to the microphone 18 inches in front of them at mouth height"	Visual focus	External focus
					"Directing their sound to a music stand approximately 9 feet across the room at a height of approximately 4 feet"	Visual focus	External focus
					"Directing their sound toward a circle, 4 inches in diameter, drawn on a white board approximately 19 feet across the room and 6 feet above the floor"	Visual focus	External focus
					"No focus of attention instructions were given"	Baseline/control	No focus

(Continued)

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TABLE 1 (Continued)

Study	Author(s)	Sample size[a]	Expertise	Instrument	Foa instruction[b] (page)	FOA categorization	
No.	(Year, Experiment)	*N*	Category	Category	Citation	Subcategory[c]	Main category[d]
5	Atkins and Duke (2013)	30	Novices	Voice	"sing while feeling the vibrations on the throat with either hand" (p. 31)	Bodily focus	Internal focus
					"Sing with the index and middle fingers placed on either side of the nose along the zygomatic arch, which we referred to as the mask, while thinking about directing the sound to the fingers"	Technical focus	Internal focus
					"Sing while thinking about directing the sound to a microphone 18 inches in front of the singer"	Visual focus	External focus
					"Sing while thinking about directing the sound toward a point on the wall, 4 inches in diameter, drawn on the white board approximately 18 feet across the room and 6 feet above the floor"	Visual focus	External focus
					"No focus instructions were given"	Baseline/control	No focus
6	Duke et al. (2011)	16	Both	Piano	"Focus either on their fingers" (p. 48)	Bodily focus	Internal focus
					"The keys"	Instrumental focus	External focus
					"The hammers"	Instrumental focus	External focus
					"Or the sound produced"	Sound focus	External focus
7	Jentzsch and Braun (2023)	49	Both	Piano	"While you perform, I want you to focus on the sounds you are creating" (p. 583)	Sound focus	External focus
					"While you perform, I want you to focus on the movements of your fingers"	Bodily focus	Internal focus
8	Lipke-Perry et al. (2022)	9	Experts	Piano	"Focusing on the fingertips and creating staccato articulation" (p. 4)	Bodily focus	Internal focus
						Technical focus	
					"Focusing on creating the style of the dance"	Metaphorical focus	External focus
					"Focusing on the beat of a metronome set at 144 beats per minute"	Auditory focus	External focus
					"Without any instruction"	Baseline/control	No focus

(Continued)

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TABLE 1 (Continued)

Study	Author(s)	Sample size[a]	Expertise	Instrument	Foa instruction[b] (page)	FOA categorization	
No.	(Year, Experiment)	*N*	Category	Category	Citation	Subcategory[c]	Main category[d]
9	Silvey and Montemayor (2014, Exp I[e])	32	Novices	Music education	"Focused almost exclusively on 'internal' matters related to knowledge of the score and development of an aural image of the music: • identified important music lines, such as melody, countermelody, accompaniment, and bass line • marked specific music materials in their scores with pencil, pens, or highlighters • listened five times to a professional recording of their excerpt while following the score and/or practicing conducting gestures • repeatedly sang individual music lines as previously identified • notated potential difficulties for individual sections or the ensemble • engaged in silent score study" (p. 164)	Other focus	Internal focus
					"Focused their preparations on observable rehearsal behaviors with a minimal amount of time devoted to score study: • brief identification of important music lines, such as melody, countermelody, accompaniment, and bass line • a general discussion of successful conductor rehearsal behaviors • observation of three expert conductors' successful rehearsal videos • self-observation of the previous rehearsal video prior to their upcoming rehearsal for both Sessions 2 and 3 • also for Sessions 2 and 3, identification of three goals for improvement after watching their video of the previous rehearsal • peer evaluation and discussion of another participant's rehearsal video, using the RES[g]" (pp. 164–165)	Other focus	External focus
10	Montemayor et al. (2016, Exp II[e])	32	Novices	Music education	"Participants' preparation related to knowledge of the score and development of an aural image of the music" (p. 458)	Other focus	Internal focus
					"Participants focused their preparations on observable rehearsal behaviors with a minimal amount of time devoted to score study"	Other focus	External focus
11	Mornell and Wulf (2019, Exp I[h])	23	Experts	Various instrument categories	"Focus on the precision of their finger movements (or lip movements for singers) and correct notes" (p. 379)	Bodily focus	Internal focus
						Technical focus	
					"Focus on playing for the audience and the expressive sound of the music"	Communicative focus	External focus
						Sound focus	
					"Without specific focus instruction"	Baseline/control	No focus

(Continued)

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TABLE 1 (Continued)

Study	Author(s)	Sample size[a]	Expertise	Instrument	Foa instruction[b] (page)	FOA categorization	
No.	(Year, Experiment)	*N*	Category	Category	Citation	Subcategory[c]	Main category[d]
12	Mornell and Wulf (2019, Exp II[h])	18	Experts	Various instrument categories	"Focus on the precision of their finger movements (or lip movements for singers) and correct notes" (p. 382)	Bodily focus	Internal focus
						Technical focus	
					"Focus on playing for the audience and the expressive sound of the music"	Communicative focus	External focus
						Sound focus	
					"Play the way they normally did"	Baseline/control	No focus
13	Stambaugh (2017)	30	Both	Wind	"Think about your fingers" (p. 48)	Bodily focus	Internal focus
					"Think about the keys"	Instrumental focus	External focus
					"Think about your sound"	Sound focus	External focus
					"No specific FOA"	Baseline/control	No focus
14	Stambaugh (2019)	56	Novices	Wind	"Think about your fingers, the ones that are moving (woodwind, valved brass group)/think about your hand, the one that is moving (trombone group)" (p. 239)	Bodily focus	Internal focus
					"Think about the sound of your playing"	Sound focus	External focus
					"As accurately as possible and like you heard in the recording"	Baseline/control	No focus
15	Williams et al. (2023)	7	Experts	Wind	• "Imagine the phrase/motif you are about to play with as much detail and nuance as you can evoke • sing and gesture the phrase/motif dramatically and with detail • play the phrase • play another version(s) of the phrase • repeat the procedure with a new phrase/motif • stop if tired, bore • avoid analyzing and judgment–focus on the imagined sound • avoid mechanical repetition" (see APT[i], S2)	Other focus	External focus
					"They were instructed to practice in their 'normal' way" (p. 5)	Baseline/control	No focus

[a]Sample size for analysis after drop out or sort out.

[b]Some citations were displayed without punctuation characters and parentheses; some citations were marginally modified in terms of grammar corrections for suitable illustration; no content was changed.

[c]Codes were developed and assigned inductive-deductively by interpretation of the FOA instruction content.

[d]Codes were assigned in two ways: (1) by authors of this review based on links between FOA groups/conditions and FOA categories referring to the FOA paradigm by Wulf (2013) in the original manuscript of the study; (2) by the authors of this review based on an interpretation of original group/condition classification in terms of Wulf's definitions of an external focus (to focus "[…] on the intended movement effect or task goal," Wulf and Lewthwaite, 2016, p. 1,402) and an internal focus ("[…] concentration on body movements," Chua et al., 2021, p. 619).

[e]Same participants in Experiment 1 and Experiment 2.

[f]Author(s) did not define or group participants in terms of musical expertise at all or both experts and novices took part in the study.

[g]Rehearsal Effectiveness Scale (RES; Bergee, 1992; see Silvey and Montemayor (2014) for detailed explanation).

[h]Different participants in Experiment 1 and Experiment 2.

[i]Audiation Practice Tool (see Williams et al., 2023).

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TABLE 2 Frequencies of FOA instruction categories, experimental groups, or conditions used in included studies.

FOA code	FOA subcategory	Study	N	%
BD	Bodily focus	Duke et al. (2011), Atkins and Duke (2013), Atkins (2017, 2018), Allingham and Wöllner (2022), Stambaugh (2017, 2019, Mornell and Wulf (2019), Exp1&2, Allingham et al. (2021), Lipke-Perry et al. (2022), Jentzsch and Braun (2023)	12	21
SO	Sound focus	Duke et al. (2011), Atkins (2017), Stambaugh (2017, 2019), Allingham et al. (2021), Allingham and Wöllner (2022), Jentzsch and Braun (2023)	9	15
CO	Control/baseline	Atkins and Duke (2013), Atkins (2017, 2018), Stambaugh (2017, 2019), Mornell and Wulf (2019) (Exp1&2), Lipke-Perry et al. (2022), Williams et al. (2023)	9	15
VS	Visual focus	Atkins and Duke (2013), Atkins (2017, 2018)	8	14
TC	Technical focus	Atkins and Duke (2013), Atkins (2017, 2018), Mornell and Wulf (2019) (Exp1&2), Lipke-Perry et al. (2022)	6	10
OT	Other focus	Silvey and Montemayor (2014), Montemayor et al. (2016), Williams et al. (2023)	5	9
IS	Instrumental focus	Duke et al. (2011), Stambaugh (2017), Allingham et al. (2021), Allingham and Wöllner (2022)	5	9
CF	Communicative focus	Mornell and Wulf (2019) (Exp1&2)	2	3
AF	Auditory focus	Lipke-Perry et al. (2022)	1	2
MP	Metaphorical focus	Lipke-Perry et al. (2022)	1	2
Total			58	100

TABLE 3 Frequencies of FOA instruction categories referring to the paradigm by Wulf (2013).

FOA code (wulf)	FOA category (Wulf)	N	%
IF	Internal focus	17	32
EF	External focus	27	51
NF	No focus, baseline, control condition, control group	9	17
Total		53[a]	100

[a]Total frequency of foci in reference to Wulf (2013) differs from the number of subcategories (N = 58) since five instructions got two assignments of subcategories, which both refer to the same categories by Wulf.

For internal focus instructions used by experimenters and authors of the studies, the wording appears often sharp, precise, and goal-oriented with a clear link to body parts or body motions, e.g., "focus on your fingers" (Duke et al., 2011), "focus on your right arm" (Allingham et al., 2021), "focus on the precision of their finger movements" (Mornell and Wulf, 2019), or "focus on your soft-palate" (Atkins, 2017). In the included studies, 21% of all instructions refer to the body ($n = 12$, see Table 2). On the other hand, there are internal FOA instructions relating to different dimensions, such as a type of auditory imagery ("[…] and development of an aural image of the music," Silvey and Montemayor, 2014) or reference to notes or the score ("[…] and correct notes," Mornell and Wulf, 2019). Some authors classify a focus on technical performance aspects as an internal FOA, e.g., "[…] keeping their vibrato steady and consistent" (Atkins, 2017) or "[…] and creating staccato articulation" (Lipke-Perry et al., 2022), even if the words refer to outcomes that could be interpreted by definition (see Wulf, 2013) as movement goals – that is, in reference to the abovementioned instructions, move in a certain manner *to* sing consistently or *to* create staccato.

Within the package of instruction wordings of the 15 included studies referring to external attentional foci in music ($n = 27$), the interpretation, abstraction, or classification is challenging, at least due to the variety of musical tasks, materials, participants' experiences, and participants' instruments. However, one crucial aspect is the interpretation of *sound* as the central goal of musical movements or musical tasks in equivalence or as a modification of the definition of external FOA in motor learning, *focusing on the movement effect* (see Wulf, 2013). This is supported by the percentage of instructions categorized as *sound focus* ($n = 9$, 33% of all external FOA instructions). A further subcategory of special relevance for research in singing is classified as *visual focus* ($n = 8$, 30% of external FOA instructions). An important difference compared to *sound* as a movement effect is the action dimension of visualizing a certain point (either near or far away) in the room (see Atkins and Duke, 2013; Atkins, 2017, 2018). Adopting a visual focus while making music is not a focus on a movement effect or movement goal; it can be seen as a supporting moderator between movement execution and sound to optimize sound. Obviously, concentrating on a visual task during a music performance is easier when musicians are not physiologically and perceptually tied because hand–eye coordination is not essential, as for singers.

Another important type of external FOA can be described as an *instrumental focus* in general ($n = 5$, 19% of external FOA instructions). Looking back at the original experimental design and experimentally manipulated instruction in the ski-simulator study by Wulf et al. (1998), an attentional instruction focusing on the musical instrument (or maybe certain aspects of voice as the pendant for singers) has the biggest theoretical overlap to *the* original external instructions in motor learning, focusing on not the feet but the wheels of the

ski-simulator platform. Allingham et al. (2021); see also (Allingham and Wöllner, 2022) used the term *somatic focus* to depict the importance of physical resistance and the tactile sensory feedback while focusing on the instrument. Duke et al. (2011) and Stambaugh (2017) also used the instrumental focus on keys to find differences between concentrating on essential parts of the piano or the wind instrument and concentrating on the sounds that arise through actuating these essential parts.

3.2 Outcomes measures in FOA studies in the music domain

Across all included studies, we collected 63 descriptions of dependent variables to measure the outcomes and, thus, the effects of experimentally manipulated attentional focus instructions on the performance of a musical task. Thereby, the distribution of used outcome measures per study is very heterogeneous and reaches from 1 (Stambaugh, 2019; *Temporal evenness*) to 14 (Allingham et al., 2021; 3 different OM categories). A detailed collection of OM and other relevant information can be overviewed in Table 4. An inductive-deductive data categorization of all OM descriptions of the original manuscripts resulted in 9 different OM categories (see Table 5), of which *expert ratings* (EXR) were used most to measure FOA effects ($n = 17$; 27%). In total, 7 out of 15 studies used EXR. Furthermore, another 4 studies used different kinds of 14 *acoustical analyses* of recorded performances as dependent measures (ACU; 22%), e.g., roughness, spectral centroid, formant frequencies, or harmonic-to-noise ratio (see Table 5). *Electromyography analysis* (EMG) for measuring the effects of FOA on muscle activity or muscle energy—and therefore on movement efficiency—was solely conducted by two studies of the same research group (Allingham et al., 2021; Allingham and Wöllner, 2022). However, six different EMG measures were applied (10%), the same amount as for *self-evaluation ratings* (SER; 10%) and *error detection* (ERD; 10%). One study used another's evaluation ratings (OER; 3%; Silvey and Montemayor, 2014), that is, an evaluation rating of performance conducted neither by an expert nor by oneself. Furthermore, one study measured FOA effects with the help of movement analysis (MVA) and used five different movement parameters (8% of all OM).

In general, the total frequency of different OM used in FOA studies in the music domain is very high considering the small number of experimental studies in the field (on average, 4.2 OM per study, $sd = 3.2$). One explanation of this result could lie in the explorative character of the included studies, although all studies applied an experimental design with a relatively fixed paradigm. Due to the tenuous research situation in this regard and the lack of clear results yet, a one-sided *focus* on one OM may not be adequate for the explorative aim of most of the research groups.

3.3 Further outcomes

In addition to the main research aim, to depict the actual research work in terms of FOA instructions and OM, a few other important outcomes emerged based on the full-text analysis and the data abstraction process. In line with the argument of the explorative character of the studies, frequency analysis showed that just 4 studies out of 15, to the best of our knowledge, formulated a clearly directed hypothesis (Mornell and Wulf, 2019, Exp1&2; Allingham et al., 2021; Allingham and Wöllner, 2022), in which the type of FOA was assumed to be superior regarding the music performance or music learning effect.

In addition to the illustration of FOA instructions, FOA sub, and main categories, Table 1 depicts the sample size, participants' expertise (experts, novices, and both), and participants' instrument category. Across all included studies, the sample size ranges from 7 to 52, with a total sample size of 401 and an average of 27.7 participants per study ($sd = 13.8$). In terms of participants' expertise, the frequency distribution is homogenous, with six studies investigating experts, five studies that defined either two groups of experts and novices or no distinction at all (both), and four studies solely with participants and authors defined as novices or amateurs. As expertise plays a big role in the discussion of FOA effects in sports or motor learning (see *Introduction* and Singh and Wulf, 2020), this differentiation was discussed in many of the included studies (e.g., Stambaugh, 2019; Allingham and Wöllner, 2022; Jentzsch and Braun, 2023). Regarding the participants' instruments category, which is strongly correlated with the type of musical task within the experimental design (see Table 4), all classical instrumental groups (wind, string, piano, and voice) are present in the included studies except for percussion instruments. However, there are two additional studies that examined music educational skills in ensemble teaching (Silvey and Montemayor, 2014; Montemayor et al., 2016) and two studies that apply the same task to various instrumental groups (Mornell and Wulf, 2019, Exp1 & 2).

Table 4 shows the research design (within-subject, between-subject, and mixed), musical tasks, the task paradigm (performance or learning paradigm) of each study, and a summarized display of post-hoc results for each OM. There are two included studies investigating FOA effects without a within-subject factor and, hence, a between-subject design containing one *internal* FOA group and one *external* FOA group (Silvey and Montemayor, 2014; Montemayor et al., 2016). In addition to that, we found three studies with a mixed design, all of them with the experimental and control conditions as within-subject factor and expertise as between-subject factor (Allingham et al., 2021; Allingham and Wöllner, 2022; Jentzsch and Braun, 2023). Musical tasks are very particular, each of them specially adjusted for the participants' instrument, research design, and performance paradigm. The two studies that applied a traditional learning paradigm (Duke et al., 2011; Stambaugh, 2017)—i.e., acquisition/training block, retention test, and transfer test—used more controlled and internally valid experimental tasks. On the other hand, investigations of more authentic music performances designed more externally valid musical tasks (for an overview, see Table 4). Finally, a summary of post-hoc results, as described by the authors of the original manuscripts of the studies, is depicted in Table 4, if available. This style of illustration is oriented to Wulf's (2013) review of FOA effects on motor learning, although the current review does not explicitly focus on FOA effects for the aforementioned reasons. Nevertheless, the results of the small number of included studies convey an impression of how heterogeneous the interplay of participant information, musical tasks, FOA instructions, and OM is (see Tables 1, 4). This fact confirmed the complexity and difficulty of outcome interpretation.

TABLE 4 Musical tasks, outcome measures (OMs), and results of included studies.

Study	Author(S)	Research design (factors)	Musical task and material	Task paradigm	Outcome measures	OM category	Results
No.	(Year, Experiment)	Category	Paraphrase	Category	Paraphrase	Category as code	FOA sub category (</>/=)[ab]
1	Allingham et al. (2021, Exp I[c])	Mixed Design (Between-subject factors [NV,EX] x Within-subject factors [BD,SO,IS)	*General bowing task:* Bow string task (4x) on the open A-string in response to a metronome *Further task-specific instruction/ requirements:* Playing in time with metronome, playing with a good, consistent sound and avoiding scratching sounds	Performance paradigm	Mean spectral centroid of audio signal	ACU	**IS** >[d] BD/IS = SO/BD = SO
					SD spectral centroid of audio signal	ACU	n.s.
					M roughness of audio signal	ACU	n.s.
					SD roughness of audio signal	ACU	n.s.
					M root mean square of audio signal	ACU	n.s.
					SD root mean square of audio signal	ACU	n.s.
					M bow contact point	MVA	n.s.
					SD bow contact point	MVA	**IS** < SO/IS = BD/BD = SO
					Scroll sway (freedom of motion)	MVA	**IS** > BD[e]/IS = SO/BD = SO
					M bow acceleration	MVA	n.s.
					SD bow acceleration	MVA	n.s.
					Deltoid muscle activity	EMG	**IS** < BD/IS = SO/BD = SO
					Tricep muscle activity	EMG	n.s.
					Bicep muscle activity	EMG	n.s.
2	Allingham and Wöllner (2022, Exp II[c])	Mixed Design (Between-subject factors [NV,EX] x Within-subject factors [BD,SO,IS)	*General bowing task:* Slow motion bow sound production task *Further task-specific instruction/ requirements:* Nuanced, slow motion control skills, no lift of the bow, no changing of direction	Performance paradigm	Number of clicks	ACU	n.s.
					Number of errors	ACU	**IS** < BD[e]/IS = SO/BD = SO
					Deltoid muscle activity	EMG	n.s.
					Tricep muscle activity	EMG	**IS** < BD/IS = SO/BD = SO
					Bicep muscle activity	EMG	n.s.

(Continued)

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TABLE 4 (Continued)

Study	Author(S)	Research design (factors)	Musical task and material	Task paradigm	Outcome measures	OM category	Results
No.	(Year, Experiment)	Category	Paraphrase	Category	Paraphrase	Category as code	FOA sub category (</>/=)[ab]
3	Atkins (2017)	Within-subject design (BD[SP],TC[VI], VS[TN],VS[CM],VS[PO], FL[SO],CO)	*Different singing tasks:* (1)Singing a three-note [α] vowel pattern (low) (2)three-note [α] vowel pattern (high) (3)1st full phrase of "My Country 'Tis of Thee"' (4)1st or 2nd phrase of a song by choice	Performance paradigm	Ring	EXR	[f](1) **FL** > CO&SP&VI&TN&CM&PO/**PO** > CO&VI&TN [f](2) **FL** > CO&SP&VI&TN&CM&PO/**PO** > CO&VI&TN [f](3) **FL** > CO&SP&VI&TN&CM/**SP** > CO/**PO** > CO&VI [f](4) **FL** > CO&SP&VI&TN&CM&PO/**PO** > CO
					Evenness	EXR	n/a
					Vibrato	EXR	n/a
					Freedom	EXR	n/a
					Intonation	EXR	n/a
					Color	EXR	n/a
					Overall	EXR	[f](1) **FL** > CO&TN [f](2) **FL** > CO&TN [f](3) **PO** > CO&CM/**Fl** > CO [f](4) **FL** > SP
4	Atkins (2018)	Within-subject design (BD[SP],TC[VI], VS[MN],VS[SM],VS[PO],CO)	*Different singing tasks:* (1)Singing a three-note [α] vowel pattern (2)1st or 2nd phrase of a song by choice	Performance paradigm	Overall Assessment	EXR	(1) n/a[g] (2) n/a[g]
					Mean harmonic-to-noise ratio	ACU	(1) n.s. (2) n.s.
					Intensity	ACU	[f](1) **PO** > CO/**SM** > VI/**SP** > VI (2) n.s.
					Formant frequencies (F1-F5)	ACU	(1) n.s. (2) n.s.
5	Atkins and Duke (2013)	Within-subject design (BD[TH],TC[MA],VS[MN],VS[PO],CO)	*General singing task:* Singing a three-note [α] vowel pattern	Performance paradigm	Overall ranking (1st–5th)	EXR	n/a
					Mean frequency (Hz)	ACU	n/a
					Formant frequencies	ACU	n/a
					Harmonic-to-noise ratio	ACU	n/a

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TABLE 4 (Continued)

Study	Author(S)	Research design (factors)	Musical task and material	Task paradigm	Outcome measures	OM category	Results
No.	(Year, Experiment)	Category	Paraphrase	Category	Paraphrase	Category as code	FOA sub category (</>/=)[ab]
6	Duke et al. (2011)	Within-subject design (BD[FI],IS[KY],IS[HA],SO)	*General piano task:* Playing a 13-note sequence composed of alternating sixteenth notes using the index and ring fingers of the right hand (for acquisition and retention, slightly different for transfer task) *Further task-specific instruction/ requirements:* Playing as quickly and evenly as possible	Learning paradigm	Temporal evenness (IOI SD)	PHY	[h](a) n/a (b) n/a (c) n/a (d) n/a (R) n.s [f](T) **HA** < BD/**SO** < BD/BD = KY/HA = SO
					Loudness evenness (KV SD)	PHY	n/a
7	Jentzsch and Braun (2023)	Mixed design (Between-subject factors [EX,IM] x Within-subject factors [SO,BD])	*General piano task:* Playing first 24 bars of *J. S. Bach's "Little Prelude in D Minor" BWV 935 (Score on Line—Digital Sheet Music Library—partitions de musique classique, 2020)* *Further task-specific instruction/ requirements:* No stress, should not be perfect	Performance paradigm	Pitch errors	ERD	**SO** < BD
					Hesitations	ERD	n.s.
					Note corrections	ERD	**SO** < BD
					Deletions	ERD	n.s.
8	Lipke-Perry et al. (2022)	Within-subject design (BD/TC, OT, AF, CO)	*General piano task:* Playing Bartók's Romanian Folk Dance, Sz. 56, No. 2 *Further task-specific instruction/ requirements:* Articulation and pedaling instruction were in the score, no other preparatory instruction	Performance paradigm	Pedal Performance Z-Score[i]:	PHY	n/a
					Expert Listener Rating of Performances	EXR	n/a
9	Silvey and Montemayor (2014), Exp I[c])	Between-subject design (OT[AI], OT[RB])	*General teaching task:* Leading an ensemble in a series of three 6-minute rehearsals on their assigned excerpt. Materials were from Volumes 1 and 2 of Teaching Music Through Performance in Band (Miles, 1997-1998)	Performance paradigm	Conductor self-evaluation of teaching	SER	n.s.
					Conductor evaluation of ensemble	SER	n.s.
					Ensemble eval. of conductor effectiveness	OER	n.s.
					Ensemble eval. of conductor score knowledge	OER	n.s.
					Panel audio eval. of ensemble performance	EXR	n.s.

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TABLE 4 (Continued)

Study	Author(S)	Research design (factors)	Musical task and material	Task paradigm	Outcome measures	OM category	Results
No.	(Year, Experiment)	Category	Paraphrase	Category	Paraphrase	Category as code	FOA sub category (</>/=)[ab]
10	Montemayor et al. (2016, Exp II[c])	Between-subject design (OT[AI], OT[RB])	See Study 9 (Silvey and Montemayor (2014), Exp I)	Performance paradigm	Frequencies of teachers' verbal behaviors, assigned to 16 musical var. (see Table S2; Montemayor et al., 2016)	FQA	Sign. difference for 1 out of 16 variables: Balance/blend (**AI** > RB)/all other var.: n.s.
					Frequencies of teachers' verbal behaviours, assigned to 7 teaching var.	FQA	Sign. difference for 1 out of 8 variables: Positive feedback/specific (**RB** > AI)/ all other var.: n.s.
					Clarity of gesture	EXR	n.s.
					Expression	EXR	n.s.
11	Mornell and Wulf (2019, Exp I[l])	Within-subject design (BD/TC, SO/CF, CO)	*General performing task:* Playing music/singing a song of their choice of approximately 3-minute duration, that they had performed in concert	Performance paradigm	Technical precision	EXR	n.s.
					Musical expression	EXR	**SO/CF** > BD/TC/**SO/CF** > CO/BD/ TC = CO
12	Mornell and Wulf (2019, Exp II[l])	Within-subject design (BD/TC, SO/CF, CO)	See Study 11 (Mornell and Wulf, 2019, Exp I)	Performance paradigm	Technical Score (mean of 5 items)	EXR	**SO/CF** > BD/TC/SO/CF = CO/BD/ TC = CO
					Musicality Score (mean of 5 items)	EXR	**SO/CF** > BD/TC/**SO/CF** > CO/BD/ TC = CO
13	Stambaugh (2017)	Mixed design (Between-subject factors [NV,EX] x Within-subject factors [BD,IS,SO,CO)	*General wind task:* Playing a 9-note sequence composed of alternating eights-notes using the index and ring fingers of the right hand (for acquisition and retention, slightly different for transfer task) *Further task-specific instruction/ requirements:* Playing as evenly and accurately as possible, coordination between fingers on both hands, breathing, and tonguing	Learning paradigm	Temporal evenness (IOI SD)	PHY	*Novices:* (A) **BD** > CO/**SO** > CO/all other var.: n.s. (R) n.s. (T) n.s. *Experts:* (A) **BD** > CO/**SO** > CO/**BD** > IS/all other var.: n.s. (R) n.s. (T) n.s.
					Pitch error (accuracy)	ERD	*Novices:* (A) **BD** > CO/**SO** > CO/**IS** > CO/all other var.: n.s. (R) n.s. (T) n.s. *Experts:* (A) **BD** > CO/**SO** > CO/**IS** > CO/all other var.: n.s. (R) **BD** > CO/**SO** > CO/**BD** > IS (T) n.s.

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TABLE 4 (Continued)

Study	Author(S)	Research design (factors)	Musical task and material	Task paradigm	Outcome measures	OM category	Results
No.	(Year, Experiment)	Category	Paraphrase	Category	Paraphrase	Category as code	FOA sub category (</>/=)[ab]
14	Stambaugh (2019)	Within-subject design (BD, SO, CO)	*General wind task:* Listening to audio file and subsequently playing each of three different 7-note patterns of alternating eights-note *Further task-specific instruction/ requirements:* Playing as evenly and accurately as possible	Learning paradigm	Temporal evenness (IOI SD)	PHY	n/a
15	Williams et al. (2023)	Within-subject design (OT, CO)	*General trumpet task:* Playing unfamiliar excerpts from baroque trumpet literature (J. S. Bach and C. P. E. Bach), participants had to practice 1 test piece three times a day 5 minutes for three days (control phase) in a "normal" way; same procedure in intervention phase, but with following APT (see Table 1)	Performance paradigm/ Learning paradigm	Pitch error (accuracy)	ERD	**OT** > CO
					Confidence	SER	n.s.
					Motivation	SER	n.s.
					Engagement	SER	n/a
					Self-efficacy	SER	n.s.

(a) = 1st training block, (A) = Acquisition block, ACU = Acoustical analysis, AF = Auditory focus, AI = (focus on) Aural image, APT = Audiation Practice Tool (see Williams et al., 2023), (b) = 2nd training block, BD = Bodily focus, (c) = 3rd training block, CF = Communicative focus, CM = (focus on) Chair-middle, CO = No focus/baseline/control condition/control group, (d) = 4th training block, EMG = Electromyography analysis, ERD = Error detection, eval. = evaluation, EX = Experts/professionals/advanced players, Exp = Experiment, EXR = Expert rating, F = Formant, FI = (focus on) Fingers, FL = Fill (the room with sound), FQA = Frequency analysis, HA = (focus on) Hammers, HZ = Hertz, IM = Intermediate players, IOI = Inter onset interval, IS = Instrumental focus, KV = Keystroke velocity, KY = (focus on) Keys, M = Mean, MA = Mask (focus on the fingers on the nose), MN = (focus on) Microphone-near, MVA = Movement analysis, n/a = Results not available or not reported, No. = Number, NV = Novices, amateurs, n.s. = Not significant, OER = Others' evaluation rating (not self, not experts), OT = Other focus, PHY = Physical analysis, PO = (focus on) Point-far, (R) = Retention test(s), RB = (focus on) Rehearsal behavior, SD = Standard deviation, SER = Self-evaluation rating, SM = (focus on) Stand-middle, SO = Sound focus, SP = (focus on) Soft-palate, (T) = Transfer test(s), TC = Technical focus, TH = (focus on vibrations in the) Throat, TN = (focus on) Tripod-near, var. = variables, VI = (focus on) Vibrato, VS = Visual focus.[a]if *post-hoc* results are available.

[b]if more than one subcategory was implemented in an experimental paradigm (e.g., three times Visual focus, see Atkins, 2017), we used more specific codes that distinguish the different instructions referring to the same category (e.g., TN for Tripod-near, CM for Chair-middle, PF for Point-far, which all refer to Visual focus, see Atkins, 2017).

[c]Same participants in Experiment 1 and Experiment 2.

[d]FOA subcategories in bold were superior to those not bold-faced.

[e]Just for experts.

[f]Just significant post-hoc results displayed, all other post-hoc comparisons were not significant.

[g]No inference statistical analysis, just quantification of qualitative statements.

[h]Just for less-skilled pianists (N = 12).

[i]See Lipke-Perry et al. (2022) for a detailed calculation of z-score.

[j]Different participants in Experiment 1 and Experiment 2.

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TABLE 5 Frequencies of outcome measures (OMs) categories used in included studies.

OM code	Outcome measures category	Study	N	%
EXR	Expert rating	Atkins and Duke (2013), Silvey and Montemayor (2014), Atkins (2017, 2018), Lipke-Perry et al. (2022)	17	27
ACU	Acoustical analysis	Atkins and Duke (2013), Atkins (2018), Allingham et al. (2021), Allingham and Wöllner (2022)	14	22
EMG	Electromyography analysis	Allingham et al. (2021), Allingham and Wöllner (2022)	6	10
ERD	Error detection	Stambaugh (2017), Jentzsch and Braun (2023), Williams et al. (2023)	6	10
SER	Self-evaluation rating	Silvey and Montemayor (2014), Williams et al. (2023)	6	10
MVA	Movement analysis	Allingham et al. (2021)	5	8
PHY	Physical analysis	Duke et al. (2011), Stambaugh (2017, 2019), Lipke-Perry et al. (2022)	5	8
FQA	Frequency analysis	Montemayor et al. (2016)	2	3
OER	Others' evaluation ratings	Silvey and Montemayor (2014)	2	3
Total			63	100[a]

[a]Total percentage has been marginally adjusted due to rounding up of singular percentage values.

4 Discussion

This review aims to overview the current research situation of investigating attentional focus mechanisms in the music performance field by systematically collecting, abstracting, and categorizing relevant data referring to FOA instructions and outcome measures used in studies with experimental paradigms, in accordance with Wulf et al. (1998). In this context, we specifically asked (1) what is the current state of research, (2) what type of FOA instructions and dependent variables are used, and (3) to what extent can a future research agenda be derived from the findings. Out of 387 records initially identified, 15 studies could be included in a more in-depth investigation through several selection steps oriented on the *PRISMA statement* (Moher et al., 2009) and the *PRISMA 2020 item checklist* (Page et al., 2021). Thereby, different types of interesting additional information were collected, that is, aspects of research design, participant information, experimental tasks, and finally, attentional focus effects. Although that data collection was not the main goal of the review, it provides useful information as a basis for the following discussion and supports taking a comprehensive view of the research field and the actual discourse.

4.1 What is the goal of movement in a musical performance?

The original FOA paradigm of comparing internal and external foci using their effects on motor learning and performance is well-established in the sports domain and movement science research. Significant results of a superior external FOA can be found in studies examining various types of sports and different kinds of gross motor skills (for reviews and meta-analysis, see Wulf, 2007a; Wulf, 2013; Wulf and Lewthwaite, 2016; Chua et al., 2021). Explanations of these effects, even the specification of distinguishing between proximal and distal external foci, are mainly based on the theory that a shift of attention onto the movement effect or a task goal prevents the constrained action effect and, thus, leads to improved motor performance. With small exceptions, included studies of the current review refer to its research questions, aims (and hypotheses), research designs, experimental paradigms, as well as outcome interpretations to Wulf's motor theory, and music-specific theoretical constructs, play a marginal role, even during outcome discussions. Overviewing the variety of external FOA instructions in the reviewed studies, the question arises, how a movement goal or movement effect is manifested in music. Many of the authors decided to operationalize the external FOA instructions with wording that targets the *sound* (see Table 1). The challenge with this implementation in the music domain lies in its self-evidence because no musician aims to execute musical movements or sound-producing gestures (Dahl et al., 2010; Jensenius et al., 2010) without aiming to produce sound. Transferring that problem back to the sports domain, we could compare this operationalization with the external FOA instruction to focus on playing basketball or darts (not to shoot baskets, e.g., see Zachry et al., 2005, p. 306; or not to throw bull's eyes, e.g., see Lohse et al., 2014, p. 124). A few of the included studies from the music domain therefore added some instructions referring to sound *quality* ("thinking about filling the room with their sound," Atkins, 2017, p. 425; "focus on playing for the audience and the expressive sound of the music," Mornell and Wulf, 2019, p. 379; "focusing on creating the style of the dance," Lipke-Perry et al., 2022, p. 425)—as it is a *quality* to shoot baskets in basketball.

4.2 Dimensions of musical goals and musical technique

However, these focus-instruction extensions in external FOA music instructions refer to a variety of musical performance dimensions, namely, music communication aspects ("filling the room" or "playing for the audience"), musical expression ("expressive sound"), or musical auditory/visual imagery or musical metaphors ("style of a dance"). These elements of musical performances and musical learning processes could be seen as *musical* goals, as it is not the sound production itself that lies in the musician's focus of attention, but how the sound is produced, whom the sound is addressed to, and what it should express. Another methodical issue appears when combining different FOA *directions* in *one* instruction. As Wulf herself stated, "[…], we have always attempted to make

external and internal focus instructions so similar that they differed in only one or two words to avoid confounds with other variables" (Wulf, 2013, p. 92). Subsequently, she mentioned that "contradictory results" (p. 92)—that is, study outcomes that showed no difference between internal and external FOA or a superiority of internal FOA—could be explained by this aspect. This suggestion of a highly controlled experimental manipulation of FOA instructions was made to optimally trace back FOA effects on motor learning effects to the fact that one word makes the difference. Across all included FOA studies of this systematic review, only two studies are close to transposing this advice (Duke et al., 2011; Stambaugh, 2019). The others more or less failed to control FOA instruction in this regard (see Table 1), at least when paying attention to the number of differently used words.

In addition, there is a big difference between changing words in FOA instructions or consciously referring the instruction to a different musical performance dimension, which took place as well while operationalizing internal FOA instructions. A few of the collected internal FOA instructions relate to technical aspects of musical learning or music performance processes ("focus on the precision of their finger movements (or lip movements for singers) and correct notes," Mornell and Wulf, 2019, p. 379; "focusing on the fingertips and creating staccato articulation," Lipke-Perry et al., 2022, p. 4; "focusing their attention on keeping their vibrato steady and consistent," Atkins, 2017, p. 425). Two points should be discussed concerning aspects of musical technique. On the one hand, the first listed FOA instruction citation refers to the precision of playing (see Mornell and Wulf, 2019). When looking at the control/baseline condition of Stambaugh (2019), she used the wording to play "[…] as accurately as possible" (p. 239), which refers to the same kind of technical dimension. This wording is also used as the basic instruction for all experimental conditions in another study (see Stambaugh, 2017, p. 48). To summarize, we have the same reference of instruction used in three different studies with different functions within the experimental FOA paradigm, i.e., as a control condition, internal FOA, and general instruction underlying all conditions. Reflecting the methodical advice by Wulf (2013) in this context, contradictory results may not be surprising. On the other hand, a technical FOA instruction ("staccato articulation" or "consistent and steady vibrato") conceptually lacks a precise assignment to one of the two traditional FOAs due to the point that it could be referred to a style of playing or a specific type of sound-production as defined as an external FOA in many studies of this review. Still, all included studies classified technical foci as internal FOA.

4.3 FOA in music and multimodal action–perception coupling processes

From a sensory perception perspective, performing music and learning to perform music are processes with many related action–perception coupling mechanisms (Jensenius, 2007; Leman and Naveda, 2010), which are linked with sensory feedback processes as auditory (e.g., Bangert and Altenmüller, 2003; Pfordresher and Chow, 2019), visual (e.g., Wöllner and Williamon, 2007; Bishop and Goebl, 2015), somatosensory (tactile or kinesthetic; e.g., Goebl and Palmer, 2008; Kuchenbuch et al., 2014), or multisensory feedback (for a recent review see Nunes-Silva et al., 2021). In general, musicians spend their whole lives practicing, concentrating consciously or unconsciously on body movements and sound, as the two are inextricably linked. Therefore, it is difficult to argue that a specific focus on one of the two aspects can succeed while not focusing on the other. Furthermore, when it comes to perception, multimodal perception processes, mainly audiovisual integration, are present in making music (see, e.g., Schutz and Lipscomb, 2007). Wulf (2007b) answered a proposal of Hegele and Erlacher (2007) to consider the perceptual dimension of FOA in motor learning, or more concretely, dimensions of the movement effect, with the following statement: The "[…] suggestion that 'temporal' and 'perceptional' dimensions of movement effects should be considered, […], is interesting. Examining those factors independently would appear to be challenging, however" (Wulf, 2007b, p. 62). She added later: "Nevertheless, examining different dimensions of movement effects would seem like a worthwhile endeavor, as it may provide more insight into the effects of attentional focus on motor control" (p. 62). In the visual perception domain, a few studies (Moore et al., 2012; Klostermann et al., 2014; Rienhoff et al., 2015) investigated the relationship between FOA effects and effects of a visual fixation duration, such as the quiet eye phenomenon (for an overview, see Vickers, 2007; Lebeau et al., 2016). Neugebauer et al. (2020) recently found a significant effect of perceptional-directed attentional foci by implementing a 2 × 2 experimental design using a dart-throwing task (visual–internal vs. visual–external vs. kinesthetic–internal vs. kinesthetic–external), that is, quiet-eye duration was increased in the visual instruction groups. On the other hand, kinesthetic instruction leads to a decrease in visual fixation duration, indicating that the perceptual dimension is highly relevant within FOA research. This outcome is also worthy of discussion because Duke et al. (2011) mentioned this topic from a methodical perspective: "It is important to note that the term focus in this research does not refer to visual focus but to focus of attention (i.e., what one is thinking about). In fact, in much of the laboratory research in this domain, participants look at a visual fixation point throughout all the experimental conditions" (p. 46). To the best of our knowledge, there is just one FOA research attempt to study the auditory perceptual dimension of movement goals in music by Cheng et al. (2011). The group experimentally manipulated the auditory feedback (normal, mute, and delayed)—that was seen by the authors as the external FOA—of a piano task performed by professional pianists. Interestingly, although Cheng et al. (2011) did not use the FOA paradigm by Wulf et al. (1998), they had no verbal FOA instructions. Instead, they apparently pre-supposed that the sound of the piano *is* the movement goal of the pianists, and the absence or manipulation of fingering while playing was associated with the presence or the absence of an internal focus. Nevertheless, the results show that even when the fingering was manipulated on instruction, the most important performance factor was auditory feedback. Based on this outcome, it is worthwhile to examine the relationships between auditory or audiovisual sensory feedback and FOA effects in music.

4.4 Musical performance outcomes: measuring more or less?

One of the core aims of the current review was to shed light on the type of application of outcome measures possible within FOA research in the music performance domain. We, therefore, collected

and categorized all data of dependent variables used to measure FOA effects on the accomplishment of the different musical tasks. As already mentioned, the number of different kinds of outcome measures was surprisingly high in relation to the small number of studies that met the eligibility criteria of inclusion and compared to the amount of applied OM in many motor learning studies from the sports domain (see Wulf, 2013; Chua et al., 2021). It almost seems as if many studies reviewed in this article used several dependent measures to find the effects of experimentally manipulated FOA instructions. One of the reasons for that high amount of OM could lie in the dimension of the movement goal in music, the *sound*. Identifying *sound* as the external FOA means finding a solution to measure the performance effect, and this challenge was solved partially by conducting an acoustical analysis (Atkins and Duke, 2013; Atkins, 2018; Allingham et al., 2021; Allingham and Wöllner, 2022; see Table 4). Considering the amount of existing information of (post-hoc) results within the original manuscripts (see Table 4) of the studies, the question arises, how exploratory in its origin research designs of FOA studies in music are. Directed hypotheses are rare and, if available, a theoretically and/or empirically derived answer to why the experimental manipulation should affect this certain outcome measure, if at all, is slightly posed. Vice versa, the methodical sharpness of the FOA paradigm in its original implementation in motor learning research—and the pervasive number of significant results supporting the superiority of adopting an external FOA—provides a solid base for a precisely formulated, directed hypothesis. We argue that one of the key aspects of this methodical issue or challenge of analysis selection is a missing theoretical underpinning of FOA effects in music in general. If we do not know how it works, we know even less how to measure it. Another issue lies in the general challenge of measuring musical performance (see Schmidt and Lee, 2012). Expert ratings have been established through their extensive use within different music educational settings, grading in the music study context, performance evaluations in music competitions, and judgments with scores for various musical performance characteristics in auditions for positions as professional musicians. However, the high amount of different OMs used in the growing FOA music field somehow prevents comparable results. Thus, the interpretation of outcomes is challenging. Moreover, this problem is grounded on the inconsistency of applied musical tasks and the musical instruments used in the studies (see Table 4). Singers, wind instrument players, and pianists have different motor skills, different sensory awareness, gestural flexibility, and finally, a different perceptual-directed focus of attention during musical performance. There is a lack of replication studies and a lack of studies with different subjective performance ratings, such as ratings of competitors or the audience, which play a big part in the discourse of musical goals.

4.5 Limitations of the review study

The limitations of the review study are mainly due to the small number of experimental studies. In addition, the inconsistent application of analysis between those studies leads to problems in classifying the results and reported effects. Challenges to the interpretation of study results from the FOA in the music field impede formulations of credible insights. Furthermore, it is not possible to estimate the effects of internal, external, or otherwise different attentional focus instructions on musical learning, music performance, or motor learning in music based on this investigation. Another limitation lies in various steps of the *PRISMA guidelines* to conduct and display systematic reviews, which are in their implementation—even if the claim is to be as transparent and objective as possible—inherently still subjective. We tried to strictly follow the checklist and explain why we deviated from it in some places. Moreover, data abstraction, data categorization, and the design of the categorization systems in terms of FOA instructions and outcome measures are explorative in nature. However, the specific goal of this review lies in focusing on the methodical aspects in detail and not evaluating the results and effects of the reviewed studies. Transparent elucidations of conducting this inductive-deductive style of analysis were given so they can be discussed or criticized in the field and may serve as an impulse for further investigations in this regard. Finally, the definition of eligibility criteria in systematic reviews is often challenging as it determines the study selection process. Formulations of the eight criteria are somehow worthy of discussion, e.g., the requirement that studies must apply an experimental FOA paradigm in reference to the Wulf et al. (1998) attempt (criteria e) and contain a precise description of FOA instruction (criteria g). There are a few theoretical contributions overviewing the situation of FOA research in singing (e.g., Helding, 2015, 2016; Brand, 2021; Treinkman, 2021, 2022b), but they failed these criteria. Other studies used qualitative methods to provide important ideas on studying FOA in music (e.g., Buma et al., 2015; Guss-West and Wulf, 2016; Oudejans et al., 2017; Parsons and Simmons, 2021; Treinkman, 2022a; Lubert et al., 2023); however, they were not included due to missing criteria (e) and (g). The study by Cheng et al. (2011); published in conference proceedings and a few unpublished dissertations (e.g., Atkins, 2013; Mentzel, 2016; Williams, 2019; Allingham, 2022) approaching aspects of FOA in music were excluded—besides other reasons—because they failed criteria (c), i.e., reports were not published in a peer-reviewed journal or we could not finally be sure of it. With the exception of the study by Mentzel (2016), the mentioned unpublished dissertations described the same studies that were included in the review. Our decision to apply somehow strict criteria in this regard is grounded on the aim of deepening face up to two of the relevant aspects of the discussion, namely FOA instructions and outcome measures.

4.6 Implications and future studies

Almost every discussion or conclusion section of the study reports included in this review contains ideas of music pedagogical implications from their study results. In other cases, the authors have concrete suggestions of didactical implications for practicing music in general or, in more detail, for singing and playing an instrument. Considering the inconclusive results and effects of FOA instructions on music performance, we would not make concrete music pedagogical suggestions for using shifts of FOA while practicing music at this point. One of the main reasons for that is the absence of FOA studies in music with a learning paradigm in an application-oriented educational setting. Concerning on-stage musical performances in *performance under pressure* contexts, the research

situation manifests as tighter due to a long tradition of multidisciplinary investigations in relation to anxiety and stress in high-pressure performing settings from psychology, sports, and music, e.g., the growing field of music performance anxiety research (for current reviews, see Fernholz et al., 2019; Osbourne and Kirsner, 2022; Kenny, 2023). However, studies showed that dealing with music-specific high-pressure challenges is highly individual and diverse, and depends on multiple factors (see, e.g., Buma et al., 2015; Oudejans et al., 2017). When dealing with the wide range of practice routines at different practice stages (see Antonini Philippe et al., 2020) and the very different pedagogical approaches of instrumental and vocal teachers, it is very difficult to assess the impact of conscious changes in attentional focus on musical learning. This is also supported by anecdotic evidence from discussions with many music students in different lectures, where practice and teaching routines, the practice stage, and the musical literature play a major role.

In relation to the last-mentioned issue and as a preliminary conclusion, future studies of FOA effects in the music domain should first go a step back. For the construction of a music-specific theoretical model, it is necessary to take the musical goals of musicians seriously. Undoubtedly, basic principles of motor learning and motor control have an important influence on how successful musicians learn and perform, but when supposing an integral understanding of musical goals, mental and physiological health and wellbeing should be noted as well. We would argue that it is necessary to conduct big qualitative and quantitative questionnaire surveys to collect as much as possible of existing FOA routines and pedagogical instructions in various music-relevant learning and performance situations of musicians with different goals. Subsequently, it could be interesting to do some in-depth investigations of singular practicing and on-stage performances, e.g., by applying video-stimulated-recall settings (see, e.g., Després, 2022), in which the relation between conscious or involuntary shifts of attentional foci, musical material, and sound characteristics could be analyzed solidly. Maybe a strict inductive strategy of data analysis will generate clusters, categories, or structures that somehow confirm the reasonableness of a transfer of the original binary FOA paradigm by Wulf et al. (1998) from sports to music—maybe not, however, because dimensions of musical performances could be more complex.

5 Conclusion

To conclude the current review, we start with a reference to the three main research questions. Out of 387 records, a small number, 15 studies, were included in the study, which, by definition of certain eligibility criteria, applied a FOA instruction paradigm in an experimental design. FOA instructions could be abstracted into 10 different subcategories, e.g., *sound focus*, *visual focus*, *bodily focus,* or *instrumental focus*, which again could be assigned to the two classifications of internal and external FOAs. We classified 63 outcome measures into 9 outcome measure categories, e.g., *acoustical analysis* and *expert rating*. Future scientific discourse in the field should focus on exploring musical goals as one of the critical aspects when comparing FOA effects in sports with those that could be expected in music. We could show that the current research situation is lacking in various points that must be considered before generalizing insights and offering music pedagogical implications. Finally, it seems to be promising to pursue a new application-oriented attempt at exploratory research on attentional focus routines and FOA shifts of musicians in different practice stages to get a solid database of music-specific attentional foci.

Data availability statement

The datasets for this study can be found in the Supplementary material (see Review protocol).

Author contributions

JH: Conceptualization, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. AI: Conceptualization, Investigation, Methodology, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Ancillary and instrumental body movements during inhalation in clarinetists

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Background: Playing a musical instrument requires physical movements that are involved in sound production and movements with more expressive and communicative characteristics. Both movements co-occur during a performance; however, the interaction between the movements is still unclear.

Methods: Using motion capture technology, the movement patterns of clarinetists were analyzed at certain points in a performance to investigate how instrumental and ancillary movements interplay. Movements in the arms and knees of clarinetists during a performance were recorded using this technology. The mean angular movements at specific points in the piece, where some players inhaled and others did not, were compared.

Results: While the players who inhaled adopted significantly more upright body and neutral arm positions, the players who did not inhale seemed less interrupted in their performance. The results showed that the players performed rather individual ancillary movements, but at specific points, such as during melodic transitions, they performed similarly. At certain points in the melody, while some players needed to inhale, others adjusted their playing according to the inhalation moment to adopt a suitable body position.

Discussion: The ancillary movement was consequently interrupted by the physiological necessity to inhale. The findings provide more insights into the interplay of instrumental and ancillary movements during a performance.

KEYWORDS

ancillary movements, instrumental movements, inhalation process, movement behavior, body posture

1 Introduction

For musicians, body movements are essential to perform musical content and create an expressive moment (Leman, 2016). Musicians' body movements can be categorized into different functions associated with auditory and visual aspects of the performance (Godøy and Leman, 2010). First, *instrumental movements* are necessary because they are required for sound production. These movements are restricted by the instrument and the notes to be played. They occur in rather similar ways in repeated performances.

In addition to the instrumental movements, musicians perform body movements that are not essential for the production of sound, but follow more intentional, communicative, and expressive purposes, the so-called *ancillary movements* (Jensenius et al., 2010; Nusseck et al.,

2018). These movements contain individual aspects and convey the personal characteristics of the musician (Godøy and Leman, 2010). Musicians use both instrumental and ancillary movements simultaneously while playing (Dahl et al., 2010).

Ancillary movements can appear in head movements, facial expressions, and side-to-side swaying (Davidson, 2012). For instance, body sways can transport emotional expressions (Demos et al., 2018) and create a shared emotional expression in a musical ensemble (Chang et al., 2019). These movements reflect musical structures, such as melodic changes and transitions (MacRitchie et al., 2013), as well as dynamics (Nusseck et al., 2022), and can aid tempo perception (Massie-Laberge et al., 2019). When studying the movements of professional pianists, it was found that certain movement strategies were used not only to express musical goals but also to compensate for individual physical constraints in order to economize movements (Turner et al., 2021).

Ancillary movements are highly individual in style and execution. However, at certain musical positions, similar movement gestures have been identified across players. Similar movements of pianists have been observed at structurally prominent positions in the score (Thompson and Luck, 2012). For clarinetists, similar movements of the bell were found across players at specific points, such as a melodic or rhythmic transition and the ending (Teixeira et al., 2015). Congruent movements were also related to key musical moments and specific, musically expressive contents. In saxophone players, knee flexions were identified as ancillary movements with an expressive purpose and were found to be performed in anticipation of specific melodic phrases (Moura et al., 2023). The knee movements were associated with pitch expectations and rhythmic density, suggesting that they are related to expressive and facilitative qualities.

In clarinet playing, ancillary movements have been largely researched (Nusseck et al., 2018). It was found that these movements mainly involve bending the knees and raising the arms (Weiss et al., 2018). At certain musical transitions or endings, ancillary movements across players become very similar, and the players adopt a rather neutral and upright body posture (Nusseck et al., 2022).

For wind instruments, breathing plays a decisive role in sound production. During a performance, the moment of inhalation needs to be considered and anticipated. The inhalation itself can be seen as an instrumental movement to prepare for sound production and must be integrated into the context of the performance. In previous studies, clarinetists played a piece in which inhalation coincided with transitions or endings of melodic phrases (Nusseck et al., 2022). The players performed at those points with a more upright body posture and neutral arm positions. As these ancillary movements are also associated with certain expressive and communicative aspects, it is difficult to distinguish whether these movements also follow a biomechanical purpose, to position the body in a physiologically supportive posture for optimal inhalation. Experienced performers certainly combine expression with movement, but it is not clear how ancillary movements constitute and support the player's technical execution (Moura et al., 2023).

This study aimed to investigate the body movements of clarinetists during the performance of a melody. Typically, ancillary movements are predominant in such performances, but there may also be a need for inhalations. By comparing the movements of players who inhaled at a particular point in the melody with players who did not inhale at that point, the results provide insights into the potential physiological functions related to inhalation. Therefore, a piece with a slow and long melody that required players to inhale while performing was selected. Movements in players during inhalation, at the end of a melodic phrase, and during the melody were observed and analyzed.

2 Materials and methods

2.1 Participants

The recordings of clarinet players used for this study are a subsample of the dataset reported by Weiss et al. (2018). Of the original 22 clarinet players, 20 players who had complete sets of movement and audio data were selected. The average age was 32.3 years ($SD = 12.6$ years). The players were at a professional instrumental level with a mean duration of playing the clarinet of 22.2 years ($SD = 12.1$ years).

The clarinetists played the theme of Maurice Ravel's "*Boléro*" one time. They were asked to practice the piece before the recording session and to play the piece as they would normally play it in front of an audience. The theme is a two-part theme with 16 bars that requires inhalation between and during the parts. The theme score is shown in the top row of Figure 1, which was created with LilyPond.[1] A music sheet was placed on a music stand approximately 60 cm before the players. The tempo was provided with a metronome (77 bpm) before the performance. During the performance, the musicians did not play with the metronome. All players provided their written consent to participate in the study.

2.2 Measuring technics

For the motion analysis, the clarinetists were recorded using an optical 3D motion capture system. Their performances were captured by four calibrated digital videos with a sampling rate of 50 frames per second using Templo software (Contemplas GmbH, Kempten, Germany). In total, 22 markers were attached to central joints and body parts to obtain a whole-body image, and the marker positions were digitized using Peak Motus 10 (Vicon). In addition, the players were acoustically recorded using an audio recorder (Zoom H4N), which was placed approximately 2 m in front of the player. More details regarding the recording system can be found in the studies by Weiss et al. (2018) and Nusseck et al. (2022).

2.3 Analyses

Based on previous studies (Weiss et al., 2018; Nusseck et al., 2022), the angular movements of the knees and arms were considered for analysis. The knee angle was calculated between the foot and the hip marker, using the knee marker as the angle intersection point. A high value indicates an extended leg, while a low angle indicates a bent knee. The knee angle measurement cannot be greater than 180 degrees due to anatomical limitations. The lowest angle found was approximately 100 degrees. Both knee angles were highly correlated ($r > 0.9$). Therefore, only one knee angle (right knee) was used for the analysis.

1 https://lilypond.org/

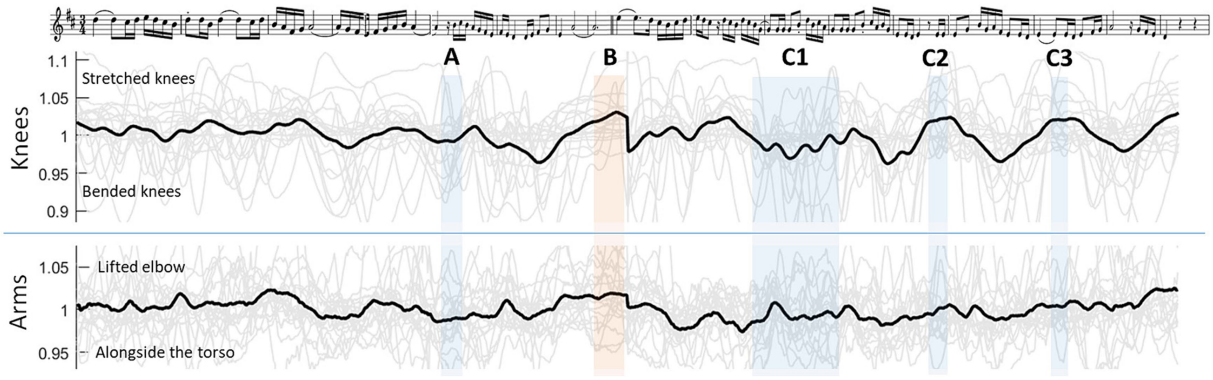

FIGURE 1
Top row: Score of Ravel's "*Boléro*" theme created with LilyPond. Second and third rows: Trajectories of the angular movement in the knees and arms (Note: values were divided by the mean angle; therefore, there is no unit. One is identical with the mean angle. In grey: each player. In black: mean of all players). A-C and marked with light blue: specific points in the theme where players inhaled (in light orange: the middle of the theme). Please note that the score is slightly offset from the movement curves due to individual tempo variations and different lengths between written and played notes. Therefore, the score has been compressed or stretched at some points to adapt it to the timeline of the movement.

The arm angle was calculated using the elbow, shoulder, and neck markers. A high value indicates an opening in the armpit. With a low value, the arms were held close to the trunk. The value ranged between 90 and 180 degrees. Both arm angles correlated highly with each other ($r > 0.8$), and thus, one arm angle was used for the analysis. As the right arm also has a holding function of the clarinet, the left arm movements were chosen.

Even with a given general tempo, the players performed rather individually. Therefore, the recordings were resampled to an equal length. This resampling was conducted for both parts of the theme separately and was then put together.

The measured knee and arm values of each player were divided by the mean of their movement trajectory to normalize individual angle differences. The resulting value is therefore scaled approximately 1 and has no unit. For instance, a value of 1.02 represents an angular difference of approximately 3–5 degrees higher than the mean angle.

The spectral centroid (SC) was used in the audio data to identify the positions when the players inhaled. The SC indicates where the center of mass of the frequency spectrum lies. Inhaling produces a type of noise in which the frequency spectrum is difficult to recognize, and the SC is very high compared to playing a sound. Using the Matlab MIRToolbox (Lartillot et al., 2008), the points at which the players inhaled were identified and used for calculating the angular movements of the knees and arms at these positions.

2.4 Statistics

The statistical analyses were performed with SPSS (version 28, Armonk, NY: IBM Corp.). Descriptive statistics were calculated for parametric variables, including mean values and standard deviations (SD). For parametric comparisons, analyses of variances (ANOVAs) were used. Simple comparisons of mean values to a single value were performed with two-sided *t*-tests. The level of statistical significance was set at $p = 0.05$.

3 Results

On average, the players inhaled 3.1 times (SD = 1.0) during the theme. The number was distributed rather evenly between two ($n = 7$ players), three ($n = 6$ players), and four ($n = 7$ players) times. Three positions during the theme were chosen for the analysis where the players inhaled the most (Figure 1): during the first part (A), between the two parts (B), and during the second part (C). All players inhaled at the transition between the two parts of the theme (B) and in the middle of the second part (C2). The mean movement trajectories in the knees and the arms across all players are shown in Figure 1.

At the melodic transition between the two parts of the theme (B), the players adopted an upright body posture with a mean knee value of 1.031 (SD = 0.035), which was significantly above 1 ($t(19) = 3.96$; $p < 0.001$). Additionally, they held their arms at a slightly higher angle than the mean angle with a value of 1.017 (SD = 0.035), again with significant difference to 1 ($t(19) = 2.16$; $p = 0.022$).

At point C2 (Figure 1), an eighth rest is noted in the score. At that point, all players adopted an upright body posture with a mean knee value of 1.024 (SD = 0.039), which was significantly above 1 ($t(19) = 2.71$; $p = 0.007$). The arms were at this point in a rather neutral angle with a value of 1.01 (SD = 0.037), without significant difference to 1.

During the first part, 12 players inhaled at point A (Figure 1), where the 16th rest is noted in the score. The other eight players did not inhale at that point and played up to point B with one breath. The mean movement trajectories of the players who inhaled and who did not inhale were calculated separately. They are shown in Figure 2.

The mean knee angle of the players who inhaled at point A was 1.02 (SD = 0.021), which was significantly higher than that of the players who did not inhale (knee angle: 0.98; SD = 0.016; $F(1,18) = 12.97$, $p = 0.002$). The arm movement angle did not differ between those players and was rather neutral (arm angle: 0.99; SD = 0.027).

In the second part, the breathing involved more individual inhalations. While all players inhaled at point C2 (Figure 1), there were some spontaneous inhalations at points C1 and C3. In the area

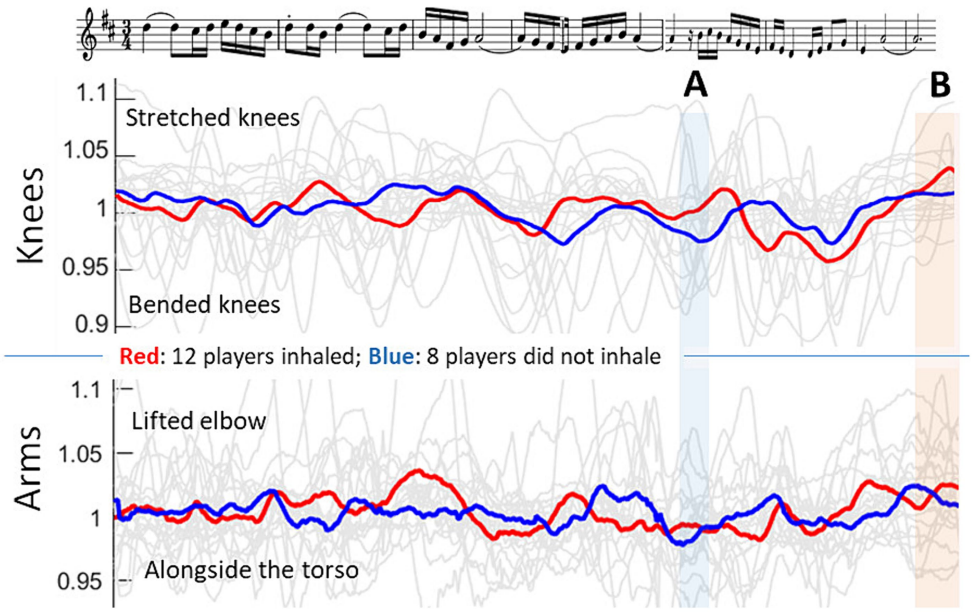

FIGURE 2
Top row: Score of Ravel's "*Boléro*" theme created with LilyPond. Second and third rows: Trajectories of the angular movement in the knees and arms (in red: players who inhaled at point A; in blue: players who did not inhale at point A). A and marked with light blue: points in the theme where some players inhaled. B and marked in light orange: the middle of the theme. Please note that the score is slightly offset from the movement curves due to individual tempo variations and different lengths between written and played notes. Therefore, the score has been compressed or stretched at some points in order to adapt it to the timeline of the movement.

of C1, there have been very individual inhalations performed by seven players. The movement values of these players were taken at their inhalation moment and compared to a mean value around the same point in the piece of the other players. There was a significant difference in the knee angle values between the players who inhaled (knee angle: 1.01; SD = 0.031) and the players who did not inhale (knee angle: 0.97; SD = 0.029; $F(1,18) = 10.5$; $p = 0.005$). The arm movements were not significantly different between both groups of players (mean arm angle: 0.99; SD = 0.034).

At point C3, there was a short pause in the score where five players inhaled. However, all players performed on average at this point with a more upright body (mean knee angle: 1.022; SD = 0.037) and neural arm position (mean arm angle: 1.01; SD = 0.028). No significant difference was found between the players who inhaled and the players who did not inhale.

4 Discussion

This study investigated whether the movement behaviors of clarinetists followed different patterns when they inhaled during a performance compared to when the players did not inhale. The aim was to find out whether the performance changed as a result of the inhalation process and how this relates to expressive movements. Previous studies showed that when inhaling, clarinet players had a rather average body posture and their arms were at an average position (Weiss et al., 2018; Nusseck et al., 2022). The trajectories of the knee angles indicated that the players were at a rather upright body position shortly before inhaling and performed a knee bending right after inhalation.

The results showed that the clarinetists played with a variety of arm and knee movements that were mainly related to ancillary movement characteristics. Despite their very individual movements, at certain points in the theme, the players showed similar movement behaviors. At the transition between both parts (B), the body was brought into an upright position and the arms were put closer to the body. Here, the first part of the melody ended and all players inhaled. The movement behavior is therefore connected to an expressive intention, but also with the purpose of preparing for inhaling. Even the arms were put in a neutral position to the torso. This confirms previous findings that players performed at those transitions with a rather neutral posture even in a different musical piece (Nusseck et al., 2022).

A similar movement behavior was found in the middle of the second part of the theme (C2); at that point, again all players inhaled. The trajectory of the knees indicated that the players had an upright posture at this point. In addition, the arms were at a rather neutral position. This movement behavior, even during a melody, suggests the simultaneous use of both ancillary and instrumental movements, as the pause in the melody was expressively facilitated and the inhalation had to be prepared at the same time.

More interesting is the movement behavior at point A (Figure 2); at this point, not every player inhaled. The players who inhaled performed at that point with a rather upright posture. The knee trajectory even indicated that they seemed to prepare the inhalation with an anticipated knee stretching. In comparison, the players who did not inhale showed less supportive knee movement behavior and continued to perform with bent knees. After that point, they performed a brief knee stretch, which seemed to follow the normal knee movement pattern previously seen during their performance.

The players who inhaled performed the second part of the first melodic phrase with even more knee bending than before. This finding indicates that the players who inhaled prepared for their inhaling by extending their legs, thereby providing a suitable posture for rapid inhaling. After the inhalation, they performed the remaining phrase with even more knee movements. This movement behavior differed from the players who did not inhale, which seemed to be ancillary movements that were more individual.

At another point in the piece (Position C1), again only some players inhaled. The exact point of the inhalation, however, was very individual. In the score, fast notes are to be played, whereby a very quick inhalation is possible between some notes. Here, the players who inhaled showed again a rather neutral and upright body posture, indicating preparation for the inhalation. The players who did not inhale performed around this point with uninfluenced, even movements. This finding clearly indicates a physiological function of the body movement to perform and prepare for the inhalation. The players briefly paused their musical expressive behavior to perform a physiologically oriented movement considering the respiration process and then continued immediately afterward with their individual expressive behavior.

The findings at point C3 in the second phrase support the facilitating and expressive purpose of the knee behavior. At this point, all players showed a similar behavior by adopting a more upright posture, regardless of whether they inhaled or not. It seems that this movement expresses the musical structure and was performed by each player. The players who inhaled at this point may have used this movement pattern to perform a quick inhalation.

4.1 Limitations

The study conducted was explorative in nature, aiming to investigate movement differences at specific points in a performance. Given the individual performances of the players, it is advisable to acquire more data at these points from a larger group of players. Furthermore, the individual reasons why some players inhaled at certain points while others did not need to be examined and taken into account. It could also be interesting to examine how the same player moves when inhaling and when continuing to play at the same point in a piece. To conduct such an analysis, a larger database needs to be compiled.

5 Conclusion

The findings showed that, in the course of the piece, there were several interplays of ancillary and instrumental movements. At certain points in the piece, the movement behavior of clarinetists were quite similar, indicating expressive functions in connection with the musical and expressive structure and showing physiological necessities to prepare for the inhalation. During the melody, the movement behavior of the players who had the urge to inhale was different from that of the players who continued to play without inhaling. This indicates the clear adaptation of a biomechanical movement to prepare for a physiologically supportive inhalation within the expressive movement behavior. On the other hand, similar movement behaviors of the players were found at a specific point in the melody that could also be used to perform a rapid inhalation. Despite being integrated into the performance, the individual movement and inhalation behavior were not explicitly exposed. Expert musicians can easily perform with ancillary movements that also constitute supportive elements for technical execution.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics commitee of the University Clinic Freiburg. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MN: Conceptualization, Data curation, Methodology, Project administration, Writing – original draft, Writing – review & editing. AI: Conceptualization, Writing – review & editing. JH: Formal analysis, Methodology, Writing – review & editing. CS: Conceptualization, Project administration, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The effects of musical practice on the well-being, mental health and social support of student, amateur, and professional musicians in Canada during the COVID-19 pandemic

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This pan-Canadian study investigates the effects of musical practice on the well-being, mental health, and social support of Canadian musicians during the COVID-19 pandemic. Using a survey questionnaire, data was collected from 1,618 participants aged 14 and above during the first wave of the pandemic up to the first half of 2022. The survey included standardized questionnaires to self-assess well-being (WHO-5), mental health (MHC-SF), and social support (SPS-10 measures social support). Results show that increased musical practice frequency correlates with improved well-being and mental health, particularly among amateurs. Professional musicians and those at a post-secondary level exhibit lower well-being scores, likely due to pandemic-related challenges. Factors such as age, gender, sports engagement, and participation in social clubs or volunteer work significantly influenced outcomes. While sports engagement was associated with higher scores on well-being, mental health and social support, no significant differences were found among participants engaged in artistic hobbies. As for involvement in social clubs or volunteer work, benefits were reported on two of the three outcomes. Overall, the findings suggest that regular amateur musical practice, especially in group settings, alongside engagement in sports and social activities, may have promoted well-being, mental health, and social support among musicians during the challenging period of the COVID-19 pandemic.

KEYWORDS

COVID-19 in Canada, music-making, well-being, mental health, social support

1 Introduction

The pandemic impacted several aspects of our daily lives, and drastically changed how we engaged with each other. The period of the pandemic gave rise to a drastic increase in people's levels of stress, anxiety and loneliness (Card et al., 2022), forcing governments to address rising public health issues related to mental health (Cost et al., 2022). The pandemic also impacted how we engaged in music practice. On the one hand, ensemble membership

declined as group music-making either came to a halt or was offered in an online format during periods of confinement (Kearney et al., 2021). Conversely some studies show that, as a result of online options, the pandemic provided new opportunities for arts engagement (Mak et al., 2021) and that musical engagement increased among the general population (Cabedo-Mas et al., 2021; Ferreri et al., 2021). For example, one study found an increase in at-home musical behaviors of young children, such as singing and doing music, in Brazil (Ribeiro et al., 2021). In a separate study on 786 Canadian university students, Finnerty et al. (2021) found that students who indicated being more open to experience were more likely to be involved in musical activities, such as playing instruments, singing or song writing. A British study revealed that participation in virtual music groups offered significant psychological support for children and young people, helping them express themselves, manage emotions, regain confidence, and maintain social connections. While virtual group music-making indirectly fostered a sense of belonging, similar to in-person experiences, the direct connection observed in traditional settings was not replicated online (Levstek et al., 2021).

It is not surprising that several studies indicated an increase in music listening during the pandemic (Carlson et al., 2021; Vidas et al., 2021), including greater use of online listening platforms, such as Spotify and TikTok, which favor the discovery of new music (Hurwitz and Krumhansl, 2021). Hurwitz and Krumhansl (2021) reported that listening to music helped American university students to uplift their mood and alleviate sensations of loneliness and isolation. In a study on 402 university students in Australia, Vidas et al. (2021) found that music listening was a highly effective strategy for stress management.

Long before the Covid-19 pandemic, music has been recognized for its social and psychological benefits. Researchers have studied the positive effects of music on multiple populations, including students from preschool to high school and beyond (Harland et al., 2000; Hallam, 2010; Kokotsaki and Hallam, 2011), marginalized youth (Parker, 2018), adults (Coffman, 2002) and older adults (Creech et al., 2014). Participation in musical activities and ensembles has been shown to provide social support for both adults and school-aged children (Scripp, 2002; Carucci, 2012; Osborne et al., 2016) and several studies have shown that participation in choirs has a positive effect on well-being for both professional and amateur musicians (Judd and Pooley, 2014; Stewart and Lonsdale, 2016).

Canada boasts the world's second-largest landmass (9,984,670 km^2), but the country ranks only 38th in population (Bossé, 2023). Unevenly distributed between 10 provinces and three territories, its population is concentrated in southern regions and cities. From the 38,683,567 inhabitants in 2022, 1,807,250 were descendants of the First Nations who were the first to inhabit the territory (Government of Canada, 2024). Census data from 2021 indicate that 15% of the Canadian population considers itself to be of diverse ethnic and cultural origins (Statistics Canada, 2023b). While there are a variety of languages spoken by Canadians, French and English are the country's two official languages. Since 1867, Canada has been constituted as a monarchy with parliamentary democracy (Marleau and Montpetit, 2000). In the Canadian federation, provinces and territories function as partially autonomous, particularly in the areas of health, education and cultural policies (Marleau and Montpetit, 2000).

As the Canadian population density varies from one area to the other and is spread over a vast territory where each province is responsible for its health system, sanitary measures during Covid-19 were implemented differently and within various timeframes. For example, the length of extreme lock-down procedures varied from cities to towns across the country (City of Toronto, 2020; Ontario – Office of the Premier, 2020). In addition, school closures were inconsistent across provinces and even in regions within provinces, with a range of 9 weeks in Quebec up to 19 weeks in Ontario (Gallagher-Mackay et al., 2021). The continuation of musical activities has varied significantly from one school to another, ranging from the temporary suspension of extracurricular activities to the cessation of all music classes (Boucher et al., 2022). For example, a study in Quebec showed that high schools were more affected than primary schools due to the fact that music classes in high schools are often taught in large ensembles, such as wind ensembles and orchestras (Barbeau et al., 2023).

Statistics Canada serves as the national statistical office, dedicated to providing Canadians with essential information about the country's economy, society, and environment. Statistics are measured quarterly and the first and second quarters of 2022 (Statistics Canada, 2023d) correspond with the timeframe during which participants responded to our survey. Employing the Canadian Social Survey, Statistics Canada monitored mental health, well-being and sense of belonging of the Canadian population during COVID 19.

Mental health is defined by the World Health organization (WHO) as "a state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community" (World Health Organization, 2004, p. 2). The WHO emphasizes that there is a close relationship between positive mental health and well-being: "mental health is the foundation for well-being and effective functioning for an individual and for a community" (p. 2). The indication of "effective functioning for a community" suggests a link between mental health, well-being and social functioning, which seems aligned with Keyes' tripartite model of well-being. Indeed, Keyes (2014) indicates that subjective well-being is a combination of emotional, psychological and social well-being, and can be linked to the perceived quality a person attributes to his or her life. Social well-being may thus be associated with social relationships, which may also be linked to perceived social support. Gottlieb and Bergen (2010) define social support as "the social resources that persons perceive to be available or that are actually provided to them by nonprofessionals in the context of both formal support groups and informal helping relationships" (p. 512). While Statistics Canada does not measure social support *per se*, it uses the concept of sense of belonging, which is considered by multiple authors (for instance, Cohen and Wills, 1985; Schonfeld, 1991; Suvak et al., 2013) as a dimension of social support. As such, the data provided by Statistics Canada may shed light on this dimension of social support, in addition to its data associated with mental health and well-being.

In the initial quarter of 2022, in response to the Statistics Canada query "In general, how is your mental health?," participants rated it as excellent or very good at 47%, good at 33%, and fair or poor at 20%. During the second quarter, the figures remained similar, with the exception that 1% of respondents transitioned from a good rating to an excellent one. If we delve a bit further into the subgroups of respondents, we observe that men perceive their mental health more positively than women. For instance, in the first quarter, 57% of men consider their mental health excellent or very good, in contrast to 51%

of women. Respondents identifying as LGBTQ2+[1] rate their mental health lower than other subgroups, with 25.5% considering it excellent or very good, 25.1% rating it as good, and 49.3% indicating that their mental health is fair or poor (Statistics Canada, 2023c). A similar trend of men rating higher than women is observed within this subgroup. For instance, in the first quarter of 2022, 29.3% of LGBTQ2+ men considered their mental health excellent or very good, compared to 23% of women. Additionally, it is noted that the older the respondent group, the more positively their mental health is perceived. Thus, the 15–24 age group is the one with the lowest scores, with 39% of respondents rating their mental health as excellent or very good, 29% as good, and 32% as poor.

During the 2021–2022 timeframe, individuals in the 65 to 84 age group in Canada consistently reported the highest levels of perceived well-being (Statistics Canada, 2023e). This observation stems from an examination of several quality of life indicators from their comprehensive analysis. More precisely, 41% of individuals aged 65 to 84 attained a combined high score, contrasting with only 25% of individuals observed in the 20 to 29 age group. It is noteworthy that, regardless of age, both men and women consistently reported similar combined perceived well-being scores. For respondents identifying as LGBTQ2+, 18% reported having a high perceived well-being. Within the LGBTQ2+ community, the younger demographic, specifically youth and young adults aged 15 to 29 years, exhibited the lowest likelihood of highly perceived well-being at 10%. This situation is not specific to Canada. A literature review targeting adolescents from several countries (Garagiola et al., 2022) showed loneliness, depression and anxiety were experienced during pandemic and will probably lead to long-term effects. Additionally, a systematic review about Covid impacts on children and adolescents general health indicates a significant link between social isolation and anxiety and depression in Oceania, Asia, Europe and America (Almeida et al., 2021).

Regarding social support during the first quarter of 2022, Statistics Canada measured it through a single question: "How would you characterize your sense of belonging to your local community?" Participants indicated a very strong or somewhat strong sense of belonging at 47.1%, while 37.7% reported a somewhat weak or very weak sense, and 15.2% had no opinion. During the first quarter, it was observed that the sense of belonging for men aged 65 and over was 56.7%, which is higher than that for women in the same age group, at 53.1%. In the second quarter, data for the whole population was similar to the previous quarter, with the exception that 1% of respondents shifted from a strong or somewhat strong sense to a somewhat weak or very weak one. In short, the sense of belonging tends to strengthen with age. The score for the LGBTQ2+ community was the lowest in terms of the sense of belonging, with 39.6% of individuals in this subgroup expressing a very strong or somewhat strong sense of belonging. Again, men of this sub group showed a higher score (42.8%) than women (37.6%) for the first quarter of 2022.

During the pandemic, the cultural sector, which includes musical artists, was among those most impacted with cessation of gatherings for cultural activities as reported by Canadian Artists and Content Creators Economic Survey Report (CACCES) (Statistics Canada, 2024). This report included 4,747 valid responses. The pandemic exacerbated challenges that artists already faced because of the precarity associated with gig work, self-employment and the rising costs of living. These concerns were also noted in two British studies (Cohen and Ginsborg, 2021; Spiro et al., 2021). One study involving semi structured interviews with 24 freelance musicians highlighted the significant emotional toll experienced by performing artists, including the loss of their careers, the absence of music-making opportunities and connections with colleagues, and concerns about the future of the music industry (Cohen and Ginsborg, 2021). In a separate study, researchers examined the effects of COVID-19 on the well-being of 385 performing artists by administering standardized psychology questionnaires. As anticipated, financial difficulties correlated with decreased well-being and increased depression and loneliness scores. Notably, individuals who engaged in more physical activity before a lockdown exhibited higher levels of well-being and social connectedness, along with lower loneliness scores. Furthermore, an uptick in physical activity during lockdowns, coupled with older age, was associated with elevated levels of well-being and social connectedness, as well as decreased depression and loneliness scores (Spiro et al., 2021).

Even before the pandemic, research has shown that music-making could impact the well-being of musicians at various stages in their development and was not just associated with professional musicians. For example, as part of a comparative case study, Jones (2018) looked at the choral experience of six non-music majors in university settings and found that music-making contributed to finding a healthy life-balance. In a study involving 375 participants engaged in various leisure activities, Stewart and Lonsdale (2016) suggest that singing in a group (choral singing) may have a greater impact on psychological well-being than singing solo. A large-scale study was conducted on 1,513 adult singers in Spain using a measurement tool to determine potential benefits of choral singing (Fernández-Herranz et al., 2022). The measure comprised five components (satisfaction, ability, group engagement, belonging, and optimism) and results indicated that choral singing impacted well-being. Lonsdale and Day (2021) conducted a study with 194 respondents in which they compared levels of well-being in six types of activity (choir singers, solo singers, band/orchestra members, solo musicians, team sport players, and solo sport players). They found that while choral membership offered psychological benefits, these were not unique to choir itself and that other individual and group activities in music and sports that promote self-accomplishment could provide similar benefits.

Studies indicate that music-making can impact mental health both positively and negatively. For example, one study explored the choral experiences of 21 adult amateur choir members, many of whom suffered from health issues, including long-standing mental health challenges, physical and intellectual disabilities. Based on interviews conducted at three points during a 12-month period, researchers found evidence that choral singing impacted participants on a personal level (e.g., emotional regulation), social level (e.g., social functioning) and through functional outcomes such as employment capacity (Dingle et al., 2013). Stress relief has been a noted benefit of music-making for musicians in high school ensembles (Varner, 2017)

1 According to Statistics Canada, "This category includes people who reported their sexual orientation as lesbian, gay, bisexual, pansexual, or a sexual orientation not elsewhere classified. It also includes persons whose reported sex assigned at birth does not correspond to their gender, including those whose gender is not exclusively man or woman (regardless of sexual orientation)" (Statistics Canada, 2023c).

and in community settings (Mantie, 2013). Conversely, ensemble music-making has also been found to have negative impacts on mental health, including anxiety, social phobia, and depression of 377 musicians in professional orchestras (Kenny et al., 2014) and on anxiety of 201 semi-professional choral singers (Ryan and Andrews, 2009). It seems that some professional musicians may experience more anxiety or depression than non-musicians, especially if they have a prominent role, such as a soloist (Vaag et al., 2016) and younger professional musicians suffer from anxiety more than older professional musicians (Kenny et al., 2014).

The social nature of music ensembles is an aspect that is often appreciated by musicians of all ages and one that also offers social benefits. For example, a study on 72 adolescent orchestral and concert band musicians found that they favorably viewed ensemble participation as opportunities to meet new people and spend time with others, and participants highly rated these social aspects when considering continued membership (Hewitt and Allan, 2013). Similar findings were found in studies with older adults (Creech et al., 2014; Barbeau and Cossette, 2019; Barbeau and Mantie, 2019). Another study conducted with 10 small choirs ranging from 20 to 80 participants and a large choir with 232 participants demonstrated that the effects on well-being were positively similar, but that a greater sense of belonging was reported by participants in the larger choir (Weinstein et al., 2016).

Studies have shown that choirs are also a place for creating social connection and developing social relationships (Cohen, 2012; Dingle et al., 2013; Lamont et al., 2018). The social aspect of ensemble music making can promote group cohesion and provide motivation for young people to join and stay in a group (Adderley et al., 2003; Matthews and Kitsantas, 2007; Mantie, 2013). In a study on band, choral and orchestra ensembles, 60 high school students indicated they valued their ensemble relationships and were motivated to participate for both social and musical benefits (Adderley et al., 2003). In a separate study comparing 660 young musicians with 655 non-musicians, results revealed that those who participated in group music-making further developed students' socioemotional competencies and leadership skills than those who did not (Ros-Morente et al., 2019).

The aim of the study was to investigate the effects of musical practice on well-being, mental health and social support among Canadian musicians aged 14 years old and over during the first wave of COVID 19 up to the first half of 2022. The objectives of the study were to study whether factors such as age, gender, sports, hobbies, volunteer work, frequency of musical practice, music level and types of practice were associated with psychosocial changes in musicians. Our hypotheses were that among participants who engaged with music during the pandemic: (1) older musicians and male musicians would have the highest levels of well-being, mental health and social support; (2) participation in group activities (sports, hobbies, volunteer work) would lead to beneficial psychosocial effects; (3) increased frequency of musical practice would positively impact well-being, mental health and social support; (4) amateur musicians would report stronger psychosocial benefits than musicians of other levels (middle/high school, post-secondary, professional); and (5) the types of practice would not affect well-being and mental health, but participation in group music-making (vocal, instrumental, or mixed ensemble) would be associated with higher social support than engagement in individual practice (solo or electronic music).

2 Materials and methods

2.1 Participants

This study was part of a larger project on the effects of music on well-being, mental health and social support in Canada at the time of the pandemic, which included populations of musicians and non-musicians, and investigated elements such as participants' music listening habits, music learning opportunities while growing up, and perceptions about the effect of the pandemic on their life. Inclusion criteria included: (1) to be 14 years or older and (2) to have Canadian citizenship or be a resident in Canada at the time of the survey. For the current study, a third criteria was added: to be a musician or to have a musical practice. Participants were recruited through networks of Canadian music associations (e.g., the Coalition for Music Education in Canada, the Canadian Band Association) professional and community conductors, university professors in music education, high school music teachers, and social media. This study was approved by the ethics Board of the Université du Québec à Montréal.

A sample of 2,438 Canadians completed the survey. In order to determine the third inclusion criteria, we asked participants if they self-identified as musicians, and later in the survey, to select whether or not practicing music was part of the activities with which they currently engaged. Since we were primarily interested in understanding the effect of musical engagement on psychosocial health, we decided to include only participants who declared having a musical practice in the following analyses. As a result, 1,619 participants (66.41%) were classified with having a musical practice and 819 without (33.59%). The current study was only carried out with the 1,619 respondents categorized as musicians (be they students, amateurs, or professionals).

2.2 Instrumentation

The online survey was developed by the authors using the LimeSurvey platform. It included demographic information (such as age, gender, ethnicity primary occupation, socioeconomic status, etc.), general questions (about hobbies, groups activities, music listening habits, etc.), music-related questions (about instruments played, musical level, frequency of practice, etc.), as well as three standardized and psychometrically sound questionnaires, all recommended by the *Institut national de santé public du Québec*, a public health expertise and reference center (Canuel et al., 2020):

- The WHO-5 is a measure that assesses well-being in the last two weeks, through questions related to mood (feeling cheerful, calm, energetic, well-rested) and interests in a person's daily life. It is an effective and often used screening tool that shows appropriate psychometric properties (Topp et al., 2015). This instrument, in the form of a comprehensible and short questionnaire, has been validated to evaluate subjective and psychological wellbeing and consists of five positively-worded items (Henkel et al., 2003; Bech, 2004) that can be answered on a 6-point scale ranging from 0 (At no time) to 5 (All of the time). The maximum score is 25, which can be transformed into a 0–100 scale by multiplying the score by four. Higher scores indicate a better state of wellbeing. Studies with general populations estimate that the average score generally falls

around 70 (Topp et al., 2015). Its use is appropriate for participants from 9 years of age onwards (Allgaier et al., 2012, 2013).

- The MHC-SF is a tool that evaluates positive mental health (Keyes, 2002), demonstrates acceptable psychometric properties for both adults and adolescents (Lamers et al., 2011), and has been validated with a Canadian population (Orpana et al., 2017). The instrument consists of 14 items and considers three aspects: emotional, psychological and social well-being. Answers are provided using a 6-point scale of frequency ranging from 0 (never) to 5 (everyday), with a maximum total score of 70. Classification of responses includes flourishing mental health (higher score), moderate mental health, or languishing mental health (lower score). The questionnaire is recognized by both the Canadian and Quebec governments and is used in official statistical surveys (Gilmour, 2014; Orpana et al., 2017).
- The SPS-10 measures social support through five subscales: emotional support or attachment, social integration, reassurance of worth, tangible help, and orientation. This 10-item questionnaire uses a four-point Likert-type scale ranging from 1 (strongly agree) to 4 (strongly disagree). Scores may vary from 10 to a maximum of 40. Because no neutral value is available on that scale, participants are obligated to position themselves (either agreeing or disagreeing) on each item. It is important to note that all items are worded positively, which means that a lower score indicates higher social support. This tool has been validated among various populations and shows adequate psychometric properties (Cutrona and Russell, 1987; Caron, 2013).

The complete survey is available in the Supplementary material.

2.3 Data analysis

Descriptive statistics were undertaken. Survey data were analyzed through statistical testing (mainly multiple linear regressions) and were performed with the R software. The distributions of the three dependent variables were checked and they all followed a normal distribution which is an assumption of the multiple linear regression. All the other assumptions were checked using the residuals of the regressions. A range of independent variables were selected to assess their effects on levels of well-being, mental health and social support. More specifically, we examined whether age (continuous variable), sex (male/female/non-binary), participation in group activities, as well as participants' musical level, frequency of musical practice, and types of musical practice could influence the three dependent variables. It is worth noting that the types of group activities in which participants were involved were categorized as follows: music practice, sports, hobbies (including social clubs, such as The Lion's Club, Rotary clubs, reading groups, chess clubs, etc.; and artistic hobbies, such as theater groups, dance groups and visual arts clubs), and volunteer work. Self-identified musical levels comprised four categories: (1) middle or high school students (including school-aged children and adolescents having access to music through formal channels such as school, private music lessons, after-school activities, etc.); (2) post-secondary students (including undergraduate or graduate music students and/or musicians engaging in music at an advanced level without identifying as professional); (3) amateur/community musicians (adults engaging in music as a form of hobby) and (4) professional musicians (adults performing at a high level of mastery, generally being paid for music performances). Frequency of musical practice was classified in five categories: every day, few times a week, once a week, few times a month, and once a month or less. Types of musical practice included solo, vocal ensemble, instrumental ensemble, mixed ensemble (vocal and instrumental), and electronic/digital music.

3 Results

3.1 Descriptive statistics

3.1.1 Demographic information

The average age of participants was 36.8 years old (SD = 18.4), with a span ranging from 14 years old to 92 years old. In terms of gender, 58.7% of participants characterized themselves as female ($n = 940$), 38.7% as male ($n = 619$) and 2.62% as non-binary ($n = 42$). Eighteen musicians preferred not to disclose their gender. In terms of ethnicity, participants were mostly of European descent ($n = 1{,}222$; 76%), followed distantly by respondents of East and South-East Asian descent ($n = 147$; 9.14%), multi ethnic descent ($n = 44$; 2.74%), African descent ($n = 42$; 2.61%), West Asian descent ($n = 33$; 2.05%), Latin American descent ($n = 30$; 1.87%), Indigenous descent ($n = 20$; 1.24%), and Middle Eastern descent ($n = 19$; 1.18%). Some individuals specified an "other descent" ($n = 14$, 0.87%) such as "American indigenous (Cherokee)," "Uzbek," "Jewish," "Canadian." Thirty-seven participants (2.3%) indicated "I do not know" or "prefer not to answer."

Participants were spread throughout Canada, although the majority were located in the provinces of Ontario ($n = 581$ or 35.9%) and Quebec ($n = 355$ or 21.9%). No musician located in the Yukon was recruited. Table 1 summarizes the distribution of participants in comparison with the proportion of population estimated by Statistics Canada in the first half of 2022 (Statistics Canada, 2023a).

TABLE 1 Distribution of musicians by provinces in comparison with the general population.

Provinces and territories	Participants		Canadian population	
	n	%	*n*	%
Ontario	581	35.9	14,996,014	38.9
Quebec	355	21.9	8,650,692	22.3
British Columbia	165	10.2	5,273,809	13.73
Manitoba	131	8.09	1,405,197	3.63
Alberta	122	7.54	4,480,956	11.58
Nova Scotia	70	4.32	1,014,827	2.62
Newfoundland and Labrador	67	4.14	52,924	0.14
New Brunswick	35	2.16	801,778	2.07
Prince Edward Island	33	2.04	16,552	0.04
Saskatchewan	30	1.85	1,173,366	3.03
Northwest Territories	26	1.61	44,828	0.12
Nunavut	4	0.25	40,489	0.10
Yukon	0	0	43,454	0.11
Total (*N*)	1,619	100	38,683,567	100

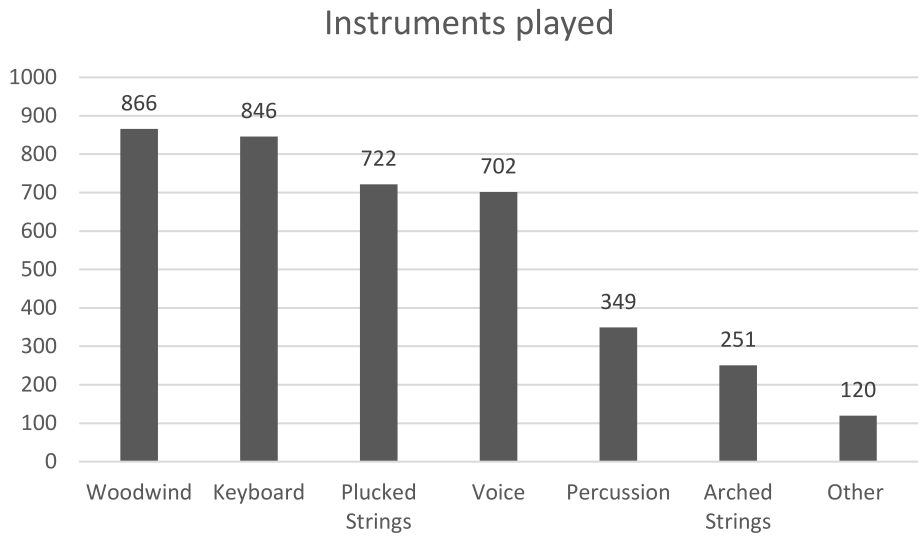

FIGURE 1
Descriptive statistics of instrument played (by family of instruments). Examples of "other" instruments included organ, kalimba, bagpipe, handbells, harpsichord, theremin, daxophone, and otamatone. Participants (N = 1,619) could select multiple options.

3.1.2 Music role

We asked participants to identify their musical role(s). Most participants identified themselves as having a single role (n = 907; 56%). Others selected multiple roles (n = 691; 42.7%), while some (n = 21; 1.3%) did not select any role from the list provided. Overall, people selected between zero and five roles (M = 1.69; SD = 0.98), among which being a "music performer" was the most common (n = 1,287; 79.5%), followed by being a "music teacher" (n = 625; 38.6%), "conductor" (n = 297; 17.2%), and "composer" (n = 202; 12.5%). Other roles (e.g., sound recorder, arranger, producer, music therapist, arts administrator) were selected by 200 respondents (12.4%).

TABLE 2 Level of musical practice.

Level of musical practice	Overall	
	n	%
Middle or High school student	384	23.7
Post-Secondary level (college or conservatory, university)	480	29.6
Amateur/Community music	443	27.3
Professional level	312	19.3
Total (N)	1,619	100

3.1.3 Instrument played

Participants reported on the instruments they played from a list provided. We regrouped these instruments by family (Figure 1). Participants played up to 23 instruments (M = 3.66, SD = 3.07). A total of 1,258 participants (77.7%) played multiple instruments and 359 (22.2%) a single instrument. Examples of instruments provided by respondents in the "Other" category included organ, kalimba, bagpipe, handbells, harpsichord, theremin, daxophone, and otamatone. Two participants (0.1%) did not select an instrument from the list, nor did they specify one in the category "Other."

3.1.4 Level, frequency and types of musical practice

The average years spent playing music was 18.1 (SD = 10.6), with a range from one to 30 years. Self-reported level of musical practice was mostly equally spread among the sample (Table 2), and the vast majority of participants (75%) played or sang at least a few times a week if not every day (Figure 2).

Most musicians (n = 1,172; 72.4%) reported practicing music in solo, whereas in terms of group music-making, instrumental ensembles was the type of practice that was endorsed by the most musicians, i.e., 64.5% of participants (n = 1,045). Because participants could choose multiple options, other forms of musical practice were also provided. Results showed that among the sample, 490 respondents (30.5%) were involved n mixed ensembles (combining vocalists and instrumentalists), 423 (26.1%) in vocal ensembles, and 196 (12.1%) in electronic/digital music.

Participants played music mainly in the community (n = 783; 48.4%) and with friends (n = 655; 40.5%). Several respondents also indicated being involved in music in an educational environment, such as in schools (n = 491; 30.1%) and in after-school programs (n = 305; 18.8%), while some specified that they did not play music in a group (n = 136; 8.4%).

3.1.5 Sports, hobbies and volunteer work

In this section, we asked questions from the general to the specific. We started by exploring if participants had hobbies (to which 98.7% answered positively) and if they participated in group activities (to which 89.3% said yes). Then, we categorized group activities and found that our sample was mostly involved in sports and volunteer work, followed by social clubs and artistic hobbies (Table 3).

3.2 Multiple linear regression

The average score of the 1,619 participants on the WHO-5 was 56.9 (SD = 20.6), on the MHC-SF was 44.2 (SD = 13.7), and on the SPS-10 was 16.1 (SD = 5.63).

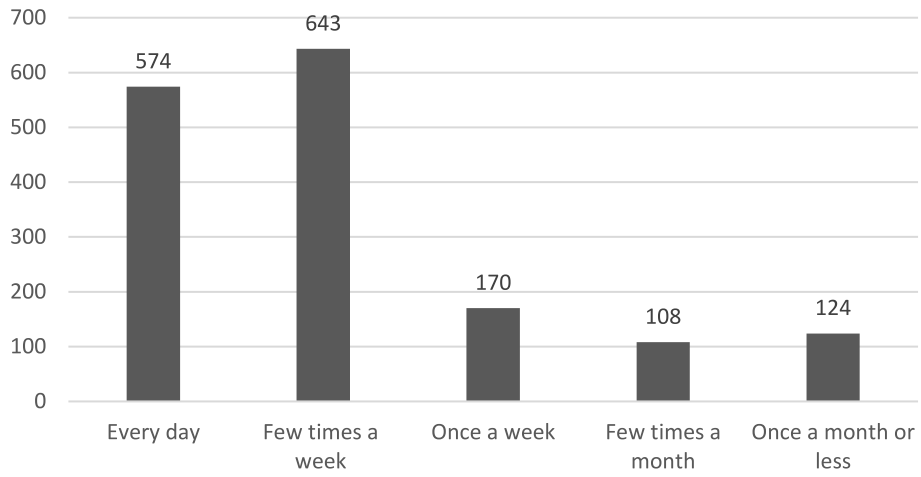

FIGURE 2
Descriptive statistics of the frequency of musical practice ($N = 1,619$).

TABLE 3 Sports, hobbies, and volunteer work.

Types of groups activities*	Overall	
	n	%
Sports	610	37.7
Volunteer work	606	37.4
Social clubs	515	31.8
Artistic hobbies (Theatre, dance, visual arts clubs)	347	21.4
Other hobbies (e.g., Gaming, gardening, circus, riding, playing bridge)	106	6.5

*Participants ($N = 1,619$) could select multiple options.

TABLE 4 Average scores and standard deviations by gender.

Gender	WHO-5 (/100)		MHC-SF (/70)		SPS-10* (/40)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Male	58.7	20.9	44.9	13.7	16.8	5.97
Female	56.4	20.2	44.5	13.4	15.6	5.35
Non-Binary	42.7	19.3	29.4	13.3	17.2	5.75

*Lower scores indicate better social support.

3.2.1 Age and gender

Age was found to be a significant predictor of well-being ($b = 0.16$, $\beta = 0.14$, $p < 0.001$), mental health ($b = 0.14$, $\beta = 0.18$, $p < 0.001$), and social support ($b = -0.03$, $\beta = -0.09$, $p < 0.001$), which means that with increasing age, scores on the WHO-5, MHC-SF, and SPS-10 significantly improved.

When compared by gender (Table 4), there was a significant difference between males and females on the WHO-5 ($b = -2.20$, $\beta = -0.11$, $p = 0.044$) as well as between males and non-binary individuals ($b = -11.77$, $\beta = -0.57$, $p < 0.001$). Post-hoc analysis also showed that non-binary participants reported significantly lower scores than female participants [$t(1491) = 2.93$, $p = 0.01$]. Regarding mental health, males and females reported similar mean scores [$t(1491) = 1.113$, $p > 0.05$], while the average score of non-binary participants significantly differed than the ones of males [$t(1491) = 5.447$, $p < 0.001$] and females [$t(1491) = 5.142$, $p < 0.001$]. In terms of social support, it was found that male participants reported a significantly higher mean score than female participants ($b = -0.83$, $\beta = -0.15$, $p < 0.004$), indicating that they experienced less social support. While non-binary individuals experienced the highest SPS-10 scores, it was not found to reach statistical significance when compared with males and females' scores, which is probably due to the smaller sample size.

3.2.2 Sports, hobbies and volunteer work among musicians

Results varied between 56.3 and 59.6 on the WHO-5, between 43.4 and 46.5 on the MHC-SF and between 15.2 and 16.7 on the SPS-10 (Table 5). Sports was found to be a significant predictor of well-being, mental health and social support. Indeed, musicians who practice sports reported significantly better scores on the WHO-5 ($b = 4.13$, $\beta = 0.10$, $p < 0.001$), MHC-SF ($b = 3.46$, $\beta = 0.12$, $p < 0.001$), and SPS-10 than those who did not ($b = -0.65$, $\beta = -0.06$, $p = 0.021$). Regarding hobbies, participants involved in social clubs reported higher scores on the WHO-5 ($b = 4.01$, $\beta = 0.09$, $p = 0.001$) and MHC-SF ($b = 2.97$, $\beta = 0.10$, $p < 0.001$) than those who did not. No significant difference was observed for social support on the SPS-10 ($b = -0.59$, $\beta = -0.05$, $p = 0.058$). As for participants involved in artistic hobbies such as theater groups, dance groups or visual arts clubs, no significant difference was found on wellbeing ($b = 0.65$, $\beta = 0.01$, $p = 0.617$), mental health ($b = -0.28$, $\beta = -0.01$, $p = 0.741$), and social support ($b = 0.45$, $\beta = 0.03$, $p = 0.177$). Volunteer work was a significant predictor of mental health ($b = 1.50$, $\beta = 0.05$, $p = 0.040$) and social support ($b = -1.05$, $\beta = -0.09$, $p < 0.001$), but not wellbeing ($b = 1.35$, $\beta = 0.03$, $p = 0.233$).

TABLE 5 Average scores and standard deviations by types of group activity.

Group activities	WHO-5 (/100)		MHC-SF (/70)		SPS-10* (/40)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Sports	59.6	19.4	46.5	13.7	15.6	5.46
Social clubs	57.9	21.2	45.1	13.4	16.0	5.55
Artistic hobbies (Theater, dance, visual arts)	56.3	21.9	43.4	13.8	16.7	5.50
Volunteer work	57.8	20.8	45.6	14.4	15.2	5.09

*Lower scores indicate better social support.

3.2.3 Frequency of musical practice

Results on the WHO-5 ranged from 52.5 and 58, from 38.9 to 45.9 on the MHC-SF, and from 15.2 to 17.4 on the SPS-10 (Table 6). For the regression analysis, frequency of musical practice was considered a continuous variable. Results showed that well-being tended to increase with the frequency of musical practice ($b = 0.97$, $\beta = 0.06$, $p = 0.039$). For instance, people who practiced everyday had higher WHO-5 scores than people who practiced less often. There was also a positive effect on mental health: increasing the frequency of practice tended to significantly increase MHC-SF scores ($b = 1.16$, $\beta = 0.10$, $p < 0.001$). No significant association was found between the frequency of musical practice and social support ($b = -0.10$, $\beta = -0.02$, $p = 0.435$).

3.2.4 Music level

When compared by music level, scores on the questionnaires varied slightly (Table 7). Amateur musicians were found to have significantly higher WHO-5 scores than professional musicians ($b = -4.39$, $\beta = -0.21$, $p = 0.007$) and respondents doing music at a post-secondary level ($b = -3.37$, $\beta = -0.16$, $p = 0.02$). No other comparisons reached statistical significance.

Regarding mental health, the only significant result was that amateur musicians had higher MHC-SF scores than professional musicians ($b = -2.08$, $\beta = -0.15$, $p = 0.047$). In terms of social provision, no significant difference was detected between music levels.

It is worth noting that while secondary students reported the lowest WHO-5 scores and MHC-SF scores and the highest SPS-10 scores in the music level category, results on the regressions were not found to be statistically significant for this group when compared to our reference group (amateurs). This result will be addressed in the discussion.

3.2.5 Types of practice

Mean scores slightly varied between types of practice (Table 8). It is worth noting that because participants could select more than one type of musical practice (solo, vocal, instrumental, mixed ensemble, electronic music), comparisons were made between participants involved in each type of practice and those who were not. Results on the WHO-5 showed no significant difference between participants who were involved in a specific type of practice (be it solo, vocal ensemble, instrumental ensemble, mixed ensemble or electronic music) and those who were not (Supplementary Table S1). Scores on the MHC-SF were found to be significantly lower for participants having a solo musical practice ($b = -1.58$, $\beta = -0.05$, $p = 0.046$) than for participants who did not. No other significant differences were observed, which means that apart from solo practice, the type of musical practice in which musicians are involved does not significantly affect their mental health (Supplementary Table S2). Finally, it was found that social support was significantly better for participants having a solo practice ($b = -0.76$, $\beta = -0.06$, $p = 0.016$) or for those practicing music in an instrumental ensemble ($b = -0.89$, $\beta = -0.08$, $p = 0.002$) than for musicians not involved in these activities. No other difference was found regarding vocal practice, mixed ensemble or electronic music (Supplementary Table S3).

TABLE 6 Average scores and standard deviations by frequency of musical practice.

Frequency of musical practice	WHO-5 (/100)		MHC-SF (/70)		SPS-10* (/40)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Every day	57.6	20.4	45.9	13.5	15.2	5.08
Few times a week	58.0	20.2	44.6	13.2	16.2	5.91
Once a week	55.8	19.6	42.5	13.2	16.9	5.53
Few times a month	52.5	23.2	41.1	15.4	17.4	5.40
Once a month or less	53.4	21.4	38.9	14.9	17.4	6.27

* Lower scores indicate better social support.

TABLE 7 Average scores and standard deviations by music level.

Music level	WHO-5 (/100)		MHC-SF (/70)		SPS-10* (/40)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Amateur	60.5	20.8	46.6	13.2	16.1	5.91
Secondary	54.8	20.3	40.3	14.6	17.2	5.21
Post-secondary	56.2	20.1	44.5	13.2	16.0	5.86
Professional	55.4	20.8	45.1	13.2	14.9	5.10

*Lower scores indicate better social support.

TABLE 8 Average scores and standard deviations by types of practice.

Type of practice	WHO-5 (/100)		MHC-SF (/70)		SPS-10* (/40)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Solo	56.4	20.3	43.9	13.8	15.6	5.41
Vocal	59.0	20.3	45.8	12.7	16.2	5.59
Instrumental	56.5	20.0	44.0	13.9	15.7	5.47
Mixed ensemble	56.9	20.5	45.6	13.2	15.4	5.35
Electronic music	56.1	23.0	43.3	14.3	15.9	5.31

*Lower scores indicate better social support.

4 Discussion

The aim of the study was to better understand the effect of musical practice in terms of well-being, mental health and social support of Canadian musicians, and to examine whether other factors (i.e., gender, age) may have played a role, in a pandemic context.

The average score on the WHO-5 was 56.9 out of 100 for the whole sample, whereas the mean score in the general population is usually

around 70 (Topp et al., 2015). Our sample thus seemed to be on the lower side of the spectrum in terms of well-being, although this is unsurprising, given the pandemic context. Scores on the MHC-SF was 44.2 out of 70, which may be considered high enough to be categorized as a "flourishing mental health" (Gilmour, 2014). Results on the SPS-10 was 16.1 out of 40, which is quite positive as the minimum possible score is 10 (Canuel et al., 2020) and lower scores indicate better social support.

4.1 Influential factors

Our first hypothesis was that both older musicians and male musicians would score the highest on all three variables. This proved to be the case for older musicians. In fact, one of the first factors that was found to have an impact on well-being, mental health and social support was the age of respondents. As age increases, scores on all three questionnaires (WHO-5, MHC-SF and SPS-10) showed a significant positive trend. These results are consistent with Statistics Canada data on well-being (2021–2022) and mental health (2022). Gender was also an influential factor, but did not meet the expectation stated in our hypothesis. While significant differences were found between males, females and non-binary individuals regarding their wellbeing (with the former reporting the highest level and the latter the lowest), mental health differed slightly: only the non-binary participants experienced significantly different (and lower) levels of mental health, when compared to males and females. Regarding social support, males were found to be significantly less advantaged than females. This last result differs from Statistic Canada, where women reported less social support than men. This may be due to the difference in data collection measures. We used the more comprehensive Social Provisions Scale (Cutrona and Russell, 1987; Caron, 2013), which consists of 10 items to assess social support, whereas Statistics Canada used a single question to assess participants' sense of belonging to the local community.

Our second hypothesis was that participating in group activities would lead to positive effects on all variables. Results varied depending on the type of activity. Sport, for instance, was identified as a significant predictor of well-being, mental health, and social support for our participants, whereas artistic hobbies were not. In fact, musicians engaging in sports reported notably higher scores on the WHO-5, MHC-SF, and SPS-10 than those who did not. This is aligned with results from Spiro et al. (2021), which indicate that British performing artists engaged in sports activities were less impacted by the pandemic than those who did not. Findings are consistent with well-documented benefits of sports reported in the pre-pandemic literature. For instance, sport participation has been shown to reduce depression and suicidal thoughts (Babiss et al., 2009). A systematic literature review done by Eigenschenk et al. (2019) also demonstrated that sport, especially outdoor sport and recreation, had a positive impact on mood, and could decrease stress, anxiety, depression and even loneliness. However, similarly to what was found with professional musicians, it is noteworthy that elite or semi-elite athletes do not benefit from sports engagement like amateurs. A meta-analysis comprising 60 studies on elite or semi-elite athletes revealed that factors such as overtraining, injuries, pressure, and the distinctive experiences encountered by athletes seem to influence the potential benefits derived from engaging in sports (Rice et al., 2016).

Participants actively involved in social clubs demonstrated higher scores on the WHO-5 and MHC-SF compared to those who were not. This aligns with existing literature. As an illustration, participation in social clubs among 1,963 middle-aged women from the USA affiliated with the Red Hat Society demonstrated a positive effect on well-being (Son et al., 2010). While similar positive effects were also observed for volunteer work, as shown in a longitudinal study based on 66,343 observations (person-years) in the UK (Tabassum et al., 2016), our findings showed that volunteer work was a significant predictor of mental health and social support, but not wellbeing. Having said that, the beneficial effects reported by Tabassum et al. (2016) are particularly evident in their sample of participants aged 40 to 70 years old. This aligns with our findings associated with age: the older our participants, the higher their scores on the three questionnaires. This is also consistent with the trends observed on well-being in the Canadian population as reported by *Statistics Canada* (Statistics Canada, 2023c).

4.2 Well-being, mental health and social support

Our third hypothesis was that practicing music more often would positively impact well-being, mental health and social support. Findings from our study revealed that well-being and mental health generally improved with increased frequency of musical practice (see Table 6), whereas this was not the case for social support. This aligns with other studies on well-being and choristers (Lonsdale and Day, 2021; Fernández-Herranz et al., 2022). In fact, regarding the social impact of musical engagement, Lonsdale and Day (2021) found that choral singing generated levels of well-being that were as similarly high as engaging in other types of hobbies, no matter if they were carried out in groups (choral singers, band/orchestra members, team sports players) or not (solo singers, solo instrumentalists, individual sports players).

While music can be experienced as a relaxing hobby for amateurs, research shows that professional musicians often face performance anxiety (Kenny et al., 2014), depression, and social phobia (Ryan and Andrews, 2009). Therefore, our fourth hypothesis was that amateur musicians would experience better well-being, mental health and social support than musicians of other levels. Results of subgroups presented in Table 7 show that, in line with our hypothesis, amateur musicians demonstrated significantly higher WHO-5 scores than professionals and respondents with a post-secondary level of music, as well as significantly better MHC-SF scores than professional musicians. However, no difference in social support was observed between the subgroups.

An important consideration must be taken into account for professional musicians: the inability to practice their profession during the COVID-19 pandemic. As shown in the literature, this has produced financial challenges and stress that contributed to lower levels of well-being and mental health (Cohen and Ginsborg, 2021; Spiro et al., 2021). Professional musicians, who are often freelancers, were severely affected by the cancellation of music activities. As the CACCES survey (2022) specified, 83.1% of the 863 participants who identified themselves as musical artists, which included vocalists and instrumentalists ($n = 774$), songwriters ($n = 336$), and others ($n = 176$), reported a decrease in income (the average across all fields being 62.2%). In comparison, writers experienced a 44.7% decrease. Notably, the impacts were higher for men (67%) than women (60.7%) and non-binary individuals (55.3%). Another subgroup, secondary students, reported lower scores on well-being and mental health. This

could be attributed to school lockdowns lasting from 8 to 19 weeks, depending on the area. Moreover, when schools reopened, music activities such as instrumental and vocal ensembles in high schools were not (Morin, 2021; Barbeau et al., 2023). This also echoes Statistics Canada's survey on Quality of Life, in which younger respondents (15–24 years) reported the lowest scores on mental health and well-being in 2022. For this population, Almeida et al. (2021) suggest that it is crucial for healthcare professionals to provide diligent follow-up care post-pandemic. Garagiola et al. (2022) recommend future research that will evaluate the long-term impact of Covid on adolescent development.

Regarding the types of music practice, we found that participants tended to engage in different forms of music-making. Because respondents could choose multiple options (solo, instrumental ensemble, mixed ensemble, vocal ensemble, or electronic/digital music), we compared categories separately, analyzing between musicians who engaged in each specific type of practice and those who did not. Using this strategy to examine scores on our three main variables, we found that the type of practice did not seem to have an impact on participants' well-being, which is in keeping with our fifth hypothesis. However, results varied regarding mental health and social support. In terms of mental health, solo practice showed the lowest scores. Results from the CACCES survey (2022) may shed light on our findings. The survey showed that 89.7% of professional musicians tended to have an instrumental or vocal practice, suggesting that they may have engaged in solo practice time, at least in preparation for performances. It is possible that, in our survey, professional musicians may have been overrepresented in the category "solo," and because they were greatly affected by the pandemic, this may have influenced our results. This is aligned with some findings reported in the literature about professional musicians (Cohen and Ginsborg, 2021; Spiro et al., 2021). In addition, as Vaag et al. (2016) indicate, professional musicians, particularly those in prominent roles like soloists, may be more prone to experiencing anxiety or depression compared to non-musicians. Interestingly, social support results were found to favor respondents with a solo practice and those practicing music in an instrumental ensemble. While it seems evident why practicing music in a group, such as an instrumental ensemble, may have an impact on social support, it is not clear why this may be the case for solo practice. Could it be that people who reported having a solo practice were also simultaneously engaged in other forms of group music-making, which may have skewed the results? Could it be that when the lock-downs happened, all musicians had to stop playing music in groups but found comfort in knowing that all of them could continue to do music at home, and even produce collective works online? Levstek et al. (2021) results showed the benefits of virtual group music making for children and young people. Could this be the same for the general population? There are no definite answers.

4.3 Limitations and future directions

When comparing the proportion of population estimated by Statistics Canada in the first half of 2022 (Statistics Canada, 2023d) with our sample size, we found that there was an over-representation of respondents in the provinces of Manitoba (over 5%), Nova Scotia (over 2%), Newfoundland/Labrador (4%), Prince Edward Island (over 2%), and Northwest Territories (near +1.5%), and an under-representation in Ontario (−3%), British Columbia (near-3%), Alberta (near −4%), and Saskatchewan (near −1.5%). Because the population is distributed very differently between the provinces and territories, a difference in number may impact the representativeness of the population significantly more in the Northwest Territories than in Ontario, for instance. Also, the cultural reality of the inhabitants of a large city in a French-speaking province like Quebec is very different from that of an English-speaking town in Alberta, especially as educational and cultural policies are decentralized. For example, we found that organizations of music professionals that could relay the surveys were practically non-existent in some locations (i.e., Yukon) or very dynamic in others (i.e., Ontario and Quebec). This may explain why survey respondents are distributed somewhat differently from the Canadian population.

To put into perspective the results of participants in our study whose gender is non-binary with those of the Canadian population, we used the LGBTQ2+ subcategory available in Statistics Canada's data. However, this subcategory includes not only gender identity but also sexual orientation. Consequently, the comparison samples are not similar. As we did not want to exclude the results obtained from the responses of non-binary individuals from a cross-comparison with the Canadian population, we retained this comparison. In future studies, it may be beneficial to use the same subcategories as those in Statistics Canada for potential comparison.

Our recruitment process deliberately targeted instrumental musicians because there had already been a major Canadian survey conducted in 2021 by Choral Canada, which had examined the impact of the pandemic on singing in Canadian schools (Morin, 2021). As a result, we collaborated with multiple partners to reach as many instrumentalists as possible which helped us recruit a significant number of participants. However, this may have also biased the type of musicians recruited. In future studies, it would be valuable to develop recruitment strategies that target independent musicians, musicians not associated with institutions, and musicians with informal or non-Western music practice.

Regarding the questionnaire's design, it is worth noting that the survey responses were self-reported. As such, it is possible that participants may have answered inaccurately, voluntarily or not. For instance, the level of musical practice: participants were asked to self-assess their musical proficiency, which could result in different interpretations based on individual perceptions. Originally, we had designed the questionnaire with three categories ("middle/high school student," "amateur," "professional"). However, we received feedback when we piloted the questionnaires that one category was missing in order to include musicians who performed music at a higher level than secondary school or amateur but did not consider themselves professional because music was not their primary source of income. This led us to add the category "post-secondary level," which included college or university music students, but also those who graduated from post-secondary music institutions and continued to perform music (paid or not) on the side. This raised the issue about how that question was understood by respondents, which led also to a more philosophical question: what makes a musician "professional"? Is it related to income, fame, musical prowess? While the purpose of the article is not to answer that question, the fact that multiple interpretations were possible suggest that we should have defined these categories for participants in order to minimize confusion.

Secondly, regarding participants engaged in artistic hobbies such as theater groups, dance groups, or visual arts clubs, no significant difference was found in well-being, mental health, and social support. At the same time, because all these artistic hobbies were combined as part of one large category, it is impossible to determine whether results would have differed if these hobbies would have been analyzed separately. It would be worth investigating this aspect in the future.

Thirdly, like we did for music, it would have been worthwhile to collect information about the time spent doing sports, hobbies, and volunteer work, in order to better compare the scope of the results obtained in terms of number of years and hours a week of involvement in other activities. Further research is needed to examine the effects of practicing more than one type of group activity (for instance, music and sport, music and volunteer work) on well-being, mental health and social support.

Finally, it may be useful to explain the statistical analysis and how some of the results may seem counterintuitive at first glance. For instance, with non-binary participants (in our analysis by gender) or with respondents playing music at a middle/high school level (in our analysis by music level), comparisons with the reference groups did not reach statistical significance despite the fact that their average scores were the lowest of their respective category. While this could be attributed to a type II error (which means a failure to reject the null hypothesis of no difference while there may have been an actual effect; Olsen, 1987), it is more likely that the corrections that were applied for statistics involving multiple testing (which control for specific error rates; Bender and Lange, 2001) decreased the apparent significance of effects (Chen et al., 2017).

5 Conclusion

This study was conducted as part of a larger project on the effects of music on the well-being, mental health and social support of Canadians and involved studying student, amateur and professional musicians in Canada during the Covid-19 pandemic. Results showed that musicians with more frequent musical practice reported greater well-being and mental health, as did practicing musicians at an amateur level. Findings also demonstrated that mental health tended to be lower for musicians reporting having a solo music practice, but that social support was stronger for them and those who performed music in instrumental ensembles. Factors such as age, gender, and practicing sports were found to have a significant impact on well-being, mental health and social support. Additionally, being involved in social clubs or doing volunteer work were associated with benefits on two of the three variables (better mental health and well-being for social clubs, and better mental health and social support for volunteer work). With the above findings, we can posit that in the context of the COVID-19 pandemic, regular amateur musical practice, primarily in a group setting, coupled with sports, may have fostered well-being, mental health, and a sense of social support.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Comité Institutionnel d'Éthique de la recherche avec des êtres humains (CIEREH) de l'Université du Québec à Montréal (certificate number: 2022-4,230). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

A-KB: Writing – original draft, Writing – review & editing. IH: Writing – original draft, Writing – review & editing. GR: Writing – original draft, Writing – review & editing. L-ÉT-P: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1386229/full#supplementary-material

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Exploring quantitative indices to characterize piano timbre with precision validated using measurement system analysis

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Aim: Timbre in piano performance plays a critical role in enhancing musical expression. However, timbre control in current piano performance education relies mostly on descriptive characterization, which involves large variations of interpretation. The current study aimed to mitigate the limitations by identifying quantitative indices with adequate precision to characterize piano timbre.

Methods: A total of 24 sounds of G6 were recorded from 3 grand pianos, by 2 performers, and with 4 repetitions. The sounds were processed and analyzed with audio software for the frequencies and volumes of harmonic series in the spectrum curves. Ten quantitative timbre indices were calculated. Precision validation with statistical gage R&R analysis was conducted to gage the repeatability (between repetitions) and reproducibility (between performers) of the indices. The resultant percentage study variation (%SV) of an index must be ≤10% to be considered acceptable for characterizing piano timbre with enough precision.

Results: Out of the 10 indices, 4 indices had acceptable precision in characterizing piano timbre with %SV ≤10%, including the square sum of relative volume (4.40%), the frequency-weighted arithmetic mean of relative volume (4.29%), the sum of relative volume (3.11%), and the frequency-weighted sum of relative volume (2.09%). The novel indices identified in the current research will provide valuable tools to advance the measurement and communication of timbre and advance music performance education.

KEYWORDS

piano timbre, timbre characterization, timbre metric, quantitative index, frequency spectrum, precision validation, gage R&R, measurement system analysis

1 Introduction

Timbre in music is like color in painting (hence its other name – tone color) and, together with rhythm, melody, and harmony, constitutes the basic elements of music (Copland, 2011). This manifests the critical role that timbre plays in enhancing musical expression. A skilled composer would always carefully select the musical instruments with the ideal timbre he/she needs in a piece of music, and a skilled musician instinctively or intentionally controls the tone color during performances for optimal musical expression. Timbre control may be even more important to pianists, as in many cases they have to perform on and adapt to given pianos rather than their own to create the tone color needed with their performing techniques. The

subtle timbre senses and control skills, however, are among the hardest to develop and are usually instilled from years of professional training.

The difficulty lies in the lack of accurate metrics to help measure and communicate timbre. To make communicating timbre even more difficult, due to a lack of sensory vocabulary for auditory experience, currently, musicians or people, in general, rely on descriptive words such as bright, dark, round, dry, harsh, and rich to associate timbre with other sensory or non-sensory attributes (Saitis and Weinzierl, 2019). It is hard to imagine how people would effectively communicate sound pitch with only descriptive words without sound frequency ever being discovered or tuner being invented. Similarly, current ways of communicating timbre bring great limitations and subjectivity.

Prior studies have provided valuable insights in exploring different ways to characterize musical timbre, either qualitatively or quantitatively, as discussed in the later section. However, the question remains to what extent the methods could reliably characterize timbre with subtle differences within a certain musical instrument, such as a piano. Therefore, the current study aimed to explore and discover quantitative indices to precisely characterize piano timbre. The precision of the timbre indices will be validated with the state-of-the-art measurement system analysis methods that have been used in engineering and pharmaceutical industries to ensure the piano timbre measurement system's reliability and replicability. Note that piano performing techniques, among other factors, can affect the timbre of the sound produced by a piano (Bernays and Traube, 2013, 2014). However, those factors are out of the scope of this study because, without a timbre measurement system with enough precision, semantic associations of timbre are subject to great variation of interpretation (Reymore et al., 2023), and analysis of piano timbre control factors is like shooting for moving (and uncertain) targets. Once the precise timbre indices are identified, they can be used to characterize piano timbre produced with such various factors as performing techniques.

2 Materials and methods

Sounds with subtly different timbre from grand pianos were produced and used as standard sounds to identify the timbre indices of enough precision.

2.1 Materials and equipment

The materials and equipment used in this study include: three grand pianos: Kawai RX-3 (KWA), Steinway Model A (STW1), and Steinway Model B (STW2); a stainless-steel weight of 120 grams; small amount of clay for cushioning the weight; an audio recorder (Zoom H4n Pro); a computer (Lenovo Thinkpad® X390); sound processing software (WavePad Master Edition v17.28); statistical analysis software (Minitab® 20.2).

2.2 Sound recording

On each of the three pianos, the G6 key was actuated four times by a performer by releasing the weight at the keyboard level (Figure 1). The performer granted consent for the inclusion of the hand images in Figure 1. The audio recorder was placed near the strings of the key to record the sounds. After the performer finished recording, the second performer recorded the G6 key in the same fashion four times on each of the three pianos. A total of 24 sounds were recorded (4 repetitions × 3 pianos × 2 performers).

2.3 Sound processing

The recorded sounds were imported into WavePad software. The volume peak levels were normalized to −3 dB. The sounds were then transformed from the time domain to the frequency domain with fast Fourier transformation (FFT), see Figure 2. Harmonic series partials were displayed as peaks in the frequency spectrum plot. Volume and frequency data of each partial were collected, with the values from two soundtracks averaged.

2.4 Calculation of timbre indices

Ten timbre indices were defined below using the Hz frequency of fundamental (F_1), Hz frequency of partials (F_n), dB volume of fundamental (V_1), dB volume of partials (V_n), and/or number of partials (N).

Index 0, Energy integral: $\Sigma F_n \times 10^{0.1V_n}$

Index 1, Harmonic mean of relative volume: $\frac{N}{\Sigma \frac{V_n}{V_1}}$

Index 2, Arithmetic mean of relative volume: $\frac{\Sigma \frac{V_1}{V_n}}{N}$

Index 3, Relative volume RMS: $\sqrt{\frac{\Sigma \left(\frac{V_1}{V_n}\right)^2}{N}}$

Index 4, Frequency-weighted arithmetic mean of relative volume: $\frac{\Sigma \frac{F_n V_1}{F_1 V_n}}{N}$

Index 5, Frequency-weighted relative volume RMS: $\sqrt{\frac{\Sigma \frac{F_n}{F_1}\left(\frac{V_1}{V_n}\right)^2}{N}}$

Index 6, Sum of relative volume: $\Sigma \frac{V_1}{V_n}$

Index 7, Square sum of relative volume: $\Sigma \left(\frac{V_1}{V_n}\right)^2$

Index 8, Frequency-weighted sum of relative volume: $\Sigma \frac{F_n V_1}{F_1 V_n}$

Index 9, Frequency-weighted square sum of relative volume: $\Sigma \frac{F_n}{F_1}\left(\frac{V_1}{V_n}\right)^2$

2.5 Statistical validation of timbre indices

To statistically validate the precision of an index to characterize piano timbre, gage R&R or gage repeatability and reproducibility analysis (Durivage, 2015) was conducted. A good timbre index must consistently measure the timbre of the sounds produced by a performer from the same piano (repeatability) and the timbre of the sounds produced by different performers with the same method from the same piano (reproducibility). The combined variability from

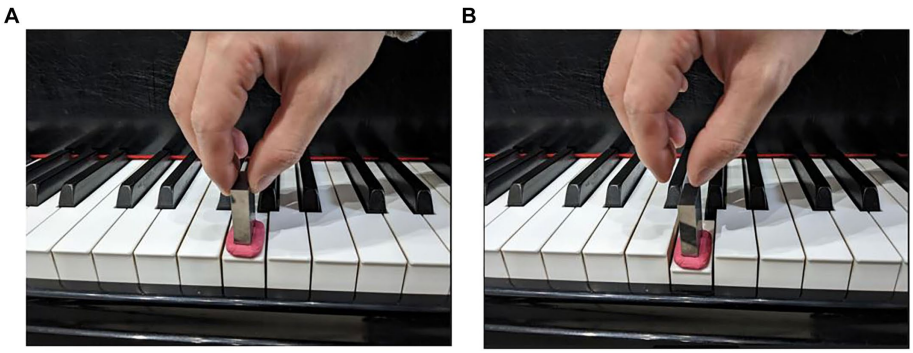


FIGURE 1
Sound recording by pressing key with a weight. **(A)** The weight was set on the clay, which provided cushioning, and placed on the surface of the key. **(B)** The weight was dropped when the key was pressed to generate the sound.

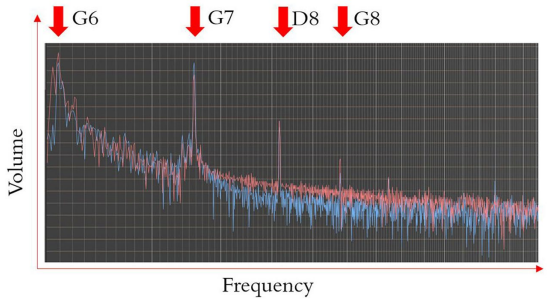


FIGURE 2
Illustration of the frequency spectrum plot. The red and blue curves are two soundtracks captured from the audio recorder. The peaks of the curves occurred on or near the partials of the harmonic series.

repeatability (σ^2_{rep}) and from reproducibility (σ^2_{rpd}) is the measurement system variability (σ^2_{TI}) of the timbre index, which is expressed as

$$\sigma^2_{TI} = \sigma^2_{rep} + \sigma^2_{rpd}$$

A good timbre index must also be able to differentiate the timbre of the sounds from piano to piano without drastically interfered by the timbre index measurement system's uncertainty. In other words, the timbre index measurement system variability (σ^2_{TI}), as noise, must be sufficiently smaller than the piano-to-piano variability ($\sigma^2_{piano-to-piano}$), as a signal. This can be evaluated with percent study variation (%SV), which is defined as

$$\%SV = \%100 \times \frac{\sqrt{\sigma^2_{TI}}}{\sqrt{\sigma^2_{TI} + \sigma^2_{piano-to-piano}}}$$

If a timbre index %SV is ″ 10%, indicating that minimal variation is from repetitions or performers (noise) versus pianos of different timbres (signal), the index has acceptable piano timbre characterization capability. If the timbre index %SV is >30%, the index is unacceptable to characterize piano timbre. If the timbre index %SV is >10% and ″ 30%, the index has marginally acceptable piano timbre characterization capability.

TABLE 1 Percent study variation of timbre indices.

Unacceptable	**Index 5**	**Index 9**		
%SV	93.12	99.43		
Marginally acceptable	**Index 0**	**Index 1**	**Index 2**	**Index 3**
%SV	15.00	12.06	12.84	10.76
Acceptable	**Index 4**	**Index 6**	**Index 7**	**Index 8**
%SV	4.29	3.11	4.40	2.09

3 Results

3.1 Volume and frequency of sounds

Volume and frequency data of the harmonic series partials from the 24 recorded sounds are plotted in Figure 3. Sounds from each of the two performers (A and B) were plotted in separate charts. The plots showed that the volume and frequency data from the two performers were similar. Data within partials were consistent.

The volume–frequency plots showed different patterns for the sounds from different pianos. KWA and STW1 piano sounds showed four partials, ranging from 1,600 Hz to 6,500 Hz, and STW2 piano sounds showed seven partials, ranging from 1,600 Hz to 12,200 Hz. The volume of overtone partials relative to the volume of the fundamental partial was also different from piano to piano. These differences determined the timbre of the sound.

3.2 Index performances in timbre characterization

Timbre of the 24 recorded sounds from 3 pianos, 2 performers, and 4 repetitions are characterized by the indices defined in Materials and Methods section 2.4. The indices results for all 24 recorded sounds are provided in Supplementary material for this article.

Gage R&R analysis was performed for each index, and the resultant %SV is presented in Table 1. Two indices were identified to have unacceptable timbre characterization precision (%SV > 30%): Index 5 (frequency-weighted relative volume RMS) and Index 9 (frequency-weighted square sum of relative volume). Four indices were identified to have marginally acceptable timbre characterization

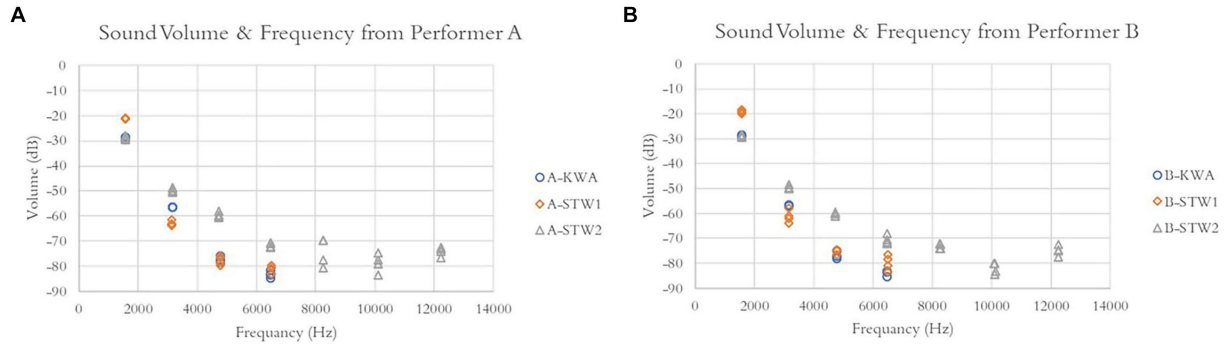


FIGURE 3
Volume–frequency plots of the recorded sounds. **(A)** Twelve sounds are recorded by performer A. **(B)** Twelve sounds are recorded by performer B.

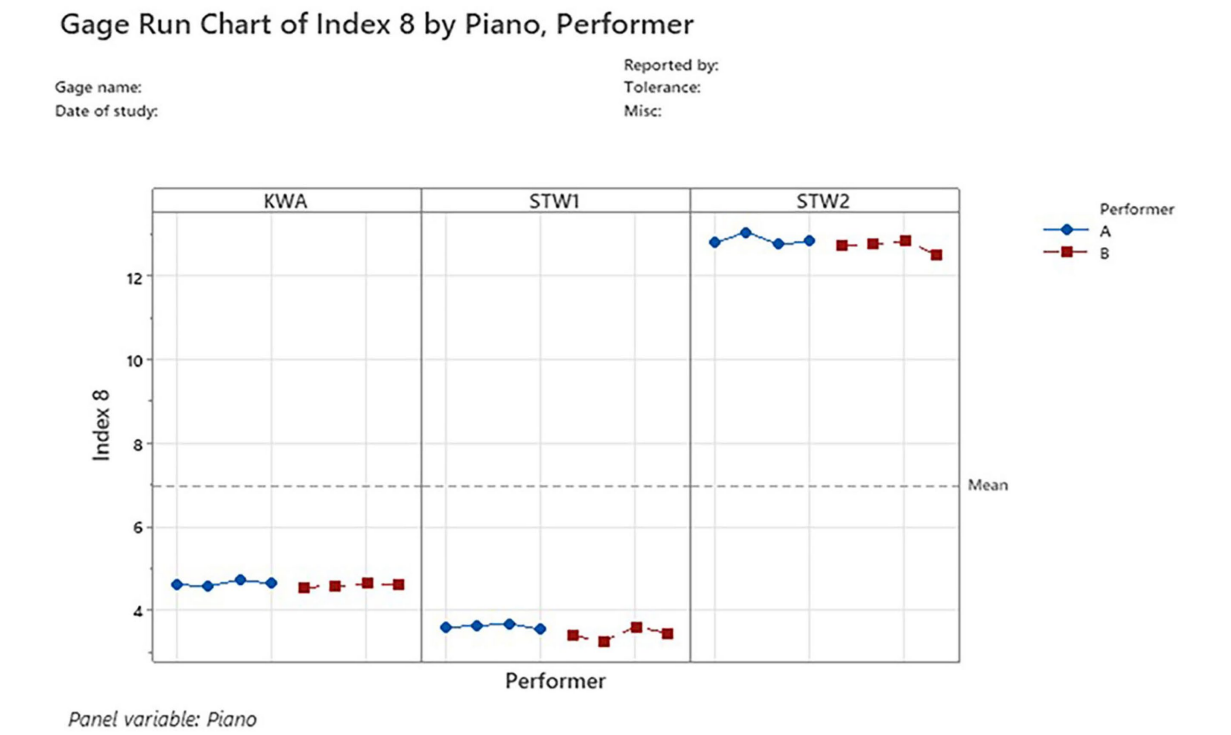


FIGURE 4
Index 8 gage run chart. The timbre measurements for KWA, STW1, and STW2 pianos are plotted in the left, middle, and right panels, respectively. Measurements from each of the three pianos are consistent, indicating good repeatability. Measurements between the sounds from performers A and B are consistent, indicating good reproducibility.

precision (10%<%SV″ 30%): Index 0 (energy integral), Index 1 (harmonic mean of relative volume), Index 2 (arithmetic mean of relative volume), and Index 3 (relative volume RMS). The other four indices were identified to have acceptable timbre characterization precision (%SV″ 10%): Index 4 (frequency-weighted arithmetic mean of relative volume), Index 6 (sum of relative volume), Index 7 (square sum of relative volume), and Index 8 (frequency-weighted sum of relative volume).

Among the four indices with acceptable timbre characterization precision, Index 8 (frequency-weighted sum of relative volume) had the best performance, with the lowest %SV, indicating that it differentiated the timbre of the sounds from piano to piano with minimal measurement system variability, as shown in the gage run chart in Figure 4. Index 8 measured KWA piano timbre at 4.609 ± 0.056, STW1 piano timbre at 3.512 ± 0.141, and STW2 piano timbre at 12.792 ± 0.149.

Gage R&R study results for Index 8 are presented in Table 2 and Figure 5. The %SV result was 2.09 (see gage evaluation in Table 2). The variability from the Index 8 measurement system accounted for only 0.04% of the total variability, while the piano-to-piano variability accounted for 99.96% (see variance components in Table 2 and components of variation chart in Figure 5). R chart in Figure 5 shows the range of timbre values (maximum – minimum) from the repeated measurements of a piano by a performer. All

TABLE 2 Gage R&R study results for Index 8—nested ANOVA.

Gage R&R (nested) for Index 8					
Source	DF	SS	MS	F	P
Performer	1	0.094	0.094	0.00	0.977
Piano (Performer)	4	411.437	102.859	9132.97	0.000
Repeatability	18	0.203	0.011		
Total	23	411.733			

Variance components		
Source	VarComp	%Contribution (of VarComp)
Total gage R&R	0.0113	0.04
Repeatability	0.0113	0.04
Reproducibility	0.0000	0.00
Part-to-part	25.7120	99.96
Total variation	25.7232	100.00

Gage evaluation			
Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total gage R&R	0.10612	0.6367	2.09
Repeatability	0.10612	0.6367	2.09
Reproducibility	0.00000	0.0000	0.00
Part-to-part	5.07070	30.4242	99.98
Total variation	5.07181	30.4308	100.00

Number of distinct categories = 67.

points in the R chart were within the upper control limit and lower control limit (UCL and LCL), indicating good repeatability (i.e., the repeated measurements from the same piano were well controlled). The Xbar chart in Figure 5 shows the average of timbre values from the repeated measurements of a piano by a performer. The points in the Xbar chart spread well beyond the UCL and LCL, indicating that Index 8 can well differentiate timbre from different pianos. Furthermore, the patterns between performers A and B were similar, as shown in the Xbar chart and Index 8 by piano (performer) chart, indicating good reproducibility (i.e., different people pressing the same piano key in the same way generated similar Index 8 values). Therefore, Index 8 has adequate precision in characterizing piano timbre.

Gage R&R analysis results for Index 0–9 except Index 8 are presented in Supplementary material for this article.

By contrast, indices with unacceptable precision (represented by Index 5) and marginally acceptable precision (represented by Index 0, see Figure 6 and Supplementary Figure S1) do not have as good repeatability or reproducibility as the indices with acceptable precision. The gage run charts for Index 5 and Index 0 (Figure 6) showed that timbre characterization results within a performer for a piano and results between the performers within a piano vary dramatically, compared to the consistent results within a piano in the gage run charts for Index 8 (Figure 4). Gage R&R analysis for Index 5 showed that most variations of the results were from the gage rather than from part-to-part (i.e., between the pianos) (see Supplementary Figure S6 components of variation), and the lack of precision in the gage failed to differentiate the timbre differences in different pianos (see Supplementary Figure S6 Xbar chart). Gage R&R analysis for Index 0 showed that although most variations were from the part-to-part instead of the gage, the repeatability within the STW1 piano was out of control, as manifested by the STW1 point went well above the UCL (Supplementary Figure S1 R chart). Those gage R&R results for Index 5 and Index 0 showed significant contrasts when compared to the results for Index 8 with acceptable precision (Figure 5).

In conclusion, the indices with acceptable precisions, as validated by gage R&R, provide reliable ways to characterize the piano timbre.

4 Discussions

Modern timbre analysis began in the mid-1970s when spectrograms became widely available to allow researchers visually see the sounds. Cogan's pioneering studies combined spectrogram analysis with a series of oppositions that can describe sound features of a given sound signal (Cogan, 1984). After that, timbre analysis gradually became a hot research topic, and the analysis methods developed into two large categories: qualitative or semi-quantitative methods and quantitative methods. Many prior studies used qualitative or semi-quantitative methods to characterize timbre and associate it with semantic meanings (e.g., Petiot et al., 2017; Kazazis et al., 2021; Reymore, 2022; Reymore et al., 2023). Other studies proposed various mathematical models developed for identifying the timbre of different musical instruments (McAdams et al., 2017; Thoret et al., 2017; Jiang et al., 2020; Jannereth and Esch, 2021). However, a common challenge is that the precision of the measurement system to characterize timbre has not been statistically validated for repeatability and reproducibility. Therefore, it is not clear to what extent the timbre characterization results following those methods are reliable and replicable. Thoret et al. (2021) computationally re-analyzed 17 datasets from studies published between 1977 and 2016 to correlate timbre features with various instrument sources and observed that original results were only partially replicable. Furthermore, within an instrument, timbre varies more subtly yet meaningfully to musical expression, and quantitative characterization with adequate precision for timbre within a specific instrument, such as a piano, becomes valuable. The current study aimed to take on the challenges by quantitatively exploring multiple mathematical indices for piano timbre and rigorously validating the precision of the indices, with state-of-the-art measurement system analysis method of gage R&R from the engineering and pharmaceutical industries, to ensure the indices' capability of characterizing timbre within pianos with subtle timbre differences. The novel indices identified and validated to have acceptable precisions in the current research will prove to be valuable tools to advance the measurement and communication of piano timbre.

As the use of the tuner could greatly help novice violinists without the sense of perfect pitch develop accurate pitch playing, the application of the piano timbre indices could greatly advance piano performance education by bridging the performing techniques and timbre outputs. One of the difficulties in piano performance study is to receive timely and accurate feedback during practice, and one

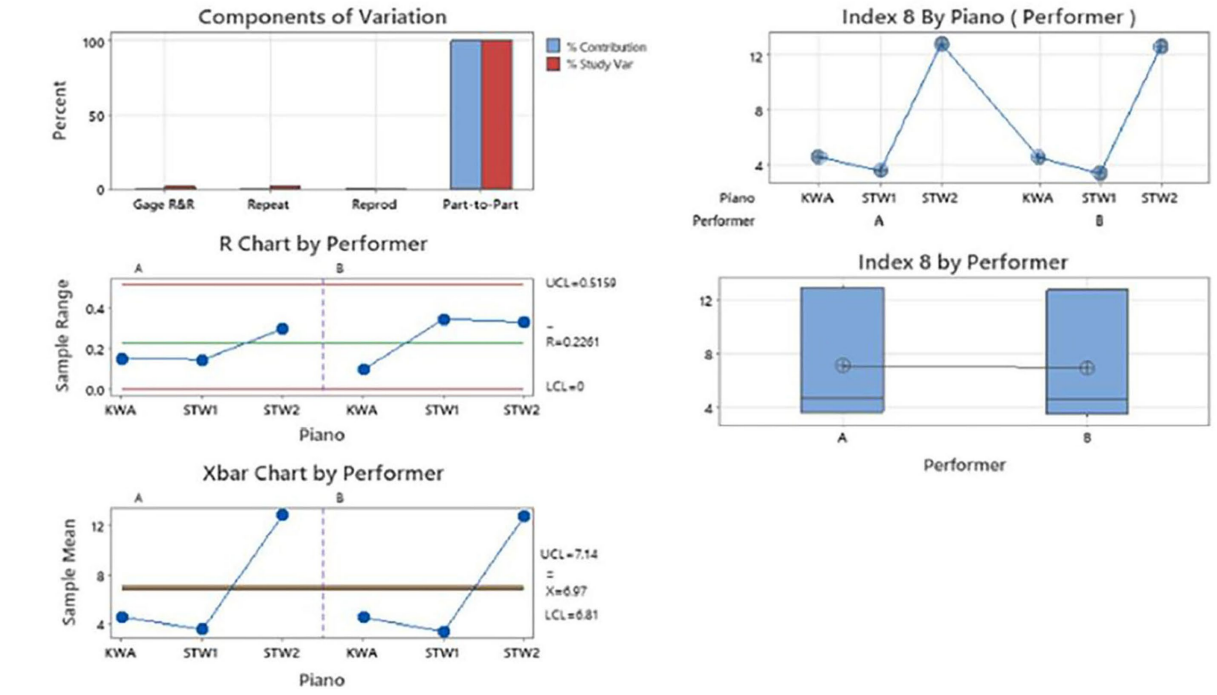


FIGURE 5
Gage R&R analysis report for Index 8 frequency-weighted sum of relative volume. The %SV result was 2.09 (see components of variation chart), indicating acceptable precision. R chart has all points falling within UCL and LCL, indicating repeatability is good. Xbar chart showed points spreading well beyond the UCL and LCL, indicating that Index 7 can well differentiate timbre from different pianos. Index 7 by performer chart and Index 7 by piano (performer) chart showed almost identical results between performers A and B, indicating reproducibility is good.

cannot always expect students to develop accurate sense of timbre for ideal musical expression. The timbre indices, especially integrated with music education software, could provide valuable feedback to aid ideal timbre control.

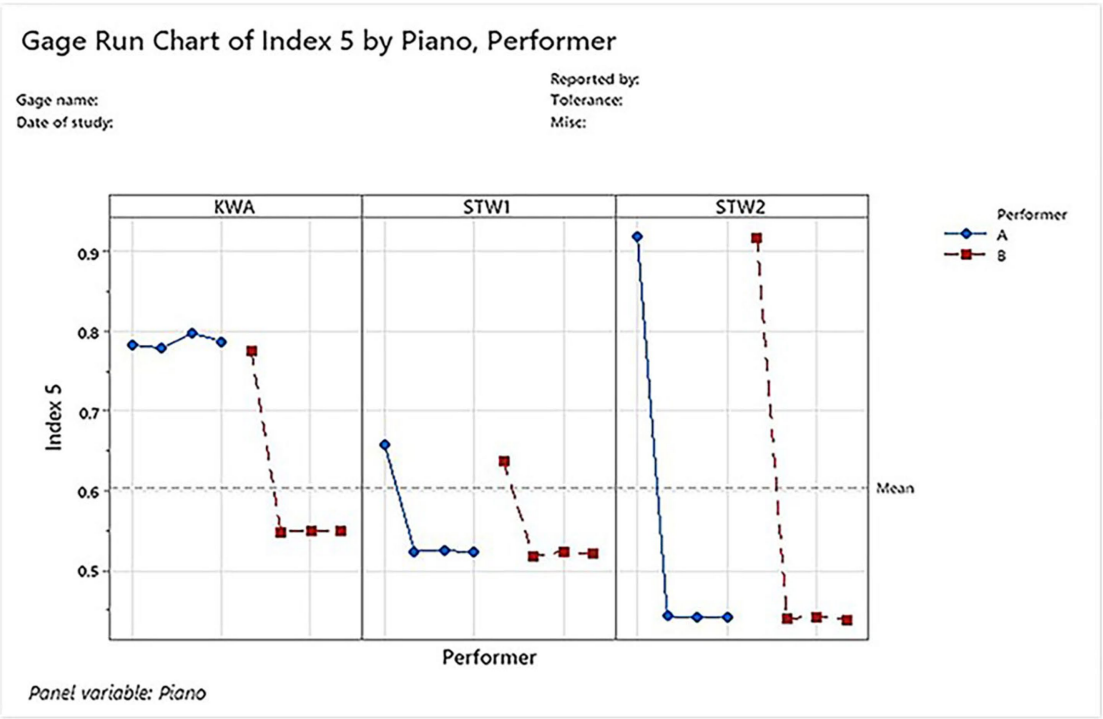
One limitation of the current research is that the indices were only validated to have adequate timbre characterization precision for pianos. This will limit the application of the indices. Many musical instruments widely used in solo performance or orchestration, such as violin, cello, clarinet, and flute have different timbre characteristics between instruments and valuable timbre expressions within an instrument. Different timbre between instruments is of great concern to composers to decide which instruments to use in a music piece. This has largely been studied and perfected throughout time. It is the timbre subtleness within an instrument that is of utmost importance for musical expression from performance and merit more research in reliable characterization. The validities of the timbre indices investigated in the current research need to be studied for applicability in those other instruments. Through those studies, potential universal timbre indices to characterize musical timbre may be discovered.

Another limitation of the current research is that the relations between the timbre indices quantities and common timbre descriptions have not been explored. This will limit the understanding of the meaning of the timbre indices, without which effective communication of timbre for ideal musical expression of a note or a music piece will be limited. The issue relates to timbre perception and cognition in human sensory and central nervous organs. It is possible that some subtle differences in timbre in a certain instrument may not be recognizable by the audience but may be detected by the timbre precision measurement system, in which case the detected differences do not carry much musical meaning. There may be thresholds of timbre differences, beyond which trained musicians and the general audience may recognize the musical expression differences and regions of timbre quantities that are associated with semantic meanings. Therefore, research in timbre perception on the scale of detectable differences and relation analysis between timbre expression and indices are merited in future studies. Those studies will greatly advance the understanding and effective communication of the musical timbre.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

A



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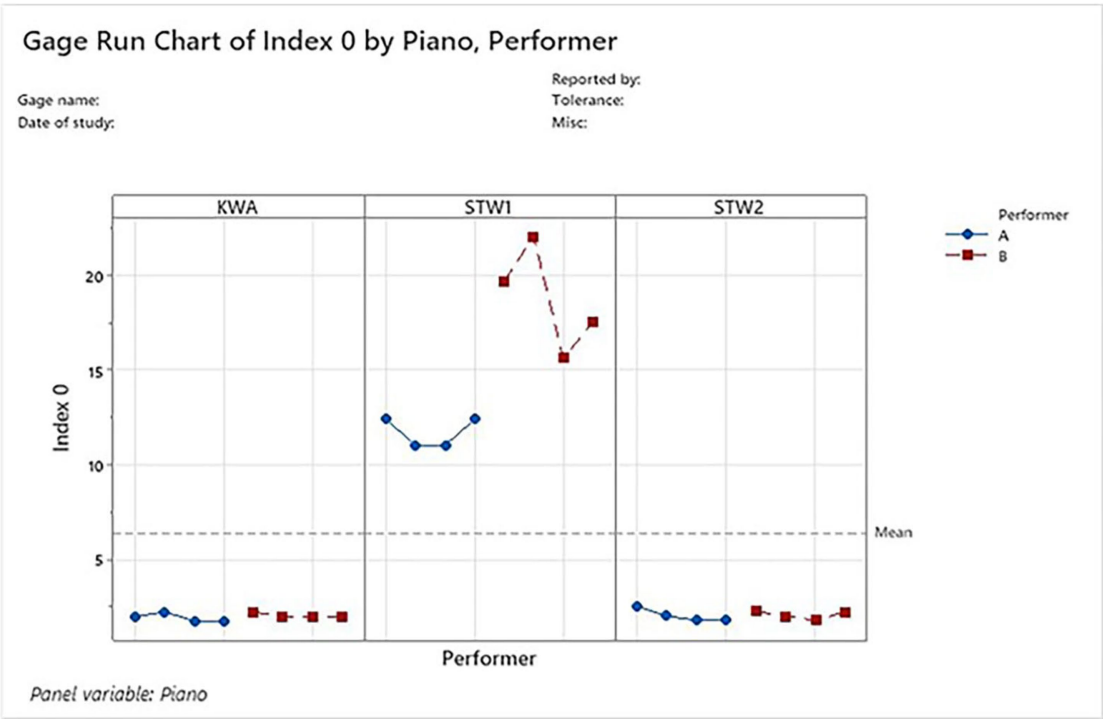

FIGURE 6
Gage run charts for Index 5 and Index 0. **(A)** Index 5 had timbre characterization results vary within a performer for each of the three pianos and vary between performers within a piano, indicating unacceptable precisions. **(B)** Index 0 had results that varied dramatically between the performers and within performer B in STW1 piano, which undermined the precision of index 0.

Author contributions

YZ: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Writing – original draft, Writing – review & editing. SY: Formal analysis, Investigation, Methodology, Software, Validation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1363329/full#supplementary-material

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Autonomous or controlled interpreters? Model of *Werktreue* internalization for classical musicians

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Self-regulated learning—a cyclical process in which a learner sets a goal, monitors, and self-reflects on one's learning to set the next goal—is vital in instrumental learning. However, many conservatory students fail to initiate self-regulated learning; they take lessons passively, practice ineffectively, and fail to give satisfactory performance. These learning experiences could harm students' well-being, and physical and mental health problems are widespread among students. Nevertheless, factors contributing to self-regulated learning remain unknown. We hypothesized that musicians' autonomy in musical interpretation, which we refer to as *interpretive autonomy*, plays a pivotal role in self-regulated learning. Without developing interpretation, musicians fail to set personal goals, monitor, and self-evaluate their performances in terms of musicality. Although previous studies imply that interpretation plays a significant role in self-regulated learning, this has not been clearly demonstrated. Studies on interpretive autonomy are scarce due to a complicated discourse surrounding performers' freedom in interpretation. The ideology of *Werktreue* underpins the classical music field, and classical music performances are evaluated based on how faithfully a performer interpreted the composer's intention. Yet musicians hold various beliefs regarding the meaning of faithful interpretation, thus the degree of interpretive autonomy cannot be assessed unless its clear definition is provided. In addition, the mechanisms that promote or hinder interpretive autonomy in learning remain unexplained. To address these issues, we proposed a model of *Werktreue* internalization by applying self-determination theory. The model defines interpretive autonomy based on internalization types, identifies its effects on musicians' learning behavior and well-being, and reveals the mechanisms that promote or hinder interpretive autonomy in learning experiences. This model allows researchers and educators to assess the degree of interpretive autonomy, attribute impaired learning behavior and well-being to a lack of interpretive autonomy, and promote interpretive autonomy by supporting students' psychological needs in interpretation.

KEYWORDS

music education, musical interpretation, interpretive autonomy, self-determination theory, self-regulated learning, well-being, performance, the *Werktreue* ideology

1 Introduction

Despite their hard work and dedication, conservatory students face various difficulties in learning. Students tend to be passive in one-to-one lessons, relying on their teachers' instructions (Gaunt, 2010). In solitary practice, students employ ineffective strategies (Hatfield, 2016; Hatfield and Lemyre, 2016; McPherson et al., 2019), and some students persist in practice even with playing-related injuries (Park et al., 2007). In performance, students become overly self-conscious and give unsatisfactory performances (Clark et al., 2014). These learning experiences endanger learners' well-being (Perkins et al., 2017), and many classical musicians suffer from both physical and mental health problems (Kenny and Ackermann, 2014).

At other times, students are inspired by teachers in lessons (Gaunt, 2010). In practice, they creatively explore musical ideas (Wise et al., 2017). In performance, when students are fully immersed in the music, they enter a transcendental state, embracing an inherent joy of music-making (Bernard, 2009). These learning experiences promote students' well-being (Perkins et al., 2017) and personal development (Jääskeläinen, 2023).

Students in the former case lack autonomy, whereas students in the latter case initiate their learning successfully. Student autonomy is considered crucial in instrumental learning (Jørgensen, 2000), and Zimmerman's (2002) self-regulated learning is a useful framework for investigating student autonomy in learning. Self-regulated learning (SRL) is comprised of three cyclical phases: forethought, performance, and self-reflection (Zimmerman, 2002). In the forethought phase, learners set goals and plan strategies to complete the task and manage motivation for learning. In the performance phase, learners enact learning behavior by employing strategies while monitoring its effectiveness. In the self-reflection phase, learners evaluate their learning performance and attribute failures to appropriate causes. Based on self-reflection, learners then set new goals and plans, initiating the next cycle (Zimmerman, 2002). Researchers show that the framework is adaptable to instrumental learning, and effective SRL is vital for optimal musical development (McPherson and Renwick, 2011; McPherson and Zimmerman, 2011; McPherson et al., 2017).

Nevertheless, what differentiates skillful self-regulators from naïve self-regulators remains unknown. Thus, a lack of self-regulated behavior is often attributed to innate abilities. When conservatory students demonstrated dependent learning behavior, the majority of instrumental professors attributed it to individual traits, such as musical talent and self-confidence (Gaunt, 2008). In addition, support offered by institutions for both teachers and students to reflect on their learning is limited (Jørgensen, 2000; Gaunt, 2008; Burwell et al., 2019). Therefore, it is urgent to identify factors that contribute to SRL to support music students' learning and well-being.

We argue that autonomy in musical interpretation, which we refer to as *interpretive autonomy*, plays a pivotal role in musicians' SRL and well-being. Classical musicians interpret meanings from notations on a score, deciding what and how to express a piece. Then, musicians convey their interpretations in performance. Therefore, developing interpretations is a prerequisite for musicians to set a musical goal and plan strategies. Furthermore, interpretation is essential to monitor and evaluate how effectively they conveyed the intended interpretation in performance. In other words, when musicians do not develop interpretation, they cannot make goals, monitor, and reflect on their performances based on musicality, failing to initiate effective SRL. The importance of interpretation in SRL has been implied (e.g., Cantwell and Millard, 1994; Hallam, 2001; Reid, 2001; Hultberg, 2002; Hallam et al., 2012; Hatfield, 2016; McPherson et al., 2019); however, it remains ambiguous. Therefore, although ineffective SRL may be caused by a lack of interpretive autonomy, interpretation has been rarely addressed in both academia and educational practice.

Investigating interpretive autonomy is challenging due to a complicated discourse surrounding musicians' freedom in interpretation. Musical interpretation is an ill-defined problem; there is no definite "right" solution or answer in interpreting a piece. This allows classical musicians to cultivate their creativity in forming and expressing an individualized interpretation of a piece (Payne, 2016; Wise et al., 2017; Héroux, 2018). However, not all interpretations are accepted in the classical music field. There is a norm that has been regulating performance practice since the end of the 18th century: the ideology of *Werktreue* (Goehr, 1992). Under the norm of being true to the work, musicians' interpretations are assessed based on their faithfulness in realizing the work the composer intended (Goehr, 1992). With the establishment of "authentic" interpretations in the 20th century, interpretations deviating from normative interpretations, performance styles, or scores often faced disapproval, being deemed disrespectful to the composer and work (Taruskin, 1995). Critics claimed that musicians reproduced normative interpretations to be regarded as faithful interpreters, and this led classical music performances to be static and monotonous (Szigeti, 1979; Small, 1986; Taruskin, 1995; Adorno, 2006; Leech-Wilkinson, 2020).

Although a lack of interpretive autonomy among professional musicians and student musicians has been pointed out (Szigeti, 1979; Small, 1986; Taruskin, 1995; Hultberg, 2002; Adorno, 2006; Leech-Wilkinson, 2020), assessing the degree of interpretive autonomy is challenging due to varying definitions of interpretation. Musicians internalize the *Werktreue* ideal differently and hold various concepts of faithful interpretation. Silverman (2007) organized them into two contrasting views: formalist and subjective. Musicians with the formalist view aim to "[let] the score speak for itself" by strictly adhering to scores (p. 102). In contrast, musicians with the subjective view interpret based on their subjective feelings and desires. Silverman argued that musicians with the formalist view fail to convey personal interpretations in performance, as they perceive themselves as "merely the 'servant' of the composer" (p. 102). However, musicians holding the formalist view cannot be automatically considered to lack autonomy or individuality in their interpretations. These musicians may genuinely wish to adhere to the score to be faithful to the composer's intention, and every musician has the right to embrace their principles in interpretation. In addition, when musicians make faithful interpretive decisions, they are ultimately expressing personal musical choices, as composers' intentions are unknowable (Cook, 2013).

In addition, mechanisms that promote or hinder interpretive autonomy in learning remain unknown. Previous studies have suggested that open questions and dialogue on musical characters are effective in promoting students' interpretations at the pre-college (Meissner, 2017; Meissner and Timmers, 2019, 2020; Meissner et al., 2021) and college levels (Hultberg, 2002; Young et al., 2003; Burwell, 2005; Nerland, 2007). Conversely, authoritarian teaching that rejects students' musical ideas has been cautioned to impede the

development of artistic voice (Persson, 1996; Silverman, 2008; Wagner, 2015). Nonetheless, the underlying mechanisms of the promoting or suppressing effects of these teaching methods on interpretive autonomy remain unexplained.

Factors that nurture or impede interpretive autonomy in learning experiences must be identified to ensure that a lack of interpretive autonomy is not mistaken for a lack of talent; as with SRL, the degree of interpretive autonomy is easily attributed to an innate ability. Some conservatory students were suspicious that interpretation can be taught or learned (Burwell, 2014). Attribution of innate ability is also observed in expressivity (Lindström et al., 2003; Laukka, 2004) and musicality (Kingsbury, 1988), which are both closely related to interpretation. However, attribution to innate ability can make learners vulnerable to negative feedback (Dweck, 1999). For instance, when a conservatory student received feedback from professors that she was "unmusical" in an exam, her self-esteem was negatively impacted because she regarded unmusicality as unchangeable (Kingsbury, 1988, p. 65).

To summarize, three research gaps exist in interpretive autonomy. First, consensus on the definition of interpretive autonomy is lacking, hindering research on interpretive autonomy. Second, the mechanisms that promote or hinder interpretive autonomy are unknown, allowing the degree of interpretive autonomy to be attributed to innate ability. Finally, the significance of interpretive autonomy in musicians' learning is implied but remains ambiguous. Because of these gaps, students' autonomy in interpretation is overlooked in both academia and educational practice. To address these issues, we propose a theoretical model that defines interpretive autonomy, explains the mechanisms that promote or hinder interpretive autonomy in learning, and identifies its effects on musicians' learning and well-being. Following self-determination theory (Ryan and Deci, 2000, 2017), we define interpretive autonomy based on types of internalization of the *Werktreue* ideal: autonomous and controlled. The model offers a new rationale for educators and researchers to recognize the importance of interpretive autonomy and consider factors affecting interpretive autonomy in music education.

The article is organized as follows. First, we examine maladaptive learning behavior found in lessons, practice, and performance, and we investigate the role of interpretive autonomy in effective SRL. In addition, we address the importance of SRL for musicians' well-being. Second, we briefly overview the historical background of the *Werktreue* ideology, illustrate its impact on performance practice, and address criticisms against "authentic" performers. Third, we introduce varied interpretive approaches adopted by musicians and categorize them into approaches that indicate interpretive autonomy or lack thereof. Finally, we present the model of *Werktreue* internalization and discuss its implications for educators and researchers in music education.

2 Interpretive autonomy, learning behavior, and well-being

This section discusses the relationship between interpretive autonomy and learning behavior in lessons, practice, and performance. SRL has been applied to investigate musicians' learning in practice (see Varela et al., 2016 for a systematic review) and performance (Williamon et al., 2017). Extending the application into the context of lessons, we intend to comprehensively capture student learning behavior in the three contexts: lessons, practice, and performance[1].

2.1 Other-regulated learning in lessons

Historically, instrumental learning has taken place in one-to-one tuition where masters demonstrate and students imitate (Jørgensen, 2000; Nielsen, 2006; Burwell, 2013). Teachers are experienced professional practitioners whose knowledge and skills reflect norms and expectations in the professional community of the field (Nerland, 2007). As students acquire musical knowledge and skills, they also acquire competencies and identity as professional classical musicians (Nielsen, 2006; Burwell, 2013).

Although the master-apprenticeship has been proven to be effective in transmitting expertise, researchers warn that student autonomy can be neglected or even impaired in the relationship (Persson, 1996; Jørgensen, 2000; Rostvall and West, 2003; Young et al., 2003; Burwell, 2005, 2021; Karlsson and Juslin, 2008; Silverman, 2008; Gaunt, 2011; Carey and Grant, 2015; Wagner, 2015; Burwell, 2021). Gaunt (2010) interviewed 20 conservatory students and found that students failed to initiate cycles of planning, monitoring, and self-evaluating in lessons. Students did not have long-term goals related to personal development and failed to communicate concerns during lessons. After the lessons, they blindly followed instructions without evaluating them critically. In addition, students in this study were overtly self-critical, possibly caused by their lack of initiative in lessons (Gaunt, 2010).

2.1.1 Interpretive autonomy and self-regulated learning in lessons

Studies suggest that interpretive autonomy helps students initiate SRL in lessons. Reid (2001) categorized students' understanding of learning into five categories and explored how it related to student learning behavior. At the first two lowest levels, students did not consider interpretation part of musical learning and aimed for the correct technical execution of the music. These students relied on their teachers' technical instructions to play a piece. In contrast, students who included developing interpretation in their learning goals were "able to make judgments about the appropriateness of their teacher's advice for their own musical situation" (p. 32). They integrated a teacher's ideas with their own and explored ideas outside the lessons. At the highest level in the classification, students aimed to find personal meaning and express themselves by conveying their original interpretations to audiences. These students regarded teachers as facilitators for their personal development. This shows that having interpretive autonomy allows students to critically evaluate and adopt their teachers' instructions for their artistic development, initiating SRL in lessons.

2.2 Other-regulated learning in practice

Students often practice in isolation. Instrumental teachers rarely address practice methods in lessons (Jørgensen, 2000), and naïve

1 We use *other-regulated learning* to describe a learning style regulated by others to contrast it with self-regulated learning.

learners tend to employ ineffective practice strategies, such as playing through a piece while ignoring mistakes (Pitts et al., 2000; McPherson and Renwick, 2001; Hallam et al., 2012). Even in higher education, students practice ineffectively without setting goals, and they fail to concentrate in practice (Hatfield, 2016; Hatfield and Lemyre, 2016). In addition, students may suffer from playing-related injuries, such as all six students in Hatfield's (2016) study. This implies that ineffective practice results in excessive workload and may cause injuries, as the amount of practice time is correlated with playing-related injuries (Robitaille et al., 2018; Gembris et al., 2020; Macdonald et al., 2022). However, even with the injuries, students and professional musicians tend to play through the pain; their identity is deeply entrenched with music, and quitting performance may result in an identity crisis (Park et al., 2007; de Kock et al., 2023).

2.2.1 Interpretive autonomy and self-regulated learning in practice

Interpretive autonomy helps students initiate SRL effectively in practice. First, active development of interpretation allows students to understand scores deeply. Cantwell and Millard (1994) investigated how students' "surface" and "deep" learning approaches are related to their levels of understanding of scores. They gave three new scores to six 14-year-old students and interviewed them to understand how they would learn the pieces. They found that a surface approach was characterized by a lack of consideration for interpretation. Students with a surface approach perceived the scores as well-structured problems that could be solved technically. They aimed at achieving literal accuracy of the scores, failing to connect the notations with musical concepts. In contrast, a deep approach was characterized by the active development of interpretation. Students with a deep approach perceived the scores as ill-structured problems of musicality, translating notations into musical themes, expressions, and characters. This difference was found among two pairs of students who held the same grades given by the Australian Music Examinations Board; thus, Cantwell and Millard (1994) concluded that consideration of interpretation differentiated how deeply students processed the scores.

Moreover, interpretive autonomy allows students to employ various practice strategies effectively. Reid (2001) demonstrated that students who did not consider interpretation as part of instrumental learning were limited in their exploration of musical ideas, whereas students who aimed to develop interpretation experimented with different phrasings of musical material. Other studies have shown that, to develop interpretations, students employ diverse strategies that do not necessarily involve playing, such as listening to recordings, singing, performing score analysis, conducting, or creating narratives (Cantwell and Millard, 1994; Reid, 2001; Volioti and Williamon, 2017, 2021; Wise et al., 2017; McPherson et al., 2019). On the other hand, a questionnaire survey among 3,325 children aged 6–19 years indicated that the use of ineffective practice strategies, such as merely running through a piece, is negatively correlated with development of interpretation (Hallam et al., 2012). These studies support that development of interpretation is vital in employing effective practice strategies.

In addition, interpretive autonomy contributes to efficient technical improvement. In the absence of interpretation, students practice techniques without a musical goal. Consequently, these students rely on the quantity of practice to evaluate the effectiveness of practice, such as students in Reid's (2001) study. In contrast, students who develop interpretation hone techniques to convey a musical expression they intend to convey (Reid, 2001; Wise et al., 2017). McPherson et al. (2019) compared the practice behavior of two first-year university students—one student in the top 5% of their cohort, and the other in the bottom 5%—and found that the high-scoring student aimed to develop personal interpretation and practiced an étude with a goal to improve a specific finger movement. By contrast, the low-scoring student did not have any aims relating to interpretation and played an étude from the beginning "because [she] did not know what [she] was going to do" (p. 27).

A deeper understanding of a score, employment of diverse practice strategies, and efficient technical improvement can lead students to experience inherent enjoyment of learning music. In the above-mentioned study by McPherson et al. (2019), the high-achieving student had an intrinsic motivation for practice and was satisfied after practice with a sense of accomplishment. The latter student practiced how she "normally practice[d], just doing what the teacher says, hopefully" (p. 28), and she left practice with a sense of guilt and helplessness; yet she did not "know what to do next" (p. 29). This indicates that active development of interpretive ideas contributes to effective SRL which leads students to experience inherent satisfaction from practice.

2.3 Other-regulated learning in performance

Conservatory students often perform in highly stress-inducing settings, such as exams, auditions, and competitions. In these contexts, the audiences comprise expert musicians, and students are aware that the audiences' assessment may impact their careers (Perkins, 2010; McCormick, 2015). In addition, performance opportunities are infrequent and unevenly distributed, which imposes pressure on students to obtain high evaluations from the expert audience (Perkins, 2013; McCormick, 2015). Accordingly, 58% of 80 German music students aged 15–19 answered that the status of the audience strongly affected their level of performance anxiety. For these students, performance situations where their teachers and professors were in the audience triggered the highest levels of music performance anxiety (Fehm and Schmidt, 2006).

Self-reflection after performance is also challenging. Daniel (2001) found that the majority of students at an Australian conservatory showed dependence on teachers' feedback to assess their own performance. However, feedback from others is often vague (Juslin and Laukka, 2000) and contradictory even among experts (McCormick, 2015; Wagner, 2015). Nonetheless, conservatory students take feedback from experts personally, making themselves vulnerable to negative feedback (Kingsbury, 1988; McCormick, 2015). Daniel (2001) reported that when students watched videos of their performances for the first time in the class for self-reflection, 43% made criticisms, such as "I hated it" (p. 222). This implied that the students were overtly self-critical and had difficulties in self-assessment of their performance (Daniel, 2001). This is a serious problem, as students cannot learn from performance experience or set a mastery goal for the next performance without constructive self-reflection.

2.3.1 Interpretive autonomy and self-regulated learning in performance

Even in this challenging situation, interpretive autonomy helps musicians self-regulate themselves in performance. First, having

interpretation helps musicians set a musical goal. Clark et al. (2014) investigated musicians' thoughts before, during, and after a performance, and they found that a musician who gave a successful performance was "absolutely 200% sure of what [the musician] was doing, musically," whereas another musician who gave a less successful performance admitted that their focus was on technical difficulties of the piece and "nothing on the character" (pp. 26, 28).

Several intervention studies have indicated that focus on musical interpretation facilitates musicians' performance. Hatfield (2016) conducted a 15-week intervention to promote SRL where he encouraged students to focus on musical expression that they wanted to convey before performance. This helped the students concentrate on music, and they experienced greater satisfaction in performance. Chen (2023) implemented a six-month experiment in which 150 conservatory students took classes specifically on musical interpretation to investigate whether a focus on interpretation promotes the experience of flow in performance. In classes, the students were exposed to different genres of music, and they analyzed and arranged classical music pieces as well as composed their own pieces. After the intervention, the ratio of students who reported a high experience of flow in performance increased 10% from 66.7 to 76.7% in the experimental group. In the control group, in which students experienced traditional conservatory training, the ratio increased only 0.9% from 68.3 to 69.2%.[2] These findings support that interpretive autonomy improves performance.

2.4 Ill-being

Due to challenging conditions—acquiring and maintaining complex performance techniques and being constantly exposed to public scrutiny—many musicians experience physical and mental health problems (Kenny and Ackermann, 2014). Students and professional musicians commonly suffer from performance-related musculoskeletal pain (Fishbein et al., 1988; Ginsborg et al., 2009; Steinmetz et al., 2012; Kenny and Ackermann, 2015; Robitaille et al., 2015; Macdonald et al., 2022). In addition, musicians' mental wellness is endangered. Questionnaire surveys revealed that music students reported a higher level of anxiety and depression than non-music students in Germany (Spahn et al., 2004) and Norway (Vaag et al., 2021). Music performance anxiety is commonly experienced (Barros et al., 2022), and to ease anxiety, both students (Hernández et al., 2018; Lupiáñez et al., 2022) and professional musicians (Fishbein et al., 1988; Kenny et al., 2014) have reported substance use, including prescribed and non-prescribed medication, alcohol, and illicit drugs.

2.4.1 Self-regulated learning and well-being

Other-regulated learning behavior may increase the risks of musicians' physical and psychological health problems. Students perceive issues like conflict with teachers, excessive practice, and stressful performance experiences as harmful to their well-being (Perkins et al., 2017). Conversely, support from others, a sense of personal growth, and enjoyment in performance were perceived as beneficial for their well-being (Perkins et al., 2017). This implies that initiating SRL in lessons, practice, and performance is essential for musicians' well-being, particularly since they are constantly exposed to pressures owing to the nature of the profession.

2.5 Summary

This section reviewed the relationship between interpretive autonomy and SRL. In addition, we showed that SRL is essential for not only musical development but also optimal well-being. We now turn to the norm in the classical music field: the ideology of *Werktreue*. The next section presents how powerfully the norm regulates musical interpretation. Furthermore, we address criticisms directed at "authentic" performers that their interpretations lacked individuality. The overview is drawn from musicological literature, primally based on Goehr's (1992) *The Imaginary Museum of Musical Works: An Essay in the Philosophy of Music*.

3 The ideology of *Werktreue*

3.1 In the 19th century

For classical musicians to be true to the work, music needs to be considered as a work. However, before 1800 music was not yet recognized as an artistic work but a function to serve in a church and at court (Goehr, 1992). Composers composed music for social events and dedicated their compositions to their employers. Scores were left incomplete, and composers often performed or conducted their own compositions differently each time. Improvisation was also a common practice as a form of public entertainment. In short, music was played for social occasions, and the distinction between composition and performance was blurry (Goehr, 1992).

During the early 19th century, a paradigm shift occurred that drastically changed the ways composers, audiences, and performers engaged with music; the work-concept emerged, in which music was regarded as a *work*. Composers began to identify themselves as freelance artists and asserted their compositions as creative works that had artistic and monetary value independent of performances (Goehr, 1992). Recitals were invented, in which audiences learned to listen to musical works for their own sake. Past compositions by Bach and Mozart were introduced as "timeless masterpieces" that "gave to early composers and their music what they had never had in their lifetimes—precise notations, multiple performances, and eternal fame" (Goehr, 1992, p. 247).

The emergence of the work-concept gave birth to the *Werktreue* ideology, which significantly influenced musicians' approach to interpretation. Composers provided complete scores to represent their imaginary work, and performers became responsible for realizing works faithfully by interpreting composers' true intentions from scores.

> "Performers should interpret works in order to present the work as it truly is with regard to both its structural and expressive aspects. Room was to be left for multiple interpretations, but not so much room that interpretation would or could ever be freed of its obligation to disclose the real meaning of the work. A performance met the *Werktreue* ideal most satisfactorily, it was

2 It should be noted that Chen (2023) reported descriptive statistics.

> finally decided, when it achieved complete transparency. For transparency allowed the work to 'shine' through and be heard in and for itself" (Goehr, 1992, p. 232).

However, the *Werktreue* ideology did not suppress musicians' individuality in interpretation nor limit interpretive possibilities to written scores in the 19th century. Performers' unique imagination, inspiration, and creativity were recognized as essential to bring compositions alive (Hunter, 2005). Improvisation remained part of performances in regular concerts, and performers added notes to pre-composed pieces or manipulated tempo freely (Hamilton, 2008). When Liszt performed Fugue by Handel in 1840, Liszt was praised in *The Times* for his performance with "scarcely any additions, except a multitude of ingeniously contrived and appropriate harmonies, casting a glow of color over the beauties of the composition, and infusing into it a spirit which from no other hand it ever before received" (Williams, 1990, p. 135).

3.1.1 The criticisms against authentic musicians in the 19th century

Interestingly, with the emergence of the *Werktreue* ideal, criticisms started to appear that musicians lacked expressivity in the name of authenticity. In his lectures on aesthetics, Hegel cautioned not to "sink to being merely mechanical" in faithful reproduction of works (Hegel, 1975, p. 956).

> "The executant has a duty to give life and soul to the work in the same sense as the composer did, and not to give the impression of being a musical automaton who recites a mere lesson and repeats mechanically what has been dictated to him" (Hegel, 1975, p. 956).

Leistra-Jones (2013) argued that Brahms and Joachim intentionally presented themselves as authentic performers by demonstrating extremely serious attitudes toward performance. This self-restraint style was criticized by Wagner in 1869 in his essay *Über das Dirigieren* as "wooden" which "degraded the works they purported to serve" (Leistra-Jones, 2013, p. 420). Wagner considered their performance style was caused by "fear, repression, and conformity rather than idealistic self-denial," and he regarded their authenticity as "actually a way of concealing a fundamental inability to 'feel' music" (pp. 420–421).

3.2 In the 20th century

In the 20th century, the *Werktreue* ideology started to impose more restrictions on musicians. From the 1920s, objectivity started to be emphasized over performers' subjectivity in interpretation (Stenzl and Zedlacher, 1995). Performers sought faithful interpretations based on musical structures and historical documents (Taruskin, 1995). When Stravinsky composed *Octet for Wind Instruments* in 1923, he requested performers to focus on execution instead of interpretation, arguing that his work would be distorted by performers' interpretation (White, 1985). International competitions were founded, in which faithful performers were awarded as prominent young stars (McCormick, 2015). Recordings became popular and were marketed for their authentic renditions of a piece (Taruskin, 1995). The developments in musicology, competitions, and recordings contributed to establishing the "authentic" interpretation of each piece, which was then shared worldwide.

3.2.1 The criticisms against authentic musicians in the 20th century

Toward the end of the 20th century, criticisms against classical musicians intensified. Critics claimed that musicians lacked individuality in interpretation, thereby monotonizing performances. Under the enforced *Werktreue* ideal, musicians restricted interpretive choices to musical notations (Adorno, 2006), historical facts (Taruskin, 1995), and performance styles (Leech-Wilkinson, 1984). Small (1986) detested concerts where players mechanically reproduced standardized interpretations, and audiences became "skilled at detecting deviations from the written text, either deliberate or accidental, and such deviations incur their severe disapproval" (p. 14). Szigeti (1979) and Adorno (2006) complained that young musicians strived for career advancement rather than artistic development, and musicians assimilated into normative interpretations. Such young musicians' "second-hand interpretation, accomplished through imitation [of the recordings], is bound to lack the conviction of a personalized conception" (Adorno, 2006, p. 24) and "the stamp of authenticity" (Szigeti, 1979, p. 18).

Taruskin (1995) argued that the cause of self-imposed restrictions in interpretation was deeply ingrained in musicians' psychology. He mocked the absence of autonomy in musicians as "a failure of nerve, not to say an infantile dependency" (p. 98).

> "'Responsible performers' are a single type—the modernist type, the type with the punitive *Werktreulich* superego, the type eager to be controlled by the composer and by the composer's surrogates both animate and inanimate, the type Stravinsky liked and the New Grove approves, who does not 'interpret' but 'transmits.' … Such performers are more likely than any others to repress the manifold authenticated historical practices that demand creative departures from the text. … They certainly have no lock on authenticity" (Taruskin, 1995, pp. 46-47).

These critics did not advocate for abandoning the ideology. They were criticizing performers who strictly obeyed notations, relied on historical facts, or imitated others' interpretations out of insecurity, willing to conform rather than pursue individuality in interpretation.

3.3 In the 21st century

In the 21st century, the *Werktreue* ideology has continued to regulate musicians' interpretation. Hunter and Broad (2017) identified three characteristics of the ideology in the current classical music world: "to do justice to (or 'respect') 'the composer's intentions,'" avoidance of "overt intrusion of 'ego' in performance and interpretation," and the score as "the ultimate arbiter of interpretative limits" (pp. 255–257). They investigated conservatory students' views on the *Werktreue* ideology and found that students were struggling to develop original interpretations within the unclear border of authenticity. Students were aware that they were left with several interpretive choices, but they also recognized that making a wrong choice would result in rejections from gatekeepers.

Some musicologists continue to argue for the reconsideration of musicians' attitudes toward the ideology (Silverman, 2007; Cook, 2013; Doğantan-Dack, 2017; Leech-Wilkinson, 2020). However, studies on the *Werktreue* ideal are scarce, implying the ideology is taken for granted by both musicians and researchers.

3.4 Summary

This section reviewed how the ideology of *Werktreue* has underpinned the classical music field since the 19th century. In the 20th century, authentic interpretations were established and became a benchmark for evaluating performances. Musicologists noted that musicians were anxious about their own musical decisions, lacking autonomy in interpretation. They argued that this led performances to be monotonous, but our review in section 2 has demonstrated that a lack of interpretive autonomy also negatively affects musicians themselves, as it impedes SRL and well-being. The next section reviews music psychological studies to explore how classical musicians approach interpretation, and how their approaches are affected by the *Werkreue* ideal. Moreover, we introduce our categorization of interpretive approaches based on an indication of interpretive autonomy or lack thereof.

4 Classical musicians' approaches to interpretation

Rather than musicians' beliefs regarding how the *Werktreue* ideal should be, we focused on musicians' behavior—how musicians approach interpretation. Psychological studies show that conservatory students, teachers, and professionals take different interpretive approaches (e.g., Hallam, 1995; Héroux, 2016, 2018). We examined six contrasting pairs of interpretive approaches; one of each pair reflects a lack of interpretive autonomy and is related to other-regulated learning, whereas the other implies interpretive autonomy and is related to SRL. Furthermore, we demonstrate how the approaches that imply a lack of interpretive autonomy were derived from the *Werktreue* ideal.

4.1 Impersonal vs. personal

Héroux (2018) investigated the process of developing interpretation by observing how nine professional guitarists learned a new modern piece. In her study, six musicians used extra-musical elements, such as creating their own stories and recalling personal memories. However, this personal approach was considered inappropriate by another musician, as it made him think that "he had placed himself above the piece," disrespecting the composer (Héroux, 2016, p. 320). This caused him to refrain from creating narratives and conduct score analysis instead. Such impersonal approach deviated from the ideology of *Werktreue*. For instance, Brahms and Joachim adopted the self-restraint approach to demonstrate their sincerity toward composers (Leistra-Jones, 2013).

While some musicians adopt the impersonal approach based on their beliefs in *Werktreue*, others may adopt the impersonal approach simply because they do not consider interpretation. In Reid's (2001) categorization of students' understanding of learning classical performance, students at the highest level actively developed interpretation and aimed "to communicate personal meaning and interpretation of the music" (p. 34). Similarly, Cantwell and Millard (1994) categorized how deeply students understood scores into five levels; students at the highest level "incorporate [ed] the literal elements of the score, but add [ed] to these an individualised interpretation" (p. 55). By contrast, students at the lower levels in both studies disregarded interpretation and expressed no personal connection to the music they played (Cantwell and Millard, 1994; Reid, 2001).

The personal approach leads to SRL, whereas the impersonal approach leads to other-regulated learning. Students with the impersonal approach in the studies above demonstrated dependence on teachers. Contrastingly, students with the personal approach explored a wide range of expression outside the lessons, seeing music-making as a process of personal development (Cantwell and Millard, 1994; Reid, 2001).

4.2 Explicit notation vs. implicit intention

In the professional world, just playing notes is insufficient; however, playing a note not written on a score may also be criticized (Kingsbury, 1988). Conservatory students felt anxious about changing notes (Hunter and Broad, 2017) or deviating from scores, as it implied "a violation of the composer's wishes" (Wise et al., 2017, p. 158). Nevertheless, how rigidly professional musicians follow scores varies. Observational studies revealed that some professional musicians neglect (Kingsbury, 1988; Héroux, 2018) or change notations (Hultberg, 2002) for expressivity or practicality of performance. In contrast, other musicians adhere to markings on scores rigidly (Hultberg, 2002; Héroux, 2016). Some musicians detest using edited scores because the editors violated the composer's original intention (Kingsbury, 1988). This explicit notation approach originated from the *Werktreue* ideology: "to be true to a work is to be true to its score" (Goehr, 1992, p. 231).

While some musicians follow explicit notations rigidly because they want to (Héroux, 2016; Payne, 2016), other musicians do so because they do not interpret the implicit intention behind the notations. This is observable in the aforementioned study by Cantwell and Millard (1994). Students who did not consider interpretation failed to draw musical meanings from notations and focused on the correct execution of the notes.

These approaches may affect exploration and self-efficacy in practice. Obedience to notations can restrict musicians' interpretive possibilities, whereas a focus on implicit meaning allows musicians to explore wide possibilities (Reid, 2001; Hultberg, 2002; Silverman, 2008; Wise et al., 2017). In contrast, musicians placing a score superior to themselves discarded personal musical ideas if the ideas did not match with the score and exhibited a low level of confidence in their musical decisions (Hultberg, 2002; Héroux, 2016).

4.3 Teacher-centered vs. student-centered

Wise et al. (2017) examined how conservatory students develop interpretation in practice and found that teachers had a significant

impact despite their physical absence in practice rooms. Students regarded teachers as "trustworthy authorities," and they rarely rejected the teacher's ideas, with one student describing it as "betraying the teacher" (p. 158). This implies that while composers' intentions and scores are the ultimate authorities in the classical music field (Hunter and Broad, 2017), for some students, teachers are the most influential authorities, and composers and scores are seen as secondary.

The teacher-centered approach is related to the *Werktreue* ideal. Since the foundation of conservatories in the 19th century, teachers have systematically passed down the *Werktreue* ideal and "faithful" interpretations. This was negatively perceived by some musicians, including Liszt, as it fostered "a dry, pedantic, and conservative approach, hopelessly devoid of inspiration or spontaneity" (Hamilton, 2008, p. 190).

Although some musicians may take the teacher-centered approach because they value the teacher's aesthetic and intellectual ideas, others may do so simply because they do not have their own ideas. This is shown in Reid's (2001) study. Students who did not consider interpretation as part of musical learning relied on their teachers' instructions. The teacher-centered approach may impair SRL, as it prevents students from exploring musical ideas that contradict teachers' ideas in practice (Wise et al., 2017). It also makes students passive in lessons (Reid, 2001).

4.4 Reproductive vs. improvisatory

Hallam (1995) interviewed 22 professional musicians and found varied attitudes toward spontaneity in interpretation. Some musicians rigorously followed one interpretation in a performance that was planned and rehearsed in advance. In contrast, others left some musical choices open to maintain freshness in performance. The former approach can be categorized as reproductive, and the latter as improvisatory.

The reproductive approach is a by-product of the *Werktreue* ideal. Before the emergence of the ideology, improvisation and the improvisatory approach to the performance of pre-composed pieces were regular performance practices (Goehr, 1992; Hamilton, 2008). However, these practices gradually diminished in the 19th century, as people started to criticize improvisation as a "circus act" or "badly composed works" and altering notes in scores as violation of the composer's intent (Goehr, 1992, pp. 233, 234).

Some musicians may adopt the reproductive approach to pursue their ideological stances, whereas others may adopt it simply because they have not grasped the musical meanings of the piece. This is implied in Hallam's (2001) study on musicians' metacognitive skills. She stated that musicians need to "develop accurate internal aural representations of the works" for effective learning and found that professionals had more sophisticated metacognitive skills than novices (p. 38). While the professional musicians were open to taking the improvisatory approach, none of the novice musicians considered the possibility of being spontaneous in performance. This suggests that without capturing musical characters, one cannot flexibly change musical parameters, such as tempo and dynamics, for musical expression.

The improvisatory approach contributes to effective SRL. Dolan et al. (2013, 2018) compared the improvisatory and the reproductive approaches and revealed the former immediately benefitted performers. Musicians felt that the "'let go' mindset" in the improvisatory approach allowed them to take risks in musical choices (Dolan et al., 2018, p. 12), and electroencephalogram (EGG) data supported that the musicians experienced a flow state. Moreover, a musicologist-researcher Dolan rated the improvisatory performances as more expressive and coherent to the score, and the audience rated the improvisatory performances higher than reproduced performances regardless of the difference in their backgrounds of musical training (Dolan et al., 2018). Similarly, classical musicians who regularly incorporate improvisatory elements found that the improvisatory approach released their music performance anxiety, as they were not restricting themselves to only what was rehearsed beforehand (Hill, 2017). In addition, students who had interpretive ideas spontaneously explored different ideas in practice (Reid, 2001).

4.5 Unconscious vs. conscious

In Hallam's (1995) study, some musicians referred to interpretation as an "unconscious and intuitive process," which will "take care of itself" (p. 120). Some musicians "did not consider interpretation at all, often, although not always, for contextual reasons" (p. 127). In contrast, some musicians developed interpretations strategically, adopting an analytic approach.

While Hallam (1995) labeled the former approach as intuitive, this approach may stem from a lack of awareness of interpretation rather than musical intuition. Ignorance of interpretation is common among students as Woody (2000) revealed that 48% of 46 music-major sophomores were unaware of expressivity until they entered high school or college. Interestingly, Hallam (1995) found that fewer musicians with the intuitive approach established personal styles in interpretation compared to musicians with the analytic approach. To differentiate it from the use of musical intuition in interpretation, we labeled the intuitive and analytic approaches as unconscious and conscious, respectively. As previously discussed, students unaware of interpretation exhibited a shallow understanding of scores, dependence on teachers, and limited exploration in practice (Cantwell and Millard, 1994; Reid, 2001; McPherson et al., 2019).

4.6 Separated vs. integrated

Some musicians grasp an overall musical character from sight-reading and never lose interpretive ideas even when they work on segments for technical improvement (Hallam, 1995; Chaffin et al., 2003; Holmes, 2005; Wise et al., 2017; Héroux, 2018). Other musicians neglect interpretation when they focus on technical aspects (Hallam, 1995). We labeled the former approach as an integrated approach. Musicians who adopt this approach consider interpretation regardless of whether they are sight-reading or working on sections. The latter approach was termed separated, and musicians who adopt this approach disregard interpretation when they focus on techniques. Despite how the separated approach deviated from the *Werktreue* ideology is vaguer compared to other approaches, Hunter (2005) notes that since the end of the 18th century, performance treaties started to focus exclusively on

techniques, separating interpretive skills from instrumental techniques explicitly.

The integrated approach indicates the active development of interpretation, whereas the separated approach may indicate a lack of the development of interpretation. In the above-mentioned study, Hallam (1995) found that musicians who grasped the overall picture from the beginning of learning a piece attained their personal style of interpretation more than those who did not. Reid (2001) demonstrated that students who were unaware of interpretation failed to comprehend the overview of the music, perceiving music as a series of disconnected technical segments that can be worked separately. In contrast, students who aimed to communicate interpretation to audiences sought musical meaning from the sight-reading phase, and they worked on sections to integrate them into one piece (Reid, 2001).

The integrated approach benefits one in practice. Wise et al. (2017) observed a horn student continuously had interpretive ideas from the initial sight-reading and honed skills effectively to communicate the intended interpretation. This student regarded practice as a process of integrating techniques and expression. Similarly, Holmes (2005) interviewed two expert string musicians and found that their technical choices, such as fingerings and bowings, were guided by their interpretation. The musicians also avoided practicing on segments excessively to maintain the whole picture of the piece. In contrast, music students with the separated approach practiced techniques without a musical aim, resulting in ineffective practice (Reid, 2001; McPherson et al., 2019).

4.7 Summary

We reviewed six pairs of interpretive approaches found in music psychological research. We explored how one approach may be adopted by musicians with a lack of interpretive autonomy, resulting in other-regulated learning, whereas the other approach indicates interpretive autonomy in musicians, helping musicians initiate SRL. We categorized the former approaches as other-oriented and the latter as self-oriented interpretive approaches (Table 1). Yet how musicians' interpretive autonomy is promoted or hindered remains unexplored. To address this issue, we will present a model of *Wekrtreue* internalization in the next section.

5 The model of *Werktreue* internalization

The literature review revealed several research gaps. First, students and professional musicians have been criticized for a lack of autonomy in interpretation; however, no consensus exists on the definition of interpretive autonomy. Second, although interpretive autonomy is likely to be affected by how musicians internalize the ideology of *Werktreue*, no systematized knowledge of the mechanisms that promote or hinder musicians' interpretive autonomy is available. Finally, although studies imply that interpretive autonomy plays a significant role in SRL and well-being, these relationships are unclear. Thus, the definition, causes, and effects of interpretive autonomy on musicians' learning and well-being remain unclarified. To address

TABLE 1 Other- and self-oriented interpretive approaches and examples of related learning behavior.

Other-oriented interpretive approaches			Self-oriented interpretive approaches		
Approaches	Description	Examples of learning behavior	Approaches	Description	Examples of learning behavior
Impersonal	Performers restrain from imposing personal views	Failing to personally connect with music	Personal	Performers bring their personality and subjectivity into interpretations	Considering musical learning as personal development
Explicit notation	Performers follow explicit notations on a score	Failing to relate notations to musical meaning	Implicit intention	Performers neglect or change notations on a score, valuing implicit expression	Understanding musical meanings behind notations
Teacher-centered	Performers expect teachers to pass on interpretations to students	Accepting teacher's interpretations passively	Student-centered	Performers expect students to develop their own interpretation	Evaluating teachers' interpretation critically
Reproductive	Performers reproduce interpretations as they were rehearsed in performance	Being inflexible on stage	Improvisatory	Performers spontaneously bring new interpretations into performance	Being flexible on stage
Unconscious	Performers unconsciously develop interpretations	Lacking awareness of expressivity	Conscious	Performers consciously develop interpretations	Intentionally exploring expressivity
Separated	Performers disregard interpretations when they work on techniques	Working on segments technically without having musical aims	Integrated	Performers continually consider interpretations	Grasping an overview initially and working on techniques to express intended interpretations

these gaps, we propose a model of *Werktreue* internalization based on self-determination theory (Deci and Ryan, 2000).

5.1 Self-determination theory

Self-determination theory (SDT) has been widely applied in the fields of academics, nursing care, sports, and workplaces worldwide (Ryan and Deci, 2017). Likewise, it has been applied in the field of music (see Evans, 2015 for a conceptual overview). For instance, researchers have applied SDT to investigate music students' motivation for study (Evans et al., 2013; Evans and Bonneville-Roussy, 2016; Miksza et al., 2021), a professional musician's motivation for practice (López-Íñiguez and McPherson, 2020), and the degree of teachers' autonomy-support in lessons (Kupers et al., 2013; Bonneville-Roussy et al., 2020).

SDT assumes that humans are inherently oriented toward growth. This is yet conditioned by support for basic psychological needs for autonomy, competence, and relatedness. They are universal needs defined by Ryan and Deci (2017) as "nutrients that are essential for growth, integrity, and well-being" (p. 10). People engage in growth-oriented activities "optimally only to the extent that the nutriments are immediately present or, alternatively, to the extent that the individual has sufficient inner resources to find or construct the necessary nourishment" (Deci and Ryan, 2000, p. 229).

Organismic integration theory, a sub-theory of SDT, explains the mechanism of internalization of external values. The theory posits that people are inclined to internalize social regulations into personal values to enact socially expected behavior without feeling constrained; internalization allows them to assimilate themselves into the wider society successfully.

However, optimal internalization requires the fulfillment of three basic psychological needs. The need for competence is fulfilled when an individual perceives "the ability to understand or grasp the meaning or rationale behind the regulation and an ability to enact it" (Deci and Ryan, 2000, p. 238). The need for relatedness is satisfied through "feelings of relatedness to socializing others" (p. 238). Finally, a complete internalization requires support for the need for autonomy to "freely process and endorse transmitted values and regulations (and to modify or transform them when necessary)" (p. 238).

Organismic integration theory identifies four types of regulations, which are categorized into controlled and autonomous regulations depending on the degree of autonomy. Controlled regulations are caused when people's needs are thwarted, for example, in excessively controlling, overchallenging, and rejecting environments. In controlled regulations, people are controlled by external or internal contingencies, such as fame and a sense of guilt. Thus, their behavior is not self-determined, and "regulations and values may either remain external or be only partially internalized to form introjects or unintegrated identifications" (Deci and Ryan, 2000, p. 236). Controlled regulations lead to poor performance and ill-being since the basic psychological needs required for optimal well-being are thwarted. Therefore, controlled regulations thwart their psychological needs further, trapping them in a vicious circle.

Conversely, autonomous regulations are facilitated when people's needs are satisfied in the process of internalization. In autonomous regulations, "people will identify with the importance of social regulations, assimilate them into their integrated sense of self, and thus fully accept them as their own" (Deci and Ryan, 2000, p. 236). Since the value is integrated into personal values and identity, the behavior is enacted autonomously. Autonomous regulations then lead to a high quality of performance and enhanced well-being (Deci and Ryan, 2000). This then satisfies the needs, promoting autonomous regulations further. In the subsequent model, we adopted the classification of controlled and autonomous to reflect different internalizations of the *Werktreue* ideal among classical musicians.

5.2 The model of *Werktreue* internalization

5.2.1 Definition of interpretive autonomy

According to Deci and Ryan (2000), "basic needs play an essential role in cultural transmission, helping to account for how memes are assimilated and maintained in and across diverse human groups" (p. 230). In classical music, the ideology of *Werktreue* is a value that has been transmitted since the end of the 18th century. Based on SDT, a model of *Werktreue* internalization categorizes two qualitatively different internalizations of the *Werktreue* ideal: controlled and autonomous. In controlled internalization, musicians' interpretive autonomy is hindered, whereas in autonomous internalization, musicians' interpretive autonomy is promoted.

When the psychological needs are thwarted in interpretation, the *Werktreue* ideology remains external to the self. In interpretation, musicians are controlled by a sense of incompetence, pressure, and fear of rejection. Thus, their self-esteem is contingent on how others evaluate their interpretation, and they are highly self-critical of their interpretation. This represents the controlled *Werktreue* internalization that hinders musicians' interpretive autonomy.

In contrast, when the psychological needs are fulfilled in interpretation, the *Werktreue* ideology is fully internalized and integrated with the self. In contrast to controlled interpreters, musicians are freed from concerns of incompetence, pressure, and rejection, and they make interpretive choices based on personal interests, feelings, and intellectual curiosity. This represents the autonomous *Werktreue* internalization that promotes musicians' interpretive autonomy (see Figure 1).

The model of *Werktreue* internalization does not define the *Werktreue* ideology or interpretation. Instead, the model identifies interpretive autonomy based on whether the ideology is alienated from or integrated with a musician's self regardless of the musician's definition of faithful interpretation. Performers with the autonomous *Werktreue* internalization are self-determined, and their faithful interpretation is connected with the true self. Therefore, they pursue their own ideological stance freely based on their interests and personalities. In contrast, performers with controlled internalization are ego-involved, and they are controlled by external or internalized contingent rewards and punishments when they interpret a piece. Therefore, they pursue objective faithfulness or their subjectivity out of anxiety.

By defining interpretive autonomy without defining the *Werktreue* ideal, the proposed model solves a dualism seen in previous studies. Researchers have shown categorizations based on whether musicians prioritized individual freedom or the composer's intention over the other (Lindström et al., 2003; Laukka, 2004; Silverman, 2007; Héroux,

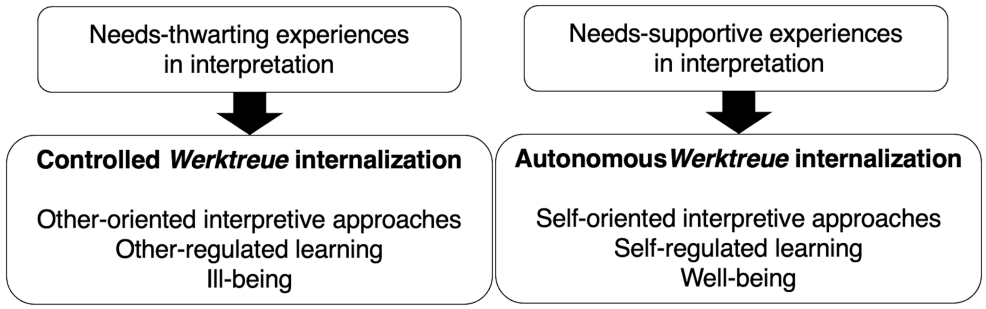

FIGURE 1
The model of *Werktreue* internalization.

2018). Although this categorization is useful for differentiating varied definitions and beliefs, it does not help us identify interpretive autonomy as we discussed at the beginning of the article. Rather than pitting one against the other, the model of *Werktreue* internalization is built on an assumption that musicians modify or change the definition of the ideology throughout their lives as they interact with social environments and pass through different stages of their personal development.

5.2.2 Factors that promote or hinder interpretive autonomy

The model explains the mechanisms that promote or hinder interpretive autonomy. If musicians understand the rationale behind the ideology (the need for competence), sense the freedom to modify the ideology (the need for autonomy), and feel connected with others through the ideology (the need for relatedness), their psychological needs are fulfilled. This facilitates the autonomous *Werktreue* internalization, and their interpretive autonomy is promoted. On the other hand, if musicians do not grasp the meaning of the ideology (the need for competence), perceive no freedom to modify the ideology (the need for autonomy), and feel isolated by the ideology (the need for relatedness), their needs are thwarted. This results in the controlled *Werktreue* internalization, and their interpretive autonomy is hindered.

Factors that are found to promote or hinder students' interpretive autonomy in lessons, practice, and performance are reviewed below. The model accounts for the psychological mechanisms of how the factors promote or hinder students' interpretive autonomy.

5.2.2.1 Needs-thwarting lessons

Karlsson and Juslin (2008) analyzed eight hours of video recordings of private lessons involving 12 students and five teachers and found that the teachers' talk dominated lessons with little demonstration of the instrument. The instrumental teachers gave technical instructions to reproduce notations and rarely mentioned interpretation or expression. Students' playing was interrupted constantly by outcome feedback, such as "good" or "bad," without any further explanation. Another study found that a conservatory teacher made interpretive decisions based on how "everyone" plays in lesson (Burwell, 2021, p. 470). Burwell (2021) cautioned that this reinforced social norms in interpretation and the authority of the teacher who knew the norms. In other cases, teachers ignored (Rostvall and West, 2003) or explicitly rejected students' original interpretive ideas (Persson, 1996; Silverman, 2008; Wagner, 2015).

When interpretation or expression is addressed, instrumental teachers employ strategies such as modeling, use of metaphors, and provoking felt emotions (Woody, 2000; Lindström et al., 2003; Laukka, 2004). While these strategies can be effective, they also have some flaws. Modeling may lead students to merely copy (Laukka, 2004). Other verbal instructions can be ambiguous, leaving students confused and frustrated (Woody, 2000; Schippers, 2006; Karlsson and Juslin, 2008).

If students perceive that they have no interpretive choices, the need for autonomy is thwarted. If students feel that their original ideas are rejected by teachers, or students cannot understand teachers' instructions, the need for competence is thwarted. These needs-thwarting experiences lead students to be internally controlled in interpretation.

5.2.2.2 Needs-thwarting practice

At the beginning of learning, some parents accompany their children in practice. While appropriate parental support promotes children's musical growth (Davidson et al., 1996; McPherson and Davidson, 2002), excessive parental involvement may hinder children's interpretive autonomy. Wagner (2015) interviewed parents of students in soloist violin classes and revealed that the parents attended lessons, took notes or videos, and assisted their children in practice. Some children were home-schooled, and their practice was supervised by their parents who voluntarily became their teachers' assistants. Some of the children then tried to avoid practicing by damaging their violins or leaving the instruments in school. Similarly, investigating 337 teacher-pupil-parent triads, Creech (2009) categorized interaction styles into six types; in one of the types, a "solo leader" type, a dominative teacher expected parents to assist their children's practice to meet the teacher's expectations. Although parents of this type gave high behavioral, cognitive, and personal support, the children rated lower scores in enjoyment of music, personal satisfaction, motivation, self-efficacy, and self-esteem than children whose parents actively negotiated with the teacher regarding the expectations, not to overtire the child (Creech, 2009, 2010).

If practice is supervised by parents who insist on children following teachers' instructions, children have no space to explore interpretive possibilities. This thwarts the need for autonomy as they cannot choose how to play a piece.

5.2.2.3 Needs-thwarting performance

Students often perform in exams, competitions, and auditions, in which their performances are evaluated normatively. In particular, competitions are greatly valued, as they may boost students' careers (McCormick, 2015). To win in a competition, however, students need to appeal to judges by demonstrating their originality *within* accepted performance styles. McCormick (2015) investigated international competitions through observation and interviews and demonstrated that although juries emphasized the significance of individuality in interviews, they also detested competitors whose interpretations deviated from stylistic conventions or scores, regarding them as uneducated or disrespectful musicians. In addition, judges differed in their understanding of what authentic interpretation is. Therefore, unconventional interpretation often resulted in split juries, and those musicians who conveyed highly original interpretations were eliminated early due to the voting or scoring system.

Pressures to conform to standardized interpretation may thwart the need for autonomy. Moreover, rejection from juries thwarts the need for competence and relatedness, making musicians psychologically controlled interpreters.

5.2.2.4 Needs-supportive lessons, practice, and performance

Several factors are found to promote interpretive autonomy. Open questions and discussions of musical characters are suggested to be effective for conservatory students (Hultberg, 2002; Young et al., 2003; Burwell, 2005; Nerland, 2007). Notably, this was effective for pre-teens and teenagers (Meissner, 2017; Meissner and Timmers, 2019, 2020; Trapkus, 2020; Meissner et al., 2021). After being aware of musical expression, children showed intrinsic motivation to learn to "make pieces 'their own,'" even when the pieces were technically challenging (Meissner and Timmers, 2020, p. 14). If students perceive that they have capability and choices in musical interpretation through open-ended questions and discussions, they autonomously internalize the *Werktreue* ideal, and their interpretive autonomy is promoted.

Exploration in practice may also fulfill the needs. McPherson and McCormick (1999) found that children who engaged in both formal and informal practice reported higher enjoyment than other children. In addition, informal practice was engaged more by high-achieving students than low-achieving students (Sloboda et al., 1996). Playful informal practice fulfills the need for autonomy, as students can freely try different interpretive ideas without pressure. Furthermore, improvisation (Hill, 2017) and listening to different interpretations expose students to diverse interpretive choices (Silverman, 2008; Volioti and Williamon, 2017, 2021), satisfying the need for autonomy. This suggests that providing a secure place where students can explore interpretation by freely manipulating performance cues, such as dynamics and tempo, is effective in supporting the development of interpretive autonomy.

Finally, performance experiences in non-traditional venues, such as hospitals and nursing homes, with no contingent rewards and punishments for musical decisions may support the psychological needs. Nine conservatory students participated in a 10-week program where they helped group music-making at nursing homes in Switzerland by playing and singing a wide variety of music, and this had a positive impact on the students (Paolantonio et al., 2022). The students received immediate reactions from the participants as they played music, and the students were moved by how intensely the older people appreciated music. Through the program, some students realized that they were trapped in a narrow mindset and standards, and they reconsidered the personal meaning of making music (Paolantonio et al., 2022). Also, Perkins (2013) found that a student appreciated performance opportunities outside a conservatory as her performance opportunities were limited within the conservatory due to the rigid hierarchies. In those opportunities outside the school, she could "make mistakes and learn," unlike performances in school (p. 206). Considering students are pressured to make appropriate interpretative decisions within conservatories (Hunter and Broad, 2017) and competitions (McCormick, 2015), these opportunities outside the classical music field offer a valuable space for students. Without being pressured to succeed, students can explore interpretive possibilities through interactions with a wider audience. If students perceive that they can choose and convey their personal interpretation and connect with others through performance, these performance experiences promote students' interpretive autonomy.

5.2.3 The effects of internalization types

In addition, the proposed model accounts for the effects of interpretive autonomy on musicians' learning and well-being.

5.2.3.1 Interpretive approaches

In the previous section, we introduced six pairs of different interpretive approaches and classified them into two categories: other-oriented and self-oriented. Other-oriented interpretive approaches deviated from the *Werktreue* ideal but may be adopted by musicians with a lack of interpretive autonomy. Conversely, self-oriented interpretive approaches are taken by musicians with interpretive autonomy.

Other-oriented interpretive approaches are likely to be adopted by musicians with the controlled *Werktreue* internalization. This is because other-oriented interpretive approaches do not require competence, autonomy, and relatedness to be employed. For instance, musicians who want to avoid punishment obey explicit notation or their teachers' interpretation to avoid being accused of unfaithfulness. In contrast, self-oriented interpretive approaches are adopted by musicians with the autonomous *Werktreue* internalization, as these approaches require a sense of autonomy, competence, and relatedness to be employed. For instance, the improvisatory approach, in which musicians make musical decisions spontaneously, requires autonomy and competence, as musicians need to make musical choices instantly.

Musicians with the autonomous *Werktreue* internalization can also employ other-oriented interpretive approaches purposefully to pursue their *Werktreue* ideals. For instance, in Payne's (2016) case study, a musician explicitly stated that he intended to express the work itself, not himself. He adhered to the score strictly but also developed a highly individualized interpretation. This "paradox" (p. 339) is dissolved if he has internalized the ideology autonomously and freely chosen to follow the text to reveal the composer's intention. These musicians, wishing to let the music speak for itself, would employ both self-oriented and other-oriented interpretive approaches.

Musicians with the controlled *Werktreue* internalization face difficulty in employing self-oriented interpretive approaches, as these approaches require a sense of competence, autonomy, and relatedness in interpretation to be employed. For example, a student anxious about the appropriateness of interpretation would depend on teachers' interpretive ideas and might not explore fresh ideas on stage, taking

the teacher-centered and the reproductive approaches. Therefore, musicians with controlled internalization employ only other-oriented interpretive approaches.

5.2.3.2 Self-regulated learning and well-being

In the first section, we discussed how interpretative autonomy contributes to SRL, and how SRL leads to enhanced well-being. Conversely, a lack of interpretive autonomy results in other-regulated learning behavior and ill-being. As students with more autonomous regulations demonstrate better learning behavior and well-being (Deci and Ryan, 2000), the model of *Werktreue* internalization integrates the effects of internalizations on SRL and well-being compatibly.

5.2.3.3 Musical identity

SDT considers the effects of types of internalizations on identity. With autonomous regulations, the external value is fully integrated with one's sense of self, whereas with controlled regulations, the value remains alienated from the self; thus, the identity is disintegrated in the activity (Deci and Ryan, 2000). This implies that musicians with autonomous internalization, who perceive no constraints in expressing original interpretation, acquire an integrated identity as a classical musician. In contrast, musicians with controlled internalization, who feel restricted in expressing personal interpretations, face difficulty embracing an identity as a classical musician.

5.2.4 Other key points

5.2.4.1 Interpretive autonomy as a state

SDT posits that individuals can "internalize a new behavioral regulation at any point … depending on both prior experiences and current situational factors" (Ryan and Deci, 2000, p. 73). Thus, interpretative autonomy can be considered context-specific; while earlier experience does affect later development, types of internalizations shift as the degree of needs satisfaction changes. This means that interpretive autonomy hindered by needs-thwarting environments can be promoted if musicians move to more needs-supportive environments. Silverman (2008) reported a case study of a Russian pianist who went through needs-thwarting experiences but subsequently regained interpretive autonomy. The pianist studied with an authoritarian teacher who allowed no interpretive freedom. The teacher forced him to reproduce the teacher's own interpretations and techniques:

> "[The teacher] damaged, for me, all composers I played. He gave me 'schooling'—a discipline of ear and fingers, no question about that. But speaking stylistically, about being authentic, he completely distorted everything that my intuition, if left alone, would have understood. If he did not intervene in such a way, I would have instinctively found my way to different styles." (Silverman, 2008, p. 263).

In the face of adversity, the pianist avoided needs-thwarting experiences by refusing to enter competitions and choosing to perform pieces that the teacher could not teach. This allowed him to focus on the development of personal interpretation. The pianist demonstrated high interpretive autonomy, adopting self-oriented interpretive approaches introduced in the previous section. However, the pianist required more than a decade to gain confidence and find his artistic voice in interpretation.

5.2.4.2 Types of internalizations and teaching style

Persson (1996) observed a teacher rejecting students' original musical ideas in lessons and concluded that the authoritarian teacher aimed to convey "artistic life" to his students, in which "commitment is crucial—commitment to others' expectations, prompted by established and inflexible traditions, rather than one's own artistic convictions" (p. 41). The teacher believed that no opportunities existed for musicians to develop personal interpretations in the professional world and felt responsible to teach that in his lessons. Similarly, Hultberg (2002) suggested that teaching styles are affected by teachers' own approaches to interpretation. Teachers adhering to explicit markings do not allow students to develop individual interpretations that deviate from a score. In contrast, teachers who value implicit meanings and take the personal approach to interpretation welcome students' original ideas, and they engage in discussion with students as "co-creative interpreters in a communication with the composer" (p. 195). This implies that teachers internalize the *Werktreue* ideal differently depending on their psychological experiences as students and professional musicians in the classical music field. This affects their teaching styles, possibly transmitting their types of internalizations to their students.

5.2.4.3 The dualistic model of passion

Although we adopted SDT, another similar theory exits, that is, the dualistic model of passion (Vallerand et al., 2003; Vallerand, 2010). The dualistic model of passion is based on SDT and considers only internalizations of activities that are related to one's identity. An autonomous internalization of the activity leads to harmonious passion, whereas a controlled internalization of the activity leads to obsessive passion (Vallerand et al., 2003; Vallerand, 2010). Studies among expert musicians confirmed that harmonious passion was associated with mastery goals and well-being, whereas obsessive passion was correlated with both mastery goals and performance goals and negatively correlated with well-being (Bonneville-Roussy et al., 2011; Bonneville-Roussy and Vallerand, 2020).

Since musicians' identity is often connected with music, the dualistic model of passion is insightful. However, we applied SDT to include learners whose identity is not related to music, such as children and beginners. McPherson (2005) highlights the significance of having interpretive ideas from the beginning of instrumental learning; the study revealed that mental strategies that included having musical ideas predicted children's achievements in sight-reading, playing from memory, and playing by ear in the first three years of learning. However, the ability to perform rehearsed music was explained little by the use of mental strategies (McPherson, 2005). This implies that a lack of interpretive autonomy may be unnoticed as long as students can reproduce what was rehearsed beforehand especially in the early years of learning.

6 Discussion and conclusion

The model of *Werktreue* internalization identifies the definition, causes, and effects of interpretive autonomy. Musicians who perceive that they are capable of interpretation, have musical choices, and are connected with others through faithful interpretation, autonomously internalize the ideology of *Werktreue*. In autonomous internalization, musicians are fully self-determined in interpretation, thus they employ self-oriented interpretive approaches. This supports SRL and positive well-being, and their musical identity is integrated.

Conversely, musicians who perceive that they are incapable, have no musical choices, and are isolated through faithful interpretation, internalize the ideology in a controlled form. In controlled internalization, musicians' self-worth is contingent on interpretation; thus, they use other-oriented interpretive approaches. This results in other-regulated learning and poor well-being, and their musical identity is disintegrated.

The model of *Werktreue* internalization contributes to both academia and educational practice by addressing three knowledge gaps. First, it defines interpretive autonomy based on types of internalizations without defining interpretation or the *Werktreue* ideal. Second, it demonstrates the importance of interpretive autonomy in SRL and well-being explicitly. Third, the model provides plausible explanations of the mechanisms that facilitate or inhibit interpretive autonomy in learning.

Based on the model, researchers and educators can assess musicians' degree of interpretive autonomy by observing their interpretive approaches, learning behavior, and well-being. Moreover, they can promote interpretive autonomy by fulfilling the basic psychological needs in interpretation. They could empower learners with interpretive knowledge and skills, provide musical choices, and offer performance opportunities where learners can connect with the audience through personal interpretation. For specific teaching strategies to promote expressivity or interpretation in lessons, frameworks (Hultberg, 2002; Meissner, 2021) and a case study on successful teachers (Nerland, 2007) are useful. The model of *Werktreue* internalization aligns with these studies, accounting for the effectiveness of the teaching methods from the psychological perspective of learners. Yet a limitation of this study is that the model is built based on the literature. Further empirical studies are warranted to test the plausibility of the model.

We noted that authoritarian teaching, excessive parental control in practice, and competitions have risks of hindering interpretive autonomy. However, if they support students' basic psychological needs in interpretation, they may be effective for students' growth. It is important to keep in mind that needs fulfillment is subjective, and learning experiences, such as competitions or authoritarian teaching, may be perceived as needs-thwarting for one while it may be perceived as needs-supportive for another student.

Nevertheless, this implies high risks of interpretive autonomy being impeded for musicians who are professionally educated from the early years of life. Students aiming to become concert soloists often go through authoritarian teaching, excessive parental control in practice, and rejections in competitions (Wagner, 2015). If these learning experiences thwart their basic psychological needs, their interpretive autonomy is hindered, potentially damaging their long-term artistic development in the early years of their music study. Even after they acquired high techniques, these musicians would be regulated by normative "authentic" interpretations. Being anxious about their interpretations, they would display other-regulated learning behavior, such as vulnerability against feedback. This endangers their physical and psychological health. Nevertheless, because performing is deeply entrenched in the identity, they would persist in performance careers while being psychologically controlled in expressing interpretation.

Interpretation is at the heart of classical musicians' learning and well-being. It is a process in which musicians cultivate intellect and empathy to find their own voice in a piece that they want to share with others. This study does not reject the *Werktreue* ideal or normative interpretations; the *Werktreue* ideal has encouraged musicians to make the most of music, and normative interpretations have become a standard because many people are moved and convinced by the interpretation. However, depending on how music students perceive and internalize the *Werktreue* ideal in learning, the ideology may become a burden, making musicians restrict their expressive freedom and strive for conformity. To support musicians' life-long musical and human development, it is imperative to consider how we can provide students with psychological support so that they can explore their artistic voice from the beginning of their study.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

MF: Conceptualization, Writing – original draft, Writing – review & editing. YU: Writing – review & editing, Funding acquisition, Supervision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Flow and performance: a quantitative study of elicitation modeling in a piano performance perspective

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Introduction: Flow, defined as a heightened state of consciousness characterized by intense concentration during an activity, is influenced primarily by the perceived challenge and the dynamic equilibrium of skills. This investigation focuses on the patterns of flow state attainment and its elicitation mechanisms within the context of piano performance among Chinese music college students.

Methods: Our study establishes a framework for accessing flow, utilizing quantitative data from music ontology to gauge the level of challenge and the level of music acquisition to assess skills. Additionally, we integrate external factors such as music culture heterogeneity and demographic variables to elucidate the causes and moderating effects of flow on piano performance.

Results: The findings reveal a positive correlation between flow and performance, with the model of challenge and skill induction partially explaining these results. Notably, melodic Shannon Entropy emerges as a potential indicator of challenge, suggesting its relevance in future studies on flow.

Discussion: This research provides multidimensional insights into the interplay between performance and flow in piano performance, guiding future investigations to explore the musical quantitative perspective more deeply.

KEYWORDS

flow experience, dynamic balance of challenges and skills, performance, Shannon entropy, quantification of musical features

1 Introduction

1.1 Flow in piano performance

Flow, a concept extensively explored across various disciplines such as sports (Kim and Ko, 2019; Goddard et al., 2023), dance (Łucznik and May, 2021), games (Pham et al., 2022), and chess (Tozman et al., 2017), has garnered multidisciplinary attention. In the field of music, particularly in the realm of music performance (O'Neill, 1999; Spahn et al., 2021; Antonini Philippe et al., 2022), music listening (Diaz, 2013; Karmonik et al., 2016; Loepthien and Leipold, 2022), music composition (MacDonald et al., 2006; Chirico et al., 2015), and music education (Custodero, 2002; Bernard, 2009), exhibit a pronounced inclination toward flow. Notably, musical performance situations are the most conducive to flow experiences. Moral-Bofill et al. (2023) contends that classical musicians, due to their academic and structured learning

environments, frequently experience heightened states of flow. The suggestion is made that musical performance or recital serves as an effective activity for inducing flow experiences. Moreover, music students, alongside elite classical musicians, demonstrate a proclivity for experiencing flow. Empirical investigations indicate divergent trends and patterns of flow scores among student musicians compared to their professional and amateur counterparts, necessitating targeted independent research. In the realm of musical performance, theoretical advancements in understanding flow, particularly in piano performance activities, are still evolving (De Manzano et al., 2010). Previous studies have explored flow across various music performance categories, including violin, piano, woodwinds, and voice. Surprisingly, results revealed that the piano had a significantly lower flow score (De Manzano et al., 2010). However, Bakker (2005) contradicts this, asserting that piano is the most flow-inducing musical activity. This discrepancy prompted the focus of our study on the distinct research direction of piano performance, aiming to investigate the patterns of flow state attainment among music undergraduates in piano performance situations.

Moreover, our study aims to elucidate the mechanisms triggering this phenomenon. Within the context of music performance, an individual's skills inherently contribute to predicting and influencing flow, while external challenges exert a relative impact on the flow process. Previous research has attempted to observe and analyze flow by predefining skills and challenges, considering them as indicators of the flow experience (Haumann et al., 2018). Fullagar et al. (2013) specifically investigated the state of flow among music major students by examining the interplay between the perceived challenge level of a musical piece and the skills required for its performance. Currently, this variable remains the most prevalent and crucial premise influencing the flow experience. However, its context specificity and susceptibility to the interaction of other unidentified factors underscore the need for further in-depth exploration in subsequent research.

In explicating the attainment of a flow state within the context of piano performance, it is imperative to consider numerous external factors alongside the aforementioned internal ones. Among these, music-related factors emerge prominently. This study focuses on specific aspects of interest, namely (1) practice duration, where musicians undergoing prolonged and high-quality practice sessions are posited to be more predisposed to entering a state of flow (Tan et al., 2021), with practice duration identified as a predictor of flow in this population (Marin and Bhattacharya, 2013). Waite and Diaz (2012) observed a similar phenomenon in the population of undergraduate music students. The explanation for this phenomenon is closely tied to an individual's perceived equilibrium between challenge and skill states, where the difficulty of challenges presented by various musical materials dynamically influences an individual's skill. (2) Musical characteristics: Some studies employ designated or specific musical compositions to predict various conditions under which flow occurs, indicating differences in flow associated with different musical composers. A recent study provided evidence from a neurological perspective, in which HRV (heart rate variability) was collected from 22 conservatory piano certified pianists during the performance of 2 assigned pieces and 1 self-selected piece, and performer heart rate data were taken using a polar watch for 5 min before, during, and 5 min after the performance, and flow state was measured. The results showed that for professionally assessed piano performers, they produced the highest level of flow experience during the performance of Bach's works (Jha et al., 2022); (3) Musical styles: Jazz/contemporary and traditional musicians exhibit higher flow state scores compared to classical traditional musicians. Piano subjects report experiencing increased flow when playing certain musical styles, with the Romantic style identified as particularly likely to induce flow (Marin and Bhattacharya, 2013). (4) Type of performance: The category of instrument played leads to variations in the flow experience. Cohen and Bodner (2021) found a positive correlation in the flow experience of professional orchestral musicians, though acknowledging a lack of validation studies and the potential for spurious effects. (5) Musical cultural heterogeneity: Exploring the intersection of musical correlates with cultural identity offers potential evidence for musical cultural heterogeneity in flow states. Musical culture encompasses the informal acquisition of musical knowledge in diverse cultural environments (Wang et al., 2024), significantly influencing aspects of music perception, such as melodic expectations (Demorest et al., 2016). China-specific cultural heterogeneity similarly affects the cross-cultural nature of the flow experience (Zhou and Luo, 2012). However, the majority of publications in the field hailed from Western cultural contexts, such as the United States (number of publications is 30), the United Kingdom (12), and Australia (10), with limited attention directed toward mobility research in Eastern cultures, especially within Chinese cultural contexts.

Another noteworthy external consideration that has garnered attention pertains to demographic factors, encompassing variables such as gender, age, and other demographics. Nevertheless, the exploration of these factors in relation to flow in the realm of music has yielded inconclusive results. While some studies propose that certain demographic factors are irrelevant to musical flow (Sinnamon et al., 2012; Marin and Bhattacharya, 2013; Wrigley and Emmerson, 2013), others validate the relevance of certain factors to the experience of flow. Notably, age has been identified as a significant predictor of flow, with recent research establishing a high correlation between a musician's age and years of performing experience. Conversely, findings regarding gender-based differences in flow experiences have not demonstrated consistency across studies (Moral-Bofill et al., 2019). Consequently, the inclusion of pertinent demographic factors was deemed imperative in this study (see Barthelmäs and Keller, 2021).

Previous research in this domain has employed psychophysiological metrics for correlation studies, utilizing measures such as questionnaires (Araújo and Hein, 2019; Kim and Ko, 2019), EEG data (Katahira et al., 2018; Tan et al., 2023), and heart rate variability data (Jha et al., 2022). The concept of the 'flow state' in music entails a technique for performing musical material inseparable from the music itself. However, the dynamics of the flow experience in piano performance have not been characterized in terms of their relation to musical ontology in several exploratory cross-sectional studies. Musical ontological characteristics encompass parameters such as technique (the level of technical performance of the musical material), rhythm (the alternation of sounds and pauses), sound quality (the quality characteristics of the musical material), and musicality (musicianship). To comprehensively interpret the musical experience, considerations extend beyond these four aspects, encompassing information about the instrument being played, the acoustics of the music, and the effects produced by the musical sound. Zielke et al. (2023) conducted two correlation studies analyzing

specific musical characteristics corresponding to flow by prompting musicians to recall information about the timing of flow initiation and interruption during performance. Results revealed correlations between flow-inducing and interrupting timing, pitch, and timbral dimensions. Subsequent in-depth analyses in their continuation study focused on the scores and melodies played by participants, uncovering common features of flow states such as gradual movement, repetition, and the absence of detached movement in melodies. These findings tentatively explicate the interconnectedness of flow and musical ontological features, setting the stage for our exploration of the correlation between piano performance and flow, particularly in terms of extracting and quantifying musical ontological features.

In the context of this study, musical ontological characteristics will serve as a metric for assessing the challenge level. Musicians face the imperative task of selecting repertoire that aligns with their skill proficiency. A discrepancy between challenge and skill goals can lead to manifestations of anxiety and boredom. Consequently, participants are encouraged to choose repertoire that not only aligns with their skill level but also presents a genuine challenge (Kirchner, 2011). The Shannon Entropy algorithm emerges as a promising tool for extracting information about musical complexity and quantifying the challenge level (Gündüz, 2023). This algorithm facilitates the derivation of musical information embedded in a piano performance, along with its complexity level, thereby enabling its integration into a quantitative analysis within a challenge and skill balance model.

Therefore, we pose the initial research question: What patterns and mechanisms lead to a state of flow in Chinese piano students who are in a performance situation? To address this question, we will construct a framework for accessing the flow state based on the challenge level represented by quantitative data from music ontology and the skill level represented by the level of music acquisition. Furthermore, we aim to elucidate the underlying causes by considering external factors such as music culture heterogeneity and demographic variables (music culture heterogeneity, demographic factors, etc.).

1.2 The correlation between flow and performance in the piano performance perspective

Flow, characterized as an optimal experiential state, serves various social functions, notably contributing to performance enhancement (De Manzano et al., 2010). In the realm of music performance, flow emerges as a theoretical framework intrinsic to learning behavior, enhancing an individual's capacity to confront challenges and accelerate skill acquisition as musical education advances with increased practice and deliberate engagement (Palomäki et al., 2021). Within a flow experience, piano performers attain an optimal state, resulting in peak performance levels (Palomäki et al., 2021). The intermittent experience of flow motivates music learners to sustain and advance their professional skills, with research indicating a positive correlation between flow and achievement among young music students (O'Neill, 1999), as well as successful performances reported by music students and professionals (Clark et al., 2014), with the challenge and skill balance profile explaining this phenomenon. Musicians aspire to maintain a state of flow in various contexts, including performance, competitions, or exams. Fullagar et al. (2013) explored the relationship between student musicians' flow experiences and music performance anxiety within a challenge and skills framework, utilizing the complexity of music performance as an indicator of challenge in relation to the perceived skills required. This study provides a referenceable research framework for our focus on the relationship between flow and performance.

The choice of context for investigating performance is crucial. Even under conditions of challenge and skill balance, changes in task types can trigger different flow outcomes. Research suggests a link between flow and classical music students' performance during exams (Clark et al., 2014; Cohen and Bodner, 2019). An analogous link is also observed in the context of musical performance (Spahn et al., 2021). Bullerjahn et al. (2020) integrated these contexts and conducted a cross-sectional survey paradigm with questionnaires in a music competition environment. They analyzed the interrelationships between practice time and motivational factors among participants in different competition categories. The results revealed that challenge was the most significant motivational factor for all participants, particularly for classical soloists. Furthermore, they noted that the significance of the music competition environment for participants' musical ability and development arises from the interaction between intrinsic motivation and the determination to practice. Therefore, we posit that the competition context established in this study may serve as an effective experimental setting.

Therefore, we pose the second research question: What is the role of the attained state of flow among Chinese music college students in moderating their piano performance, particularly in an examination situation where piano performance constitutes the primary content?

2 Method

2.1 Participants

Participants for this study were recruited through the public campus service platform of Chinese universities and colleges. Inclusion criteria comprised individuals who (1) had a minimum of 3 years of musical training experience, (2) had undergone at least one musical performance, and (3) were 18 years of age or older. A total of 109 music college students (major in piano) were screened to participate in the experiment, and the participants were mainly distributed in the first year of college, accounting for 27.5% ($N = 30$) and the third year of college, accounting for 25.1% ($N = 28$) (refer to Table 1 for specifics). There was a larger proportion of females ($N = 78$, 71.6%), and their ages ranged from 18 to 22 years old, with a mean age of 19.51 years. The results of the sample's diversity distribution in the self-assessed music-related elements were as follows: in terms of music acquisition, the vast majority of the participants had received 10–13 years of music education up to this point in time; in addition, more than 80% of the participants had mastered basic music skills such as fundamental knowledge of music theory and solfeggio; and with regard to subjectively-assessed musical ability, the majority of the participants perceived themselves as being at an intermediate level (Ave = 3.43, 45%, $N = 51$).

2.2 Challenges and skills models

Primarily, a database of piano pieces was curated by a specialized research team with expertise in piano performance examinations. To

TABLE 1 Descriptive statistics of basic information.

Variable	Categories	*N*	Percentage %
Gender	Male	31	28.4
	Female	78	71.6
Age	18	25	22.9
	19	36	33.0
	20	22	20.2
	21	19	17.4
	22	7	6.4
Grade	Freshman	30	27.5
	Sophomore	35	32.1
	Junior student	28	25.7
	Senior student	16	14.7
Years of piano study	1–3	10	9.2
	4–6	27	24.8
	7–9	23	21.1
	10–13	26	23.9
	14–16	14	12.8
	17–19	0	0.0
	20 and up	9	8.3
Piano training time per day	In 30 min	8	7.3
	30 min - 1 h	7	6.4
	1–1.5 h	23	21.1
	1.5–2 h	20	18.3
	2–3 h	32	29.4
	4–6 h	13	11.9
	6 h and up	6	5.5
Musical skills acquired	Vocal performance	44	40.4
	Instrumental performance	101	92.7
	Music appreciation	61	56.0
	Harmony theory knowledge	57	52.3
	Music score readability	90	82.6
	Solfeggio	92	84.4
	Music composition	23	21.1
	Music history knowledge	48	44.0
	Fundamental knowledge of music theory	88	80.7
Musical ability	1	4	3.7
	2	7	6.4
	3	51	46.8
	4	32	29.4
	5	15	13.8

mitigate the influence of extraneous factors and minimize objective variations, the following criteria were established: (1) the piano music collection encompasses both Chinese and Western piano compositions; (2) it spans diverse periods, composers, and genres. Adhering to these criteria, the Experimental Piano Collection comprises 100 piano works. Of these, 70 are Western piano compositions, spanning the Romantic, Classical, and Baroque periods, while the remaining 30 are Chinese piano works composed between 1934 and 2003.

Shannon Entropy is one of the concepts in information theory, which is used to measure the uncertainty and randomness of a piece of information, and has multiple meanings in physics, psychology and musicology. In cognitive psychology, the Shannon Entropy can be used to analyze the way people process information and their cognitive load in complex situations, such as information processing and decision-making behaviors; and in music, the Shannon Entropy has been used to measure the complexity of a musical piece and to differentiate between musical genres (Febres and Jaffe, 2017; Gündüz, 2023).

In this study, we use the Shannon Entropy (later referred to as SE) as a measure of challenge in piano works. The reason is that in piano performance, individuals are not able to unify the definition of difficulty and challenge for any type of work, so the number of notes in the piano score all over the piano becomes an objective measure of challenge, and the notes contained in the score are not subjective to the performer's subjective influence of the challenge, so the study selects the SE as one of the measures of musical complexity. Following Gündüz (2023), we randomly selected six musical compositions for the calculation of the SE based on the criteria of piano performance and cultural identity of the work (See formula below). Specifically, we include the notes contained in the score (except for ornamental notes that do not account for time values) in the data pool for calculation and define them as the Entropy of the piece. To refine the findings, we will also provide the Entropy of the entire piece separately (Shannon Entropy $_{\text{overall}}$, SE), the soprano voice (Shannon Entropy $_{\text{right hand}}$, RSE), and bass voice (Shannon Entropy $_{\text{left hand}}$, LSE) values (see Equation 1).

$$S(P) = -\frac{1}{\ln 2}\frac{1}{n_i}\left[n_{ic4}\ln n_{ic4} + n_{id4}\ln n_{id4} + n_{ie4}\ln n_{ie4} - n_i \ln n_i\right] \quad (1)$$

The data included in the skill model were obtained from the questionnaire CFSS-2 and were categorized into four dimensions: (1) years of piano study; (2) Average hours of piano practice per day; (3) Acquired musical skills; and (4) self-assessment of musical ability. The equilibrium model value for the challenge and skill was computed as the absolute difference between challenge (entropy of works) and skill (four dimensions) (Fullagar et al., 2013).

2.3 Measurements

2.3.1 Demographic information

This self-administered questionnaire serves as a tool for gathering fundamental information about the participants. Comprising eight questions, the survey requires approximately 02:00 min for completion and encompasses essential details, including the subject's age, gender, and academic grade. Moreover, it incorporates musical information related to the subject's years of musical training, acquired musical skills, average daily duration dedicated to musical training, and a self-assessment of their musical proficiency.

2.3.2 Flow state scale-2

The Flow State Scale-2 (FSS-2, Jackson et al., 2004) serves as a self-report instrument for quantifying flow intensity through a 36-item, nine-dimensional scale, with each dimension consisting of four question items. This scale, widely employed in the field of music performance, requires participants to reflect on the recently completed activity while responding to questions. Subjects express their agreement on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). To minimize disruption to participants, the scale is administered within 1 h of the test conclusion (Cronbach's alpha = 0.924) (Jackson and Eklund, 2002). Mean scores are computed for each of the nine flow dimensions, each comprising 3–4 question items, and an overall mean flow score is determined. For the purposes of this study, flow scale scores are categorized into three groups: low agreement (mean scores ranging from 1 to 2), indicating a lack of inherent flow experience; moderate (mean scores ranging from 2 to 4), suggesting some endorsement of the flow experience; and high (mean scores ranging from 4 to 5), signifying strong agreement with the flow experience in the chosen activity. The FSS-2 exhibits sufficient reliability, construct validity, and internal consistency, establishing it as an excellent measure of state flow experience.

2.3.3 Dispositional flow scale−2

The Dispositional Flow Scale-2 (DFS-2, Jackson and Eklund, 2002) evaluates the general inclination to experience flow in a specific situation. Comprising four dimensions, it features 33 question items corresponding to the FSS-2, differing only in wording and phrase tense. Participants respond to the DFS-2 questions by reflecting on their overall experience in the situation across various contexts and timeframes, or their typical experience during activities such as work or leisure. Responses are rated on a 5-point Likert scale, ranging from 1 (never) to 5 (always). It is essential to complete the DFS-2 independently of direct engagement in the activity. This scale was exclusively administered to the English-speaking sample. The global flow score is derived by summing all the question items. The scale demonstrates high reliability, with Cronbach's alpha measuring at 0.931.

The FSS-2 and DFS-2 underwent translation (resulting in the Chinese versions CFSS-2 and CDFS-2) and cross-cultural validation by Sinology, ensuring a valid measure of the flow experience for Chinese participants (Table 2). Coefficients for the CFSS-2 ranged from 0.64 to 0.92 (M = 0.77), and for the CDFS-2, coefficients were 0.65–0.92 (M = 0.78). Five out of the nine flow factors surpassed 0.7, indicating a considerable level of stability. Consequently, both the CFSS-2 and CDFS-2 demonstrated acceptable reliability and validity, warranting their inclusion as indicators of subjects' flow status.

TABLE 2 Questionnaire description.

	CFSS-2	CDFS-2
Number of items	45	45
Fill in time	State of the process at the end of the exam	Mobility at the end of exams
Scope of Filling	From 1 (strongly disagree) to 5 (strongly agree)	From 1 (strongly disagree) to 5 (strongly agree)
Mode of filling	Fill in online	Fill in online

2.4 Procedure

This study employed a within-subjects repeated measures design, encompassing both flow and non-flow conditions for all participants (refer to Figure 1 for the experimental paradigm). Prior to commencing the experiment, subjects received a concise description of "flow": "*Flow refers to the state in which we are focused on the score and the performance while playing music, and it usually feels like time is passing quickly and other things do not seem to be in your consciousness for a while. It is a very pleasurable experience and is associated with optimal performance.*" The research received ethical approval from the Institutional Review Board of the First People's Hospital of Qinhuangdao City, and participants provided written informed consent.

During the pre-experimental phase, the researcher conducted a survey to gather demographic information and assess the level of music acquisition, regarded as a measure of skill level in subsequent data analysis, using an independent variable scale. Subsequently, a database of piano repertoire was curated as performance materials, following meticulous screening for repertoire length, time constraints, diversity in composers and their works, and adherence to various structural and stylistic elements. Subjects and judges meeting the experiment's criteria were recruited through online platforms using web-based methods. The final selection of valid subjects occurred after presenting the structured experimental paradigm and implementing exclusionary inclusion criteria.

Pre-experimental and formal experiments were conducted within the controlled environment of a concert hall, emphasizing strict regulation of experimental conditions. This included standardized piano facilities (utilizing a consistent piano brand, KAWAI, to eliminate potential variations in sound quality) and meticulous control over the physical environment (employing white, cool-colored lighting with a color temperature of 5,000-7000 k; maintaining a temperature range of 20–22 degrees Celsius; and regulating humidity within 40–60%). Subjects were randomly assigned to perform 1 or 2 pieces from the portfolio based on their grade level, presenting a complete piano performance lasting between 20 and 45 min. Post-performance, subjects assessed their own flow state using the CFSS-2, while five experienced music faculty piano majors evaluated their performance, considering factors such as tempo, technique, musicianship, and piece coherence. A follow-up assessment of subjects' flow state (using the CDFS-2) was conducted one to 2 days after the experiment. Finally, the researcher quantified score information characteristics (e.g., composer, period, style, and notes) in the piano portfolio, aiming to explore the elicitation of flow and its mechanisms on performance when perceived challenge dynamically aligns with the level of musical skill acquisition.

The questionnaires used in the experiment were published and collected in the public student services software of a university in China, and have been verified for their utility in a music performance setting and even validity of the research topic. The data were collected on 18th November 2023.

3 Statistical analyses

Statistical analyses conducted using IBM SPSS version 27. To examine the correlation between flow and performance as posited in

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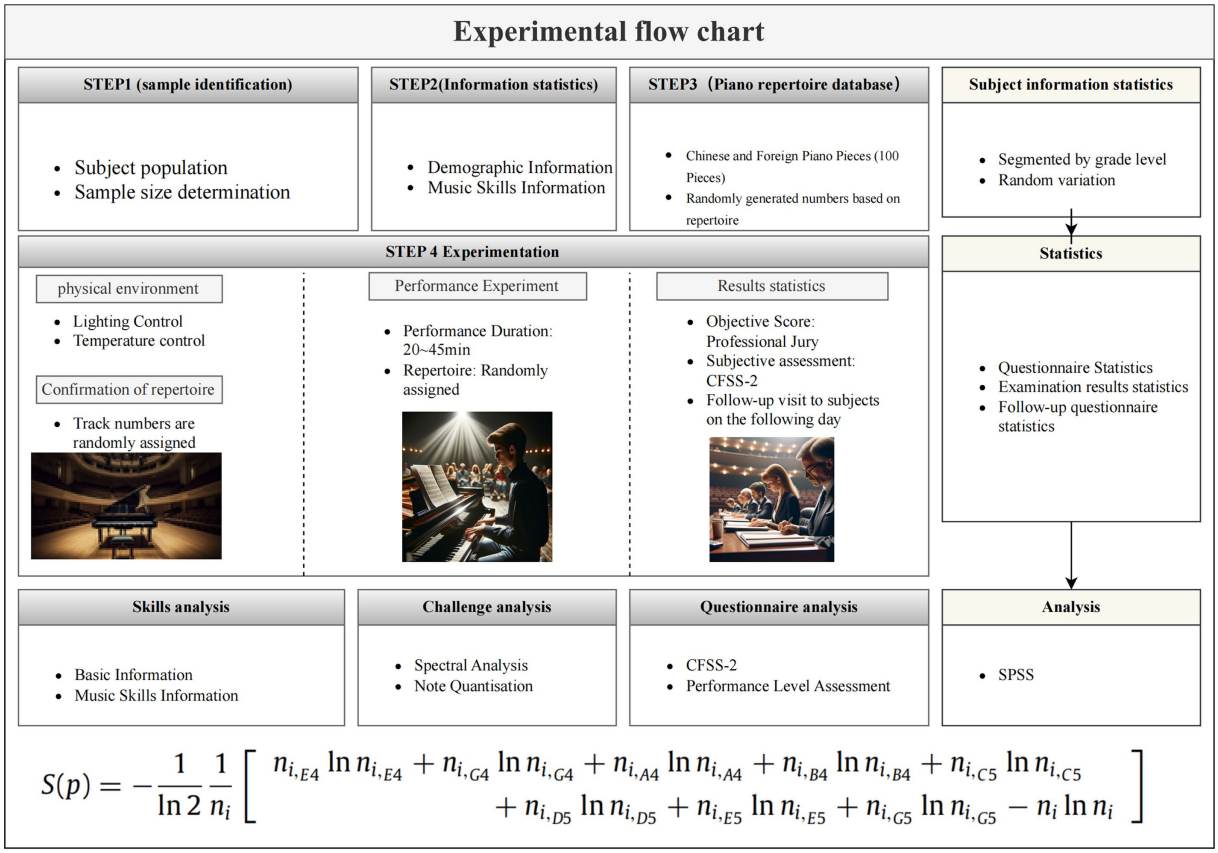

FIGURE 1
Flow chart of the experiment. Images generated by ChatGPT, version 4.0. The enhancement prompts for the three images in the flow chart from left to right are as follows: "Please draw an image of a grand piano placed in a concert hall"; "Please draw an image of a student performing on a piano in a concert hall"; "Please draw an image of judges scoring a student performing on a piano in a concert hall". OpenAI (https://chat.openai.com/chat) (December 20, 2023).

Hypothesis 1, along with the impact of demographic and musical factors, initial analyses involved descriptive assessments and Pearson's correlation coefficient tests on the comprehensive dataset. Subsequently, to test Hypothesis 2 and explore the influence of flow on performance within the context of the balance between challenge and skill, sub-model construction was performed on the two variables of challenge and skill.

4 Result

4.1 Descriptive statistics

4.1.1 Flow and performance scores

To facilitate the examination of the subject group's flow experience, both state flow and trait flow were separately analyzed descriptively. Table 1 shows that the majority of subjects entered a moderate level of flow, but at a lower level compared to the flow experience in other instrumental studies, validating Moral-Bofill et al. (2023) research. Notably, the overall mean scores for trait flow surpassed those for state flow. Among the individual trait flow dimensions, dimensions 2 to 4 exhibited the highest mean scores, while dimensions 7 to 9 displayed lower mean flow scores, suggesting limited experiences for certain subjects. Additionally, alpha coefficients for both state flow and trait flow, as well as the nine sub-items, were calculated, and all scores exceeded 0.8, indicating good reliability. Furthermore, the mean score for all subjects' piano performance exceeded 84, indicative of a commendable level of performance (Table 3).

4.1.2 Challenges and skills models

The study constructed four balanced challenge and skill models, detailed in Table 4. Given that performance is a key variable, challenge was quantified using performance scores, randomly selecting two subjects each with scores at high and low intermediate levels. Models 1 to 4 represent the absolute difference between SE and the number of years of piano study, average daily practice time, musical ability, and acquired musical skills, respectively, indicating the state of challenge and skill balance. Table 4 reveals that the SE of the piano piece played by Subject No. 1 is the highest. Within the high and low performance levels, the SE of the subject is positively proportional to the score of Model 4, suggesting that flow occurs when the subject's mastered musical skills maintain a specific equilibrium with the Shannon entropy of the played piece. Additionally, SE represents the complexity of a piece, with higher values indicating greater musical structure complexity. All entropy values are positive within the three performance levels. However, it's noteworthy that, except for the high-performance group, the entropy values of the middle and low-performance groups are negative. This implies that the complexity of the works in the

middle and low-performance groups is less connected to Challenge-Skill Model 4. Further elucidation on the generation of entropy values in the middle and low-performance groups will be provided in the conclusion.

4.2 Relevant relationship

4.2.1 Flow and performance

Figure 2 shows the intercorrelation between the study variables of state flow and performance, according to the CFSS-2, indicating that there is a positive correlation between flow and performance $r = 0.236^{*}$, $p < 0.05$, with dimension 1 $r = 0.277^{**}$, $p < 0.01$, dimension 3 $r = 0.305^{**}$, $p < 0.01$, and dimension 6 $r = 0.247^{**}$, $p < 0.01$ being significantly positively correlated with performance. Among the demographic factors, the results showed a significant positive correlation between subjects' age $r = 0.271^{**}$, $p < 0.01$, grade $r = 0.344^{**}$, $p < 0.01$ and performance, but there was no correlation between gender and performance $r = -0.097$, $p < 0.01$. In addition, there was a significant positive correlation between the number of years of musical training received by the subjects and performance $r = 0.287^{**}$, $p <. 01$, and the average number of hours of musical training per day likewise had a significant positive correlation with performance $r = 0.312^{**}$, $p < 0.01$. Surprisingly, there was no correlation between the musical skills acquired by the subjects and performance $r = 0.166$, $p < 0.01$. However, musical ability had a significant positive correlation with performance $r = 0.441^{**}$, $p < 0.01$.

TABLE 3 Descriptive statistics for CFSS-2, CDFS-2 global mean scores, nine sub-dimensions and performance ($N = 109$).

		M	SD	MIN	MAX	α
CFSS-2	F1	3.29	0.92	1.25	5.00	0.88
	F2	3.55	0.89	1.67	5.00	0.81
	F3	3.85	0.90	1.67	5.00	0.87
	F4	4.01	0.81	2.50	5.00	0.87
	F5	3.75	0.94	1.25	5.00	0.88
	F6	3.34	0.97	1.00	5.00	0.88
	F7	3.08	1.02	1.00	5.00	0.84
	F8	3.53	1.00	1.00	5.00	0.83
	F9	3.28	1.08	1.00	5.00	0.91
	Total	3.51	0.75	2.21	5.00	0.96
CDFS-2	F1	3.30	0.73	1.25	5.00	0.85
	F2	3.40	0.77	1.67	5.00	0.82
	F3	3.82	0.83	1.67	5.00	0.86
	F4	3.88	0.73	2.25	5.00	0.90
	F5	3.61	0.76	2.00	5.00	0.91
	F6	3.30	0.78	1.00	5.00	0.82
	F7	2.91	0.86	1.00	5.00	0.82
	F8	3.28	0.92	1.00	5.00	0.85
	F9	3.28	0.89	1.00	5.00	0.89
	Total	12.76	2.17	8.33	18.78	0.95
Performance		84.20	5.21	59.00	95.00	/

M, Mean; SD, Standard deviation; Min, Minimum; Max, maximum; and α, Cronbach's alpha.

Figure 3 shows the intercorrelations between the study variables of trait flow on performance, according to the CDFS-2, indicating that there is a significant positive correlation between flow and performance $r = 0.268^{**}$, $p < 0.01$, with Dimension 1 $r = 0.300^{**}$, $p < 0.01$, Dimension 3 $r = 0.291^{**}$, $p < 0.01$, and Dimension 9 $r = 0.294^{**}$, $p < 0.01$ being significantly positively correlated with performance. The results for demographic factors and performance were consistent with the results for state flow, with age and grade significantly and positively correlated with performance $r = 0.271^{**}$, $p < 0.01$, $r = 0.344^{**}$, $p < 0.01$, and the results for gender were similarly uncorrelated with performance $r = -0.097$, $p < 0.01$. Additionally, the number of years that the subjects had received music training, the average number of hours of music training per day, and the musical abilities and performance were consistent with the results for state mobility, all of which were significantly positively correlated $r = 0.287^{**}$, $p < 0.01$, $r = 0.312^{**}$, $p < 0.01$, $r = 0.441^{**}$, $p < 0.01$, and there was no correlation between acquired musical skills and performance $r = 0.166$, $p < 0.01$.

4.2.2 The relationship between flow and performance in the balance of challenges and skills

The Challenge-Skills Balance dimension, as an important but not exclusive factor in the production of the flow experience, contains the following question items: *q1 just now I was challenged but I believe that my skills are able to cope with this challenge, q8 just now my abilities matched the high demands of the situation, q17, just now I felt that my abilities were sufficient to meet the high demands of the situation, q25 just now both the challenge and my skills were at an equally high level*. Based on the above descriptive analyses, we found that the dimension did not

TABLE 4 Challenges and skills model and SE descriptive statistics.

Number	Piece	SE	LSE	RSE	Model 1	Model 2	Model 3	Model 4
1	Three Preludes-for Piano	4.99	3.56	3.77	0.01	0.01	0.01	3.01
2	Barcarolle in F-sharp Major Op.60	4.59	3.44	3.97	0.41	1.41	0.41	2.41
3	Etude in F minor	4.20	2.74	3.31	−2.20	−0.20	−1.20	2.80
4	Nocturne in E flat major	4.83	4.29	3.68	−2.83	1.17	−1.83	−1.83
5	Czerny 740 No.3	4.59	3.32	4.06	−0.59	−2.59	−0.59	3.41
6	Inventions et Sinfonias	4.38	2.98	3.10	−2.38	−2.38	−2.38	−1.38

Number is the serial number of the subjects, from 1 to 6 representing two subjects at the high school and low school levels of piano performance; piece is the name of the musical work performed by the subject; SE is Shannon Entropy; LSE is the left hand SE of the work, Left hand SE; and RSE is the Right hand SE of the work, Right Hand SE (See appendix for more information on piano works).

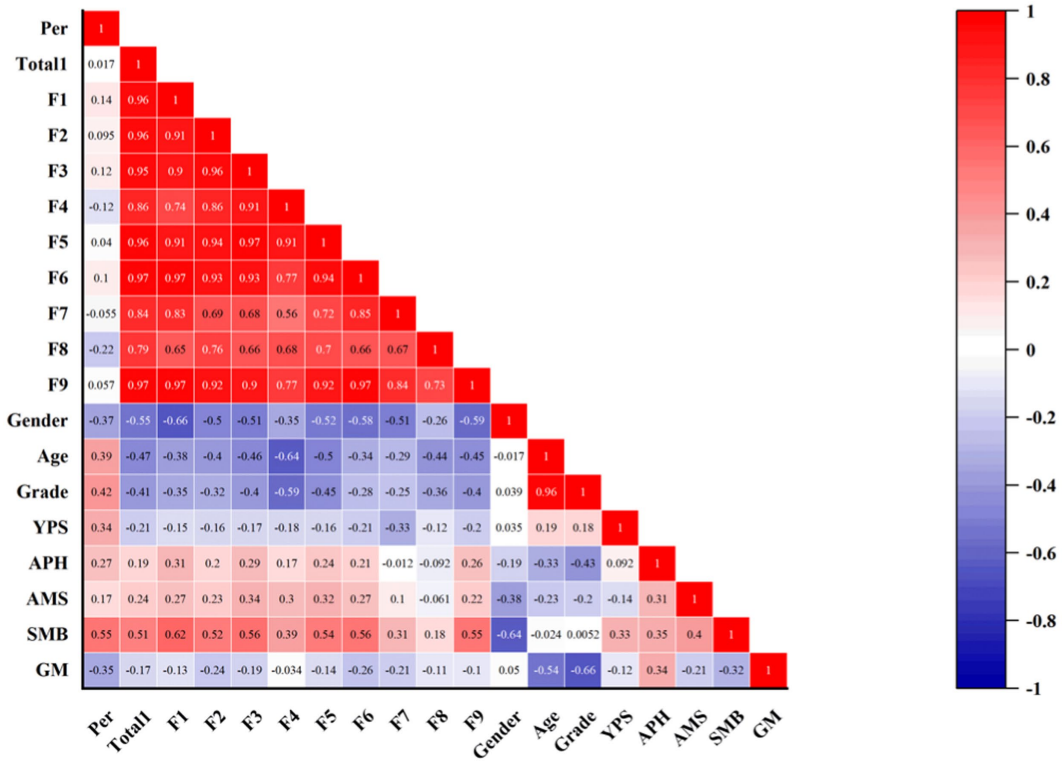

FIGURE 2
Results of CFSS-2, demographic, and performance-related analyses. Per: performance; Total1: total mean score of CFSS-2; F1-F9: average scores on nine dimensions; Genders, Ages, and Grades are not abbreviated; YPS, years of piano study; AHP, Average hours of piano practice per day; AMS, Acquired musical skills; SMB, Self-assessment of musical ability; GM, Genre of music.

score the highest in the state flow versus the trait flow; the correlation between the dimension and the total flow score in both flows was more significant in the trait flow $r = 0.870^{**}$, $p < 0.01$, and the same finding was obtained in the correlation with performance, which was more relevant in the trait flow $r = 0.300^{**}$, $p < 0.01$. Therefore, we explored the correlation between the challenge and the Skills model in the trait flow by correlating the model with the quantified Challenge and Skills, respectively, with the trait flow as shown in Figure 4. The results showed that none of the four models set up according to the above were correlated with the total mean score of the flow, but there was a certain negative correlation between Model 3 and Dimension 4 of the trait flow $r = -0.860^{*}$, $p < 0.05$, and in the correlation with Performance, the results showed that there was a positive Performance and Model 2 correlation $r = 0.870^{*}$, $p < 0.05$, and a significant positive correlation with Model 4 $r = 0.996^{*}$, $p < 0.01$, but the result was not found for Challenge and Skills within the model. Surprisingly, in the challenge dimension, the right-hand SE of the piano piece was positively correlated with dimension 7 $r = 0.836^{*}$, $p < 0.05$, dimension 8 $r = 0.856^{*}$, $p < 0.05$, and dimension 9 $r = 0.825^{*}$, $p < 0.05$, in trait flow. In addition, in the challenge, Model 3 was positively correlated with left-handed SE $r = 0.905^{*}$, $p < 0.05$. No correlations existed between the other main variables relevant to this study.

5 Discussion

The present study firstly validated the pattern of flow state attainment and its evoked mechanisms in Chinese music college students in a piano performance situation, and compared these results with the findings of Jha et al. (2022). Subjects in the study demonstrated the same findings, all being able to achieve a flow experience at a level where challenge and skill were matched to each other. This finding demonstrates the cross-cultural validity of the flow experience.

By quantifying music ontology data and music acquisition levels, we have successfully established an access framework in equilibrium, utilizing challenge and skill as the metrics for flow. The equilibrium level is represented by the quantification of the relationship between the complexity of the work, characterized by SE, and the degree of musical skills acquired by the subject. According to our findings, in the high-performance level, the SE value of Challenge and Skill Model 4 is significantly correlated with the growing complexity of the work as musical skill increases. This implies that subjects are more likely to experience flow when Model 4 is positively proportional to the complexity of the work. In contrast, in the middle and low-performance levels, some SE values yielded negative numbers, suggesting that complexity cannot be accurately measured by SE values in piano practice pieces. Consequently, establishing a conclusive relationship between the challenge-skill model and entropy values was challenging, requiring further research. This study marks the first quantification of this equilibrium relationship in the exploration of flow theory in the field of music performance, with implications for subsequent research. Specifically, self-reported levels of music acquisition prove to be valid skill guidelines. The results reported in this paper demonstrate that the SE algorithm effectively

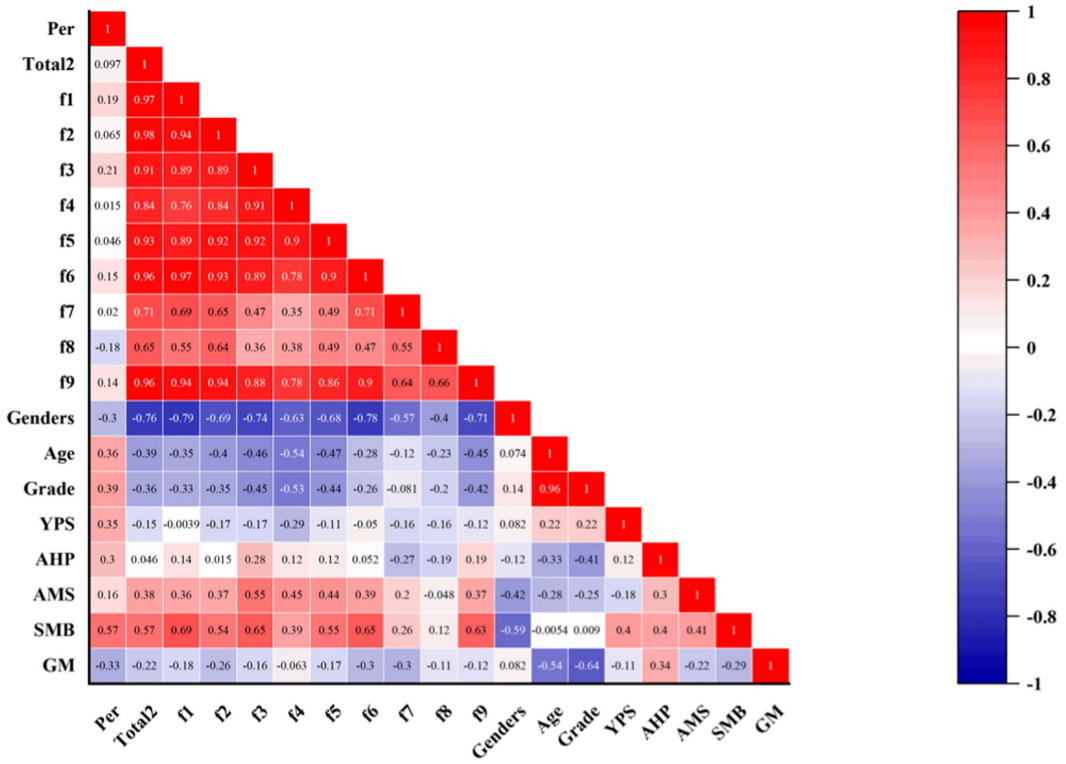

FIGURE 3
Results of CDFS-2, demographic, and performance-related analyses. Total2: CDFS-2 average score; the rest of the abbreviations are consistent with Figure 2.

quantifies the complexity of musical compositions in a well-documented manner.

In addition to this, external factors such as age, grade, years of musical training, average daily musical training time, and musical ability could also partially elucidate the induction of flow, with grade and musical ability potentially emerging as more influential factors in this regard. These findings align with and reinforce the conclusions drawn by Cohen and Bodner (2019). Notably, the current study revealed novel insights from music-related information, emphasizing the significant impact of musical ability on flow experiences, which progressively shapes the unfolding experiences in response to outcomes within the flow experience (Marin and Bhattacharya, 2013). For instance, as grade level rises, there is a discernible impact on frequency (Koehn and Morris, 2014) versus duration, among other factors – a result that awaits further validation. Contrary to expectations, indicators of gender and acquired musical skills proved less explanatory in the emergence of flow, possibly attributed to the geo-cultural nature of the sample in this paper.

Equally pivotal in addressing the second research question of this paper, a notable positive correlation emerged between the attainment of a flow state and piano performance. Furthermore, the impact of flow, induced by the quantified challenge-skill balance model, exhibited a more pronounced effect in high-performance scenarios. Here, SE in Music, serving as a quantitative representation of the musical characteristics inherent in challenge and skill, played a moderating role in the connection between flow and performance. This result provides further evidence of the important impact of the balanced modeling of challenge and skill in the flow experience on the enhancement of musical ability in a competitive environment (Bullerjahn et al., 2020). Changes in SE, a key aspect of characterizing the complexity of a piano piece (Ribeiro et al., 2012; Tozman et al., 2017), demonstrated a relational effect on performance flow, as evidenced in the results (Marty-Dugas et al., 2021; Tan et al., 2021). In summary, the dynamic equilibrium between challenge and skill, identified as a significant influencer of flow, yielded unexpected outcomes in attempts to quantify the complexity of a work. Simultaneously, this approach has introduced novel perspectives for interpreting the intricate relationship between flow and performance (Zielke et al., 2023).

6 Limitation

While diligent efforts have been exerted to regulate experimentally relevant variables, it is crucial to acknowledge potential limitations in the generalizability of these findings, considering regional disparities, instrument-specific nuances, and the distinctive experimental context. Consequently, the scope of these results may be constrained within the realm of piano performance and may not be universally applicable across diverse musical domains. There are potential limitations to the present study's induced modeling of the flow experience and the use of SE as one of the objective measures of piano challenge, due to the fact that there are many other unpredictable factors that contribute to the quantitative limitations of the challenge during a true challenge, and, also, due to the pianist's respective playing skills. Thus, future

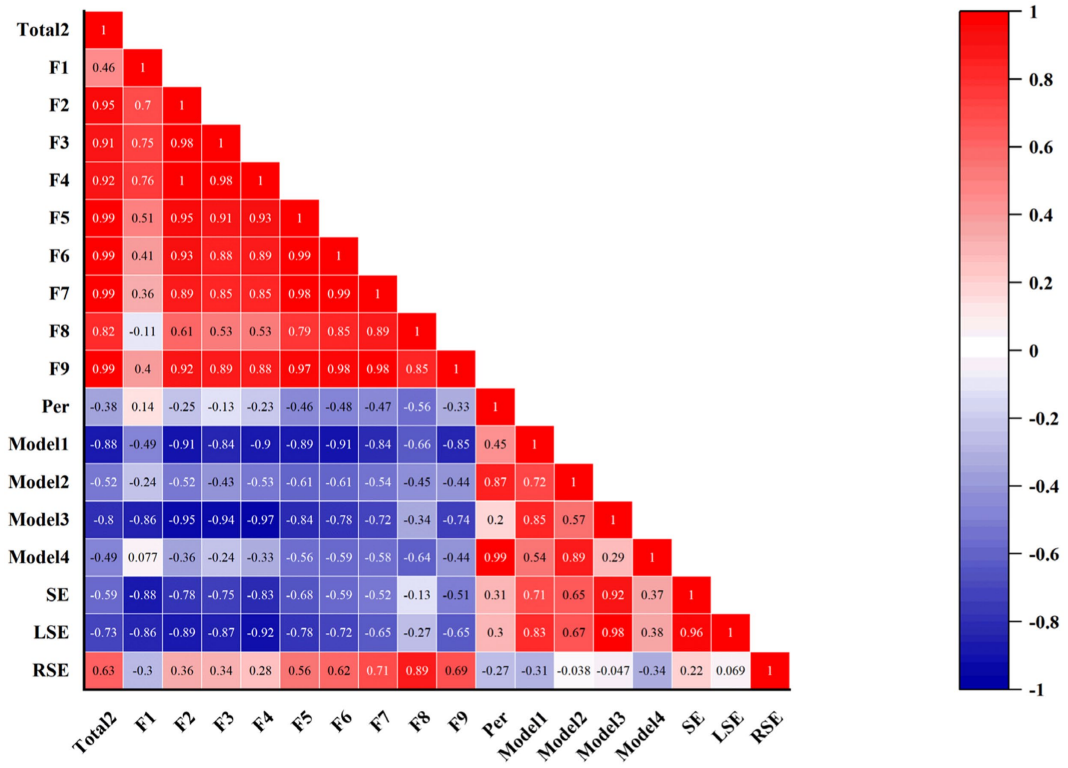

FIGURE 4
Results of CDFS-2, Performance and Challenge Skills Model, and SE Correlation Analysis. Total2: CDFS-2 average score; F1-F9: average scores on nine dimensions; Model 1 - Model 4: Balance of Challenge and Skills model constructed in 4.1.3, 4 in total. SE, Shannon Entropy; LSE, Left Hand SE; RSE, Right Hand SE.

research could start with objective quantification of musical compositions (e.g., SE) and explore other measures of challenge in the flow experience. Additionally, the relationship between areas other than the field of piano performance (e.g., other instruments versus the experience of flow in a musical listening environment) and SE should be investigated, suggesting an expansion of the current theme. Moreover, cross-sectional investigations of this nature may encounter unforeseen factors influencing the emergence of the flow experience. Future research endeavors should explore connections beyond piano performance, such as diverse musical instruments or the encounter of flow in a musical listening environment, highlighting an expansion of the present inquiry. It is imperative to conduct further studies to authenticate the aforementioned results, fostering a comprehensive understanding of the intricate relationship between flow and musical attributes. Additionally, the correlation between the physical attributes of music and the flow state remains an unanswered query, prompting subsequent research to incorporate these factors into the investigative framework.

Subsequent research endeavors could delve into a detailed exploration of specific underlying factors. Examining these features in depth may provide a more nuanced understanding of the intrinsic dynamic characteristics associated with positive emotions and flow. Such insights, in turn, could serve as a means for enhancing well-being through musical engagement. In summary, additional research in the field of music practice is essential to assist less experienced students in cultivating flow experiences during their practice sessions, ultimately fostering more meaningful experiences in the realm of music learning.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statement

The studies involving humans were approved by the First People's Hospital of Qinhuangdao City. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JL: Methodology, Funding acquisition, Writing – original draft. YX: Writing – review & editing. XW: Validation, Writing – review & editing. XY: Writing – original draft, Visualization. ShL: Writing – original draft, Resources. ML: Writing – original draft, Validation.

XR: Project administration, Writing – original draft. DY: Supervision, Investigation, Writing – original draft. SiL: Visualization, Writing – original draft. ZJ: Writing – original draft, Data curation. QG: Writing – original draft, Resources. MY: Data curation, Writing – original draft. QX: Writing – review & editing, Supervision, Data curation.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1386831/full#supplementary-material

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"I feel like a fish out of water": interpreting the occupational stress and well-being experiences of professional classical musicians

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Introduction: Professional classical musicians operate within a highly demanding environment, which includes organizational, social, and emotional demands. When not effectively coped with, these demands may cause stress and negatively impact well-being. This qualitative study explored the perceived stress and well-being experiences of professional classical musicians through a transactional theory of stress. The study employed a double hermeneutic interpretation of the lived experiences of the perceived demands faced, stress appraisals made, resources used, and the influence on well-being.

Methods: Six professional classical musicians were purposefully selected for participation. Semi-structured interviews were conducted and participants reflected on two events: one they perceived as a positive experience and one that was negative. Transcripts were analyzed using Interpretative Phenomenological Analysis and Group Experiential Themes emerged.

Results: Three Group Experiential Themes were identified: (a) Performance Demands; (b) Organizational Demands; and, (c) Relationship Demands. Participants predominantly appraised demands as a threat. A small number of demands were appraised as a challenge or benefit, and the fewest demands were appraised as causing harm or loss. Participants' appraisals were informed by underlying properties of stress appraisal such as self and other comparison, and preparation. Participants often relied on personal resources as opposed to available workplace resources. They perceived well-being to relate to stress appraisals with participants experiencing acute and long-term outcomes.

Discussion: This study offers insight into the lived experience of the occupational stress process within professional classical musicians. The findings demonstrate that organizational interventions targeted at continuing professional development and social support are appropriate to help musicians cope more effectively with demands.

KEYWORDS

performance, musicians, stress, demands, appraisal, coping, well-being, interpretative phenomenological analysis

Introduction

Professional classical musicians experience a variety of demands due to the occupational environment within which they operate. This includes intrapersonal, interpersonal, and organizational demands (Willis et al., 2019). On an individual level, classical musicians are required to attain a high level of technical proficiency whilst also demonstrating emotional expressivity during performance (Williamon, 2004). Interpersonal demands arise due to relational issues with colleagues and management. In addition, freelance musicians require business acumen and self-promotion skills when engaging with key stakeholders to ensure further work opportunities (Kubacki, 2008; Coulson, 2012). Ensemble musicians also report a high demand on their interpersonal skills, which are needed to facilitate musical communication and positive relationships with colleagues (Lim, 2014). At an organizational level, musicians experience demands due to scheduling, touring, low remuneration, and contract insecurity (Rickert et al., 2013; Vervainioti and Alexopoulos, 2015). In the UK, a large number of orchestral musicians work in a freelance capacity (Association of British Orchestras, 2019) meaning that these individuals receive short-term contracts with irregular work patterns. If not coped with effectively, the demands faced by professional classical musicians can cause occupational stress and threats to well-being (Willis et al., 2019).

Professional classical musicians draw on internal and external resources to cope with the demands experienced. Musicians value the importance of teamwork, a feeling of community amongst colleagues, and collaborative working environments (Brodsky, 2006; Ascenso et al., 2017). Researchers have demonstrated, for example, that social support from colleagues can help manage the stress response resulting from career insecurity and emotional demands (Parker et al., 2019; Pihl-Thingvad et al., 2022). Musicians have also described active coping skills such as planning, problem solving, consulting medical professionals, learning to handle disappointments, and maintaining good physical health in order to protect their well-being against the occupational demands experienced (Burland and Davidson, 2002; Sandgren, 2002; Pecen et al., 2018).

Both demands and resources may affect professional classical musicians' well-being outcomes. The intra-individual process(es) whereby they do this are not well understood. Willis et al. (2019) asserted that holistic approaches to assessing occupational stress and well-being in musicians should be taken. One approach is by using a Cognitive-Motivational-Relational Theoretical approach (CMRT) (Lazarus, 1999). This approach may provide insight into the stress processes experienced by an individual musician, particularly in why and how they appraise occupational demands.

In his CMRT, Lazarus (1999) suggested that stress should be viewed as a transaction, incorporating the ongoing relationship between the individual and the environmental demands they encounter, with emotional and well-being outcomes resulting from such transactions. Lazarus (1999) argued that the demands experienced may arise from a variety of contexts such as the workplace, family, or wider cultural expectations. Central to the experience of stress in the face of such demands is the concept of appraisal. Split into primary and secondary appraisals, Lazarus suggested that for an individual to view a demand as stressful, the demand must first be appraised to be relevant to their personal goals or motivations. Such demands may be appraised as threatening, a positive challenge (i.e., an opportunity for growth), beneficial, or harmful (primary appraisal). An additional layer to primary appraisals is the concept of underlying properties. Specifically, Lazarus and Folkman (1984) suggested that at least one of eight properties is required for an individual to make a stress appraisal. These include novelty, predictability, event uncertainty, imminence, duration, temporal uncertainty, ambiguity, and the timing of stressful events in relation to the life cycle (Lazarus and Folkman, 1984). Thatcher and Day (2008) extended this work and examined the underlying properties of stress appraisal in a sports context. Based on their findings, they expanded the factors of underlying stress appraisal to include "self and other comparison" and "inadequate preparation." Definitions for each underlying property of stress appraisal are provided in Table 1 alongside an example of how this could translate to a musical context. Secondary appraisal then involved the individual evaluating whether they have the resources available to cope with the demand, which Lazarus (1999) differentiated from the act of coping.

Dependent on the results of individuals' appraisals of their coping resources, they may attempt to use cognitive, emotional, or behavioral coping strategies (Lazarus, 1999). Lazarus and Folkman (1984, p. 141) argued that coping is a process and defined it as "constantly changing cognitive or behavioral efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person." In other words, coping is the steps or actions an individual uses to manage the demands they experience. Lazarus (1999) suggested two distinct factors of coping: problem-focused and emotion-focused. Problem-focused coping refers to taking action and using strategies that change the relationship between the person and the environment, (e.g., planning, problem solving). Emotion-focused coping describes efforts to regulate an emotional response through strategies such as venting about a situation or avoiding a demand. Research on the resources individuals use to cope with demands has been extended by the JD-R theory, which includes occupational resources and personal resources (Bakker and Demerouti, 2014). Schaufeli and Bakker (2004) suggested that occupational resources can decrease occupational demands, support the achievement of work goals, and contribute to personal development and well-being.

Considering conceptualizations of well-being, both hedonic and eudaimonic well-being are relevant to the occupational experiences of musicians (Willis et al., 2019). Hedonic well-being is made up of affective and cognitive dimensions (Diener et al., 1999). The affective dimension of hedonic well-being includes positive and negative affect, and the cognitive dimension is represented by perceived satisfaction. Eudaimonic well-being is more holistic and includes six dimensions: self-acceptance, positive relations with others, autonomy, environmental mastery, purpose in life, and personal growth (Ryff, 2014). Bartels et al. (2019) argued that hedonic and eudaimonic well-being are distinct despite being highly correlated. Therefore, hedonic and eudaimonic well-being can be considered complementary (Waterman, 2008; Huta and Waterman, 2014), and VanderWeele et al. (2020) suggested that studies of psychological well-being examine both concepts.

Through CMRT, Lazarus (1999) argued that appraisals will influence the emotions experienced. For example, threat may cause anxiousness and challenge may lead to excitement. Such emotional experiences may be conceptualized as the affective dimension of hedonic well-being. Additionally, the reciprocal nature of experiences of stress and emotion, respectively, as depicted in CMRT, can give rise to longer-term well-being responses such as satisfaction from the knowledge of coping well with stressful encounters.

TABLE 1 Definitions of underlying properties of stress appraisal (Lazarus and Folkman, 1984; adapted from Thatcher and Day, 2008).

Underlying property of stress appraisal	Definition	Example
Novelty	Situations that the person has not previously experienced. Previous experience may include both experiencing a similar situation and information that can be read, heard or inferred	First orchestral trial
Predictability	When established expectancies are no longer met the situation becomes unpredictable	A change in rehearsal or performance schedule compared to usual
Event uncertainty	The likelihood or probability of an event's occurrence. These can be subjective or objective probabilities although subjective estimates do not necessarily match objective ones	Subjective probability: The likelihood of performing correctly Objective probability: The likelihood of a performance taking place
Imminence	The period of anticipation before an event occurs	Anticipation whilst travelling to a performance
Duration	The length of an event. Events of a long duration will be deemed more stressful than those of a short duration	Tours taking place over several months
Temporal uncertainty	The individual knows that an event will definitely happen but is unsure of the precise timing	Waiting to be called into an audition
Ambiguity	When the information needed for appraisal is unclear or insufficient resulting from a lack of situational clarity	An unknown conductor leading a performance
Timing of events in relation to life cycle	Events occurring at the same time as other stressful events in the individual's life cycle may be appraised in relation to these other events	Performances taking place during a period of increased caring responsibilities
Self and other comparison	Comparing any physiological, psychological, or social aspect of performance or the associated environment with that of another individual	Comparing personal performance of a piece of music to a colleague's performance
Inadequate preparation	The individual does not feel well prepared for performance	Poor practice prior to a performance

In the literature on classical musicians, no study has considered a holistic approach to understanding stress and well-being, which incorporates demands, appraisals, coping, and well-being. A holistic approach that is underpinned by CMRT has been adopted in other demanding performance environments such as sports to explore the occupational stress process and well-being outcomes (e.g., Neil et al., 2016). Such studies have examined appraisals, underlying properties of appraisals, and coping strategies and their effectiveness (e.g., Hanton et al., 2012; Didymus and Fletcher, 2014; Didymus, 2017). Notably, an individual's experience of the stress process has been linked to well-being outcomes (Neil et al., 2016).

Like athletes, musicians work in situations with high performance demands. As such, the potential exists for comparable experiences of occupational stress and well-being. However, as identified by Willis et al. (2019), no qualitative studies underpinned by CMRT have yet considered the stress process and well-being outcomes in classical musicians. Given that this theory, with the inclusion of appraisal and associated underlying properties of stress appraisal, has successfully been used to inform approaches for exploring stress and well-being outcomes in high performance-based roles, this study explored these concepts in professional classical musicians.

Aim and research questions

The aim of this study was to interpret the lived experiences of perceived occupational stress and well-being of professional classical musicians through a rich understanding of the demands they face, the appraisals they make, the resources they use, and their perceived influence on self-reported well-being. The following research questions framed the research design:

> *RQ1*: What are the perceived demands associated with the lived experiences of professional classical musicians?
>
> *RQ2*: What primary appraisals do professional classical musicians report when experiencing occupational demands?
>
> *RQ3*: What occupational and personal resources do professional classical musicians report using to cope with the occupational demands experienced?
>
> *RQ4*: How is well-being experienced by professional classical musicians when encountering occupational demands?
>
> *RQ5*: What are the perceived connections between occupational demands, primary appraisal, occupational resources, personal resources, and perceived well-being outcomes?

Methods

This study is reported in accordance with the journal article reporting standards for qualitative research (Levitt et al., 2018).

Philosophical position

This study adopted a critical realist position (Bhaskar, 2008), in which an independent reality exists "out there" (O'Mahoney and Vincent, 2014). The authors of the present study acknowledge subjectivity in how individuals perceive reality and reject the notion of multiple realities (Fleetwood, 2014). Aligned to this philosophical position, the study used Interpretative Phenomenological Analysis (IPA) (Smith et al., 2022; Smith and Nizza, 2022).

Research design

The focus of an IPA design is the deep exploration of the lived experiences of participants. IPA considers participants' experiences alongside their actions, thoughts, and feelings (Smith and Nizza, 2022). The theory of IPA is drawn from the areas of phenomenology, hermeneutics, and idiography. IPA is interpretative on two levels: first, the participant interprets and makes sense of their own experiences and second, the researchers are involved in interpreting the participants' sense-making (Smith and Shinebourne, 2012). This process is referred to as a "double hermeneutic" (Smith and Osborn, 2003). The interpretative function of the researchers is central to IPA, although it is acknowledged that the phenomena is viewed primarily through the rich descriptions and details provided by the participant (Smith et al., 2022).

IPA was adopted for this study as a suitable means to explore the phenomenon of occupational stress as it relates to associated thoughts (i.e., primary appraisal, cognitive well-being outcomes), actions (i.e., use of personal and occupational resources), and feelings (i.e., affective well-being outcomes). The idiographic approach of IPA was considered appropriate to explore both appraisals and perceived well-being as these are subjective. Further, appraisals are often made using unconscious schema, meaning it can be difficult to gain access to these cognitive processes using nomothetic approaches. An idiographic approach involves considered questioning and allows individuals adequate time for reflection in order to provide detailed accounts of their personal experiences regarding their thoughts and feelings when encountering occupational demands.

Researcher characteristics and reflexivity

To interpret the participants' lived experiences, the primary researcher engages closely with the interview transcripts. This requires the researcher to put aside or "bracket off" their initial ideas and preconceptions about a topic (Pietkiewicz and Smith, 2012; Smith et al., 2022). This bracketing off is not only necessary prior to conducting interviews but is a continual process throughout the research (Smith et al., 2022). In this study, the primary author engaged with reflexive interviews with research team members, framed by the reflexive interview model developed by Dallos and Vetere (2005).

This process necessitates some key positionality acknowledgements. The first author completed an undergraduate music degree at a UK Conservatoire and previously worked as a musician. This work mostly involved peripatetic teaching and included a small number of freelance performances within orchestral and chamber music settings. In this way, the first author was familiar with the professional classical musicians' practice community. The last author was previously involved in a wide variety of research on classical musicians' health and well-being. The second and third authors are experienced researchers and practitioner psychologists with extensive experience of working in mental health, well-being, and performance psychology across a variety of demanding performance driven environments. They had not previously worked in classical music.

To encourage reflexivity during the study, a research journal was kept throughout the process of data collection and analysis. Journal entries included initial thoughts on the process of interviewing, thoughts and feelings about interviews in relation to prior experience, progress notes, conceptual notes, and ideas relating to existing literature. Regular meetings were held between the research team throughout the data analysis process to discuss and critically challenge the development and refinement of themes.

Sampling, recruitment, and participants

In this study, participants were recruited from a previously utilized research population (Willis et al., in preparation). To be eligible to participate, musicians needed to be professional classical musicians, defined as individuals earning the majority of their salary through performance and music-related activities (e.g., teaching). All instrumental and vocal categories were eligible and participants were required to be aged 18 or above. Musicians were excluded if they were amateur musicians or mostly performed music of a different genre (e.g., popular music). Musicians who had not completed the full questionnaire in the previous study were not eligible to participate in this study.

Given that the previous questionnaire study had included questions regarding demands, stress, resources, and well-being, it was perceived that these individuals had the experiences necessary and motivation to be potential participants for the present study. Their participation would better ensure the homogeneity of participants as per IPA expectations (Smith et al., 2022). To reflect the idiographic approach of IPA, a small sample was recruited ($n = 6$).

Recruitment was carried out between January and February 2021. Participants from the questionnaire study were contacted via email and invited to participate. Of those who volunteered, 16 professional musicians were eligible to participate. Five volunteers from outside the UK were excluded to assure participant homogeneity. Six professional musicians were contacted and all agreed to be interviewed. Participant demographics are presented in Table 2. Participants consisted of two full-time contracted musicians and four were self-employed. Participants included four males and two females and ranged in age between 29 and 54. Two participants played string instruments, one of whom was also a conductor, two played woodwind instruments, and two played brass instruments.

Instrumentation

An interview schedule was developed and included questions that would allow participants to provide a "rich" account of their experiences. Questions were designed to be open-ended and focused on the types of occupational demands experienced, appraisal of those demands, resources, and perceived well-being outcomes (see

TABLE 2 Participant demographics.

Name	Gender	Age	Instrument	Employment
Adam	Male	43	Woodwind	Employed
Ben	Male	29	Brass	Self-employed
Charlotte	Female	48	Woodwind	Self-employed
Daniel	Male	52	Brass	Employed
Eva	Female	49	Strings	Self-employed
Kieran	Male	54	Conductor/Strings	Self-employed

Supplementary material). Participants were asked to provide examples of specific situations in which they had encountered an occupational demand and explored their experiences, actions, thoughts, and feelings. Participants were asked to reflect on two stressful events: one they perceived as a positive experience and one which was a negative experience. Given that interviews took place during the COVID-19 pandemic, some participants were working under exceptional circumstances or had minimal employment within the classical music sector at the time of interview. To enhance the relevance of the research to the broader occupational experiences of classical musicians, participants were asked to discuss events that had occurred prior to COVID-19 or those that were minimally impacted by COVID-19. The interview schedule was piloted with two musicians from the professional network of the first author. Pilot interviews took place between October–December 2020 and included musicians with a range of occupational experiences (including freelance, permanent employment, and chamber music work). Following the pilot interviews, minor changes were made to the interview schedule to refine the clarity of questions, use of prompts, and usability of the interview guide.

Procedure

Ethical approval for this study was provided by the University Ethics Committee. Prior to interview, participants were provided with information sheets and completed a consent form. Participants were reminded of their voluntary involvement and right to withdraw. As a safeguarding consideration, participants were asked to use a location away from others to help safeguard the anonymity of anyone discussed during the interview and maintain confidentiality of the interview content. After completion of the interview, participants were signposted to appropriate organizations should they experience a significant reaction to the interview resulting in a high level of stress and impact on well-being.

Six semi-structured interviews lasting 63–126 min (mean = 92 min) were conducted by the first author with individual participants in February 2021. Due to the COVID-19 pandemic and the necessity to maintain social distancing measures laid out by the Welsh and UK Governments, all interviews were conducted via an online video conference platform (Zoom; https://zoom.us/). Interviews were audio recorded using a digital audio recorder and notes were made following interviews. Interviews were transcribed using an automatic online transcription software, Transcribe.[1] Transcripts were then reviewed, manually edited, and pseudonymised. Participants were given the opportunity to check and reflect on their transcript to ensure that text and pseudonyms provided sufficient confidentiality and that they were in agreement that the narrative account was a "genuine" and "authentic" representation of the interview (i.e., member check). Some participants made minor clarifications about the meaning of phrases at this stage.

Data analysis

Data analysis took place between September 2021 and September 2022, and IPA protocols were followed throughout (Smith et al., 2009; Smith and Nizza, 2022). Transcripts were imported into NVivo 1.3 (2020). Transcripts were read and reread by the first author for familiarity and initial exploratory notes were made. Exploratory notes included descriptions of participants' experiences, comments on the use of language, and conceptual notes. From these exploratory notes, experiential statements were developed. Experiential statements were generated from components within CMRT, related psychological concepts, and concise phrases that reflected the exploratory notes made on the transcript. Experiential statements were then clustered into groups through abstraction and subsumption to create Personal Experiential Themes using MindView 7 (MatchWare, 2017, see Supplementary Figure S1). Following this, Personal Experiential Themes were contextualized according to conceptual and temporal elements of the participants' experiences to visually reduce the data. Memos were written detailing how experiential statements fitted within Personal Experiential Themes and exploring relationships between superordinate themes.

Following this, Personal Experiential Themes across transcripts were compared. This was done by clustering Personal Experiential Themes into Group Experiential Themes using mind maps and comparing memos across participants. A table of Group Experiential Themes was created for cross-case analysis and used to refine themes at the group level (Smith and Nizza, 2022). This table included quotes and descriptions of each participant's experience of the stress process. Group Experiential Themes related to the different types of demands that participants experienced.

To address the research questions, participants' experience of each demand was considered in turn, in accordance with elements of the stress process. As such, the table of Group Experiential Themes was expanded to include primary appraisals, underlying properties of stress appraisal, resources, and well-being aligned to each demand described. Each was categorized, described, and an example quote was noted. Categorization was consistent with concepts in CMRT (Lazarus, 1999; Thatcher and Day, 2008), and hedonic and eudaimonic

1 https://transcribe.wreally.com/

TABLE 3 Summary of group experiential themes.

Group experiential theme		Example participant experiences	Type of appraisal				
			Threat	Challenge	Benefit	Harm	Loss
1.	Performance Demands	Daniel: Chamber music performance Eva: Recording project	23	5	7	1	–
1.1.	Performance Standards	Daniel: Maintaining performance standards Ben: High performance standards on tour	6	1	–	–	–
2.	Organizational Demands	Kieran: Touring	21	3	3	–	–
2.1.	Role Demands	Adam: Multiple roles Adam: Presenting concert	4	1	1	–	–
2.1.1.	Responsibility	Eva: Orchestral leader	4	–	–	–	–
3.	Relationship Demands	Charlotte: Colleagues' argument Adam: Management staff relationship	7	–	3	2	2

well-being (Diener et al., 1999; Ryff, 2014). Appraisals were categorized as either threat, challenge, benefit, harm, or loss; underlying properties of stress appraisal were categorized as one of the 10 dimensions identified by Thatcher and Day (2008); resources were categorized as either personal resources or occupational resources; perceived well-being experiences were categorized as either hedonic (positive affect, negative affect, or satisfaction) or eudaimonic (autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, or self-acceptance).

As the initial development of Personal Experiential Themes and Group Experiential Themes was conducted by the first author, critical reflective and reflexive discussions were held with co-authors throughout the data analysis process. Within these meetings, the categorization of experiential statements into Personal Experiential Themes was challenged, preconceived conceptual ideas were discussed, and the influence of insider knowledge was critiqued to better assure interpretations were trustworthy. Additionally, the conceptual representation of superordinate themes and the mind maps created for each participant were critiqued. Further, the conceptual framing of Group Experiential Themes and associated participant quotes was critiqued.

Results

In this section, participants' experiences of the occupational stress process and perceived well-being outcomes are detailed and illustrated by quotations. All six participants are represented in the quotations chosen. Through analyzing the transcripts, three Group Experiential Themes were developed, which were encompassed under Occupational Demands: (a) Performance Demands; (b) Organizational Demands; (c) Relationship Demands. Within each Group Experiential Theme, examples of specific demands, primary appraisal, underlying properties of stress appraisal, resources, and perceived well-being outcomes are illustrated. These components of the stress process are presented together to illustrate the depth of participants' experiences and to preserve the idiographic quality of IPA. Through this representation, the research questions are clearly addressed. A summary of Group Experiential Themes and the types of appraisal participants described is provided in Table 3. An overview of all participant experiences is presented in the Supplementary material.

Theme A: Performance Demands

Performance Demands are operationalized as those demands that related to participants' experience of the musical demands they encountered (e.g., technical demands, musical interpretation demands) and demands directly arising from performance contexts (e.g., recording demands). All participants discussed Performance Demands. Participants largely appraised Performance Demands as a threat (23 appraisals), followed by appraisals of benefit (7 appraisals), challenge (5 appraisals), and harm (1 appraisal).

Daniel was employed as an orchestral musician and occasionally performed chamber music. Daniel discussed performance *demands,* describing the need for greater stamina when performing chamber music due to the need to play more continuously in comparison with orchestral repertoire. Daniel used the simile of a sprinter to describe the differences:

> *It's a bit like asking a sprinter to do a 10k race… You would not say, "Okay. We're just been marking you on your sprinting… Go and do a 10k and be back in forty-five minutes." … it's a similar situation of brass players doing chamber music. So it's different.*

Daniel *appraised* performing chamber music as threatening, demonstrated in his feelings of discomfort: "Like a fish out of water. I feel like a fish out of water." However, Daniel had previously benefitted from performing chamber music and saw the potential to benefit again: "I think, is really good for us… if it's handled correctly." Daniel described the *underlying properties of threat appraisal* of preparation and self and other comparison. Daniel perceived that there was insufficient rehearsal time to achieve a high level of artistic quality: "I think we need preparation… we should be given more… We should be given extra time." Considering self and other

comparison, Daniel compared the standard of chamber music he could achieve currently with his past experience:

> *Having done it to a high level in the past but quite a long time ago, I've got that standard of chamber music in my head and it's very difficult to replicate that just by throwing a bunch of orchestral musicians together and giving them a day or two.*

Regarding "relaxed" performances, Daniel discussed the work resources of relatedness and autonomy: "it's a very collegiate atmosphere in the rehearsals" and "it's quite a musician led project… That works quite well." However, Daniel perceived a lack of organizational *resources* such as time and artistic management: "that's not really being managed artistically at all [laughs]." Despite his discomfort, Daniel experienced a positive affective *well-being* outcome when performing in some chamber music contexts, particularly relaxed concerts. However, overall, Daniel experienced a lack of satisfaction from chamber music performances as he did not find them as beneficial as they could be: "I think are not, are not as satisfying as they could be. Not as satisfying as they should be."

Considering the performance *demands* of a recording project, Eva discussed rehearsing and recording a large amount of material within a tight timeframe: "there is then pressure… if you did not get it right, there is no time to get it right… You have to get it right now [laughs]." Eva needed to perform at a high standard as she was the soloist: "trying to do that absolutely perfectly… a kind of almost unrealistic quest for perfection." Eva *appraised* the recording as a challenge and opportunity for development: "a very nice… way of… growing out of the leader's chair into the soloist chair." Reflecting, Eva appraised a benefit in terms of industry esteem recognition and financial reward. In terms of the *underlying properties of challenge appraisal*, Eva discussed duration and preparation: "I made an arrangement… I prepared that. I prepared the arrangement and the put the music…" Eva used multiple work *resources* including social support and autonomy. Concerning her colleagues, Eva reported tangible support from a producer who took responsibility for scheduling: "they keep an eye on the time… and it was a producer I trusted with my life." Eva discussed emotional support from the orchestral musicians: "it was a wonderful… feeling of being supported… almost carried, carried in a nice way [laughs]," as well as feelings of relatedness. Eva also experienced autonomy demonstrated through the repetition of the word 'I': "I chose the repertoire and I made an arrangement of a harpsichord concerto… I prepared that. I did that. I arranged that. I prepared the arrangement." Eva reported a number of *well-being* outcomes related to this project. Considering positive affect, Eva experienced excitement during the recording due to the appraisal of challenge, and gratitude towards her colleagues. Regarding the finished recording and the appraisal of benefit, Eva was proud: "I am very proud of it. Of course, I'm proud of it… So [laughs] so, so that's brilliant." Eva also discussed eudaimonic well-being and the dimensions of environmental mastery, positive relations with others, and personal growth. Eva demonstrated environmental mastery in her contribution to the artistic direction of the project and through creating arrangements. Eva also developed her practice as a soloist and reported personal growth linked to the benefit appraisal.

Within the theme of Performance Demands, participants discussed demands created by the performance standards required for their roles. Participants described the need to perform to a high standard, which was closely linked with their own and others' expectations. Performance standards were discussed by three participants: Adam, Ben, and Daniel. Participants mostly appraised performing at a high standard as a threat (6 appraisals), followed by challenge (1 appraisal).

Daniel discussed the *demands* of maintaining high performance standards: "recently the day-to-day demands are, for me, are meeting my own expectations." Daniel discussed an occasion when he had done some freelance work outside his employed role. During this, Daniel felt he was not performing at his usual high standards, a feeling that continued when he returned to his substantive role: "I felt as though my playing had gone off track a bit… gone off course a little bit." Daniel *appraised* the situation as threatening due to the possibility of being judged unfavorably by his colleagues: "trying to make sure that… the people around me do not notice a deterioration in my playing [laughs]." Daniel experienced multiple *underlying properties of threat appraisal*: preparation, event uncertainty, and self and other comparison. The performance demands were in the area where Daniel was struggling and he felt unprepared. As a result, Daniel experienced event uncertainty in the form of subjective probability and was unsure whether he could perform at the requisite standard. Further, Daniel compared his performance standards now with his performance standards across his career:

> *When you start off on an instrument your, your progress curves. Your progress line is very steep… once your playing's plateaued and you think, oh, hang on… I'm still putting the work into my playing but it's not getting any better… this is something that I've always taken for granted in my playing and suddenly it feels a bit difficult… you start thinking about that trajectory and you almost, you almost feel like you are on a ballistic trajectory where you have gone up and now you are going down.*

Daniel discussed the work *resource* of colleague social support. On the one hand, Daniel perceived his colleagues as emotionally supportive: "if somebody's genuinely struggling then, then people have a lot of sympathy." On the other hand, Daniel perceived a lack of emotional support from some colleagues: "there are people who, they will not have as much time for somebody who's not, who's struggling with their playing." Daniel also discussed the personal resources of routine practice and mindfulness. Considering mindfulness, Daniel focused on the present moment: "focusing back on the breathing and… the music." Regarding hedonic *well-being*, Daniel experienced negative affect due to the appraisal of threat: "I felt very uncomfortable." Daniel also reported a negative impact on eudaimonic well-being in terms of environmental mastery and his concern about losing skills when he discussed being on a "ballistic trajectory." However, during the performance, Daniel's use of mindfulness restored his feelings of mastery and he was able to perform to a high standard.

Ben also discussed *demands* related to performance standards, which he experienced whilst on an international tour. Ben had been asked to join the tour at very short notice. Although he had not attended the main rehearsals, he needed to fit in with the orchestra members, who were familiar with the repertoire. As a freelancer, Ben understood that being "able to read music quickly and react to it" was a key part of his role. Ben *appraised* the situation as a challenge and believed he would perform "to a good enough standard, if not a high

standard." Ben experienced the *underlying property of challenge appraisal* event uncertainty in terms of his ability to perform at the required standard, feeling "quite confident" in his abilities. Ben discussed using personal *resources* in the form of personal practice and emotion regulation. Ben described how emotion regulation helped him to stay in control of his performance:

> *Try and temper the excitement and the, the energy and the—hate the word but—passion and the emotion… try and put it to one side and just focus on what you are doing, but still be aware that you do enjoy it.*

Ben's feelings of confidence reflect the environmental mastery element of eudaimonic *well-being*. Having performed successfully on the tour, Ben reported an increased perception of mastery, which implied that he appraised the experience as a benefit on reflection.

Theme B: Organisational Demands

Organizational Demands are defined as those demands controlled at the organizational level (i.e., by management staff). These demands included travel, scheduling, and role related demands. Organizational Demands were discussed by all participants and were predominantly appraised as a threat (21 appraisals), followed by benefit (3 appraisals), and challenge (3 appraisals).

Kieran discussed organizational *demands* related to a world tour in terms of accepting the offer to tour and the schedule. He discussed needing to make a quick decision whilst also considering his family:

> *They said, "Look, we are off on a world tour next year… would you come and conduct all of the orchestras?" To which this time, I did not consult with my wife. I just said, "Yes." And then went home and we had a consultation.*

Kieran *appraised* a threat, in that he might lose the opportunity if he did not act quickly: "if you say no, people will just move on." Kieran also appraised the tour as a challenge: "It was an opportunity came and, and I thought, right. I'm going to try this. I'm going to go headlong into it." In this situation, Kieran experienced the *underlying property of threat appraisal* event uncertainty as he was unsure how long the opportunity would be available. He accepted the opportunity with the knowledge that he could later refuse. Kieran discussed the personal *resource* of family social support: "we sat down and we made that choice as a group, as a family… So those things are always important."

Considering the tour itself, Kieran discussed the *demands* of travelling and performing in different countries: "You'd be in Taiwan for three or 4 days, and then you were in China, and then Indonesia, then Malaysia, then to Japan, then Hong Kong…" Kieran *appraised* the tour as a challenge and on reflection made an appraisal of benefit: "I learned much about myself by doing the touring." He later said, "[Touring] gave me what I have now… career as a conductor and as a, as an all-round portfolio-type musician." Kieran discussed the *underlying property of benefit appraisal* of novelty in relation to visiting different countries: "there were always new experience to have, new foods to try." Kieran thought of the tour as a development opportunity, which is a work *resource*: "I gave myself the opportunity to take that and run with it." Kieran discussed several positive *well-being* outcomes. Related to the appraisal of challenge, Kieran experienced positive affect: "that was terribly exciting." Regarding the appraisal of benefit, Kieran experienced the positive affective outcome of gratitude. Further, linked to the appraisal of benefit, Kieran experienced the eudaimonic well-being outcome personal growth by realizing what was important:

> *I learned that I did not need quite so much stuff in my life… there were certain things that were very important to me… two little books, one, one for each tour, my wife built for me with pictures of my kids in… I had little notes that were written by the children… So, those things were important. But I realized that I did not need, you know, oodles and oodles and oodles of clothes.*

Additionally, Kieran experienced increased environmental mastery through conducting on the tour: "really opened my eyes to so many other things. Of what I was, I thought that I probably wasn't capable of… And that I became very capable of eventually."

Role Demands

Within Organizational Demands, participants discussed role-related demands, such as role insecurity, role conflict, and role strain. Role conflict related to the demands of holding multiple roles within and across organizations, and role strain related to the level of responsibility a musician had within their organization. Role Demands were considered by Adam, Ben, and Daniel. Mostly, participants appraised Role Demands as a threat (4 appraisals), followed by challenge (1 appraisal), and benefit (1 appraisal).

Adam discussed role conflict and the *demands* of performing multiple roles at the same organization. Due to a vacancy, Adam was required to perform in his employed role and two additional roles. Although the roles were related, they required changes to Adam's performance: "that's probably one of the biggest demands for me… I like to think of it as wearing different hats… even moving two seats along left or right, it's amazing how different it feels." Adam discussed a chamber music performance where he played in the principal position. Adam *appraised* a threat in this situation and experienced role instability: "there's a sort of fragility to it…" Further Adam appraised a threat due to the potential for being judged negatively and being asked not to perform in the principal role: "The management have the power to say, 'I'd rather you did not do that anymore.'" Adam experienced the *underlying property of threat appraisal* temporal uncertainty when performing in the principal role as he knew the role was being advertised yet he did not know when he would be required to stop performing the role. Considering *resources*, Adam used the psychological technique of minimization: "I'm quite happy where I am… I have not got much ambition to sort of climb the ladder and become a principal." Adam implied that this experience had a negative impact on his *well-being* due to the appraisal of threat and he discussed the issue with management: "I felt I needed to communicate what though, what that… for my own confidence and my own mental health."

Adam discussed another occasion when he experienced role related *demands* due to presenting a concert: "there's been recently opportunities to stand up front, in front of the orchestra and be a presenter." Adam introduced the concert, talked to the audience between pieces, and performed his instrumental role. Adam *appraised*

the demands as challenging: "Yeah, I also had to play. That was… also the challenge." Further, Adam appraised a benefit to his career from presenting: "something that stands me out from my other musicians." Adam experienced the *underlying property of challenge appraisal* of novelty as this was the first time he had presented a concert for the full orchestra. Adam also experienced self and other comparison as an *underlying property of benefit appraisal*:

> *Here's something I think I can do that not a lot of my colleagues can do. Because a lot of my colleagues would not ever stand up and talk to… a big audience. And a lot of them to be honest probably would not be very good at it.*

Adam drew on the same personal *resources* he used for musical performances and used imagery during rehearsal: "imagining that there was the audience there… it's exactly the same thing that I have done… as a musician." Adam described his preparation: "I scripted what… I was going to say and then I condensed it into bullet points, and then I put those bullet points… onto a card." There was a positive impact on Adam's hedonic *well-being* as a result of his appraisals of challenge and benefit: "I felt very good. I felt very good doing it actually, which is probably why I want to do more of it because it felt like a, a good experience… I felt very happy."

Responsibility

Role Demands also encompassed role strain and the level of responsibility participants held. Demands relating to responsibility were discussed by Charlotte, Eva, and Kieran, and were solely appraised as a threat (4 appraisals).

Considering a prestigious orchestral performance, Eva had an elevated level of responsibility: "I was guest leading it, I usually just play in the section there." Eva discussed the responsibility of an orchestra leader and the *demands* this created:

> *You have to make sure that the conductor gets what, what he or she wants to get and then the orchestra's needs are met. As in, is the conductor clear enough? … you have to play and you have to lead your section, so that your body language… conveys how and when the section should play… And if there's any question, if the conductor is not clear at any point, then the leader's job is to kind of rescue the situation and be very clear and, and save the day, as it were. And gave a big gesture—here, we are now.*

Within this scenario, the conductor made an unexpected and unclear gesture: "In the concert X Conductor did something… slightly different from what… [they] did in every rehearsal." As the leader, Eva felt it was her responsibility to "rescue the situation… and save the day." However, Eva was not able to bring the performers together: "there was a bit of a car crash." Eva *appraised* a threat to her employment as she had not adequately fulfilled the role of leader: "being in the, in the leading chair, there is a responsibility with you." Further, she appraised a threat to her employment due to her colleagues' perception of the event: "It made me feel fearful of what my colleagues think of me." Eva also appraised the event as causing lasting harm: "it leaves you pretty, you know, pretty… scarred." Eva reported the *underlying property of threat appraisal* of self and other comparison in two ways: firstly, there is the implication that Eva compared her leadership to the ideal she described; secondly, Eva was concerned about being negatively evaluated by her colleagues according to acceptable industry standards. Additionally, Eva experienced ambiguity in trying to evaluate whether she had correctly interpretated the conductor's gesture: "whether I was right or wrong, I still do not know." To cope, Eva used workplace *resources* and sought emotional and informational social support from her colleagues. Eva used informational support to address the ambiguity: "I wanted an honest opinion. What they think happened… That was a good way of… getting some clarity for myself." Additionally, Eva used psychological skills in the form of self-talk to regain a sense of control:

> *It left me needing to have a kind of chat with myself and think, okay. So, what exactly happened? What could I have done differently? … what aspect of that was, you know, something that was in, that is in my control to change now?*

This experience had a lasting negative hedonic *well-being* outcome related to Eva's appraisal of harm and she experienced anxiety: "even now when I talk about it… I feel the knot in my stomach." Eva was also dissatisfied and felt disappointment: "It made me… disappointed with myself." Reflecting, Eva moved towards self-acceptance, a dimension of eudaimonic *well-being*: "I wasn't sure that in that moment I could have done anything differently… so, like an instinct, instinctive reaction."

Theme C: Relationship Demands

Relationship Demands are defined as demands that involved interpersonal relationships between musicians and their colleagues and/or management staff. Four participants discussed Relationship Demands: Adam, Ben, Charlotte, and Kieran. Relationship Demands were appraised mostly as a threat (7 appraisals), followed by appraisals of benefit (3 appraisals), harm (2 appraisals), and loss (2 appraisals).

Charlotte discussed an occasion when an argument had taken place and created a relationship *demand*: "During the rehearsal… [there] was an enormous row between… a small group of players, including my co-soloist and the management… about the way the stage was set." Following the argument, one of the musicians left the rehearsal. This occasion related to a performance where Charlotte was performing as a co-soloist, which was a role she performed infrequently. Charlotte made an *appraisal* of threat and perceived a risk of becoming involved in the argument:

> *Initially, I was not in the same room… I'll just keep my head down and stay out the way. Because the last thing you want when that's going on is to stick your head round the door and find out.*

After the concert, Charlotte appraised that loss and harm had been caused. Considering loss, Charlotte said of the colleague who left the rehearsal, "You spoiled a day that was a really important one for me." Considering harm, Charlotte used the simile "it just felt like we'd all had a kicking." Although not part of the argument, Charlotte was vicariously affected and experienced the *underlying property of threat appraisal* of predictability. This was due to the fact that usual workplace norms regarding colleague interactions had not been followed. Considering the underlying property of the loss appraisal, Charlotte experienced novelty as this was not her typical experience. Charlotte employed personal *resources* and used avoidance and

emotion regulation. Regarding avoidance, at the time of the argument Charlotte tried to "stay out the way," and additionally avoided the situation during the break. Charlotte also focused on her breathing: "I try and remember to breathe [laughs]—really deeply… if you concentrate on it, you can help yourself a lot." Charlotte discussed multiple negative hedonic *well-being* outcomes. Related to the appraisal of threat, Charlotte experienced anxiety: "unsettling, upsetting, unpleasant." Linked to the appraisals of harm and loss, Charlotte experienced anger and sadness: "I just felt really angry," and "it just left me feeling incredibly upset." Further linked to the harm and loss appraisals, Charlotte was dissatisfied as the experience had not lived up to her expectations: "I felt upset because usually I get a lot of positivity from engaging in ensemble work, especially with that group of people." Regarding eudaimonic well-being, the dimension positive relations with others was negatively affected, particularly with the musician who left the rehearsal: "I just thought you selfish so-and-so."

Adam described how his relationship with management staff created a *demand* for a chamber music performance:

> *[Pause] Now [Pause] I want, you see [laughs] there was, there is a bit of background to this in that prior to that… there was a, a miscommunication from my management, where they said… that they were going to get… a guest in to play that part, rather than me, have me do it… So, the reason for this was because, as I said, there're only two of us in the orchestra at the moment. The other… the actual principal wasn't available. So that basically leaves just one person left. That's me. Or, the management can decide that they do not want me to do it and they want to bring a guest in.*

Initially, Adam thought that the management's final decision was to employ a guest performer for the occasion. Adam *appraised* the demand as a threat to his reputation in the orchestra: "What that communicates to me… they'd rather not have the risk of… using me, who's on salary, so I do not cost them any more money… this will make me feel that you have, I have not got your trust." Adam experienced the *underlying property of threat appraisal* self and other comparison and was concerned about evaluation both by management and his colleagues. Adam's perception of management was that they had "a perceived hierarchy… and I do not fit into the… top tier." In terms of evaluation by colleagues, Adam said, "in the paranoid part of my brain started thinking, blimey… has one of my colleagues said, 'I'd rather not have Adam play this part'?" Adam used problem solving as a personal *resource* and decided to speak with management: "I had a little bit of a conversation with them, had to email them about this… yeah, it was a miscommunication but I had to communicate." Adam implied that the situation had a negative impact on his *well-being*: "I felt I needed to communicate… what that… for my own confidence and my own mental health."

Discussion

This study sought to interpret the lived experiences of perceived occupational stress and well-being of professional classical musicians through understanding the demands faced, appraisals made, resources used, and the perceived influence on self-reported well-being. Each of these aspects is addressed in turn in the discussion below followed by consideration of the relationship between these elements of the stress process and well-being outcomes. The following sections are aligned to the five research questions outlined in the Introduction.

Perceived demands (RQ1)

Participants discussed demands within the Group Experiential Themes: (a) Performance Demands; (b) Organizational Demands; (c) Relationship Demands. These themes relate to the categories of occupational demands experienced by classical musicians as identified in a systematic review by Vervainioti and Alexopoulos (2015). The theme Performance Demands included demands related to performance contexts, exposure, and performance standards. Given the centrality of performances to musicians, it is unsurprising that participants often discussed Performance Demands. Such demands occurred across a variety of settings including orchestral and chamber ensembles, recording sessions, and auditions, all of which have been considered in the literature (e.g., Parasuraman and Purohit, 2000; Brodsky, 2006; Lim, 2014; Kegelaers et al., 2022). Participants also discussed the demand of meeting high performance standards, which related to high self-expectations and the perceived expectations of others. Similarly, Creech et al. (2008) reported that self-doubt regarding the ability to meet high performance demands was a significant challenge for musicians.

Organizational Demands related to those demands controlled at the level of the organization (i.e., by management), which included touring schedules, travel, and role-related demands. Zendel (2021) suggested that the demands of touring, such as frequent travel and scheduling issues, could increase the precarity experienced by professionals. The experience of role-related demands might be due to the complexities of the work environment, and participants discussed role insecurity, role conflict, and role overload. Adam discussed two contrasting situations involving Role Demands. Firstly, Adam described performing across multiple roles within one organization. Here, Adam focused on the differences between the roles, which led to role conflict, which Anglin et al. (2022), Appendix C defined as "the occurrence of two or more incompatible behavioral expectations." Secondly, Adam described presenting and performing within the same concert. However, this did not create role conflict and Adam viewed the roles as complementary. Adam's experience is representative of the multiple roles musicians take on within a portfolio career and the findings suggest that role conflict may occur when roles are perceived as incompatible.

Relationship Demands related to interpersonal relationships with colleagues, peers, management staff, and audiences. Participants often discussed demands associated with colleagues, which may be due to the importance of such relationships for work opportunities and performance outcomes. Indeed, Dobson (2010a) discussed the term "professional sociability" and suggested that high interpersonal skills could lead to work retention and future work opportunities.

Primary appraisals and underlying properties of stress appraisal (RQ2)

Across all demands experienced, threat appraisals were most commonly reported. A small number of demands were appraised as a

challenge or benefit and the fewest appraisals were made for loss and harm. The frequency of threat appraisals suggests that the occupational environments of professional classical musicians can be characterized as threatening. Similarly, in a study of popular musicians, occupational demands were most commonly appraised as a threat (Cohen, 1999). However, Cohen (1999) reported that harm was the second most frequent appraisal, followed by challenge and benefit.

Threat appraisals frequently related to employment security, career advancement, and negative judgement by colleagues or management. The precarious employment conditions and threats to employment security that musicians experience have been discussed in the literature (Dobson, 2010a; Umney and Kretsos, 2015; Chafe and Kaida, 2019). Musicians often work on a freelance basis, which may lead to employment uncertainty alongside financial insecurity (Chafe and Kaida, 2019). That participants perceived a threat due to the potential for negative judgement by colleagues is also relevant to employment security. Coulson (2012) described the importance networking played in obtaining employment, with colleagues providing performance opportunities. Colleagues' perception of performance skills is therefore crucial for musicians to be able to access employment.

Challenge appraisals were made when participants were in unusual circumstances but had experienced similar scenarios previously. This suggests an element of prior learning and reflection, where participants have previously benefitted from engaging with similar demands. Participants believed they could experience personal growth through taking on demands, which suggests they perceived the demands as an opportunity. Within CMRT, Lazarus (1999) suggested that perception of opportunity is part of the transactional stress process and contributes to challenge appraisal. Another potentially relevant concept is growth mindset, which is the belief that one's traits are malleable and can be changed through effort (Dweck, 2008). Dweck and Yeager (2019) suggested that individuals with a growth mindset are more likely to seek out challenges, which may explain why participants made challenge appraisals when in unusual situations.

Benefit appraisals were made when participants perceived that the experience had been beneficial to their career, personal development, or audiences. Often, benefit appraisals were made after taking on new roles that represented career progression. Given the precarity of musical careers, many musicians adopt portfolio careers that encompass activities such as performance, teaching, and composing (Thomson, 2013). Portfolio careers may provide stability for musicians through regular engagements or teaching work, whilst also allowing time for performance work (Umney and Kretsos, 2015). Therefore, taking on new roles may have provided increased employment security and thus been perceived as beneficial.

Harm and loss appraisals related to not meeting the perceived role requirements and low-quality experiences. Consistent with CMRT (Lazarus, 1999), harm and loss appraisals were made when participants were unable to achieve their goals and perceived negative consequences. Harm and loss appraisals have been explored in high performance sports coaching (Didymus, 2017). Similarly to the present study, sports coaches reported harm or loss when they were unable to achieve their goals or perceived damage to their well-being.

Participants reported experiencing all 10 underlying properties of stress appraisal (Thatcher and Day, 2008). Two novel findings regarding underlying properties of stress appraisal emerged from this study. Firstly, participants discussed preparation more broadly than suggested by Thatcher and Day (2008), referring not only to inadequate preparation but also to adequate preparation. Secondly, considering self and other comparison, participants made direct as well as indirect comparisons.

Preparation was largely discussed in relation to practice and a significant body of literature exists on the topic of deliberate practice in music (e.g., Hambrick et al., 2014; How et al., 2021; Kegelaers et al., 2022). When participants discussed adequate preparation, they were more likely to report positive performance outcomes and the opposite was true for inadequate preparation, a finding reflected by Clark et al. (2014). A possible reason why adequate preparation was not suggested as an underlying property of stress appraisal by Thatcher and Day (2008) was that participants discussed their most stressful competition experience. Therefore, the situations considered are likely to have involved significantly high levels of demand. Contrastingly, in the present study, participants were asked to describe two demanding scenarios: one perceived negatively and one perceived positively. This may account for why adequate preparation emerged as an additional underlying property of stress appraisal.

The most common underlying property of stress appraisal was self and other comparison, which was observed in two ways. Firstly, participants made direct comparisons between themselves and colleagues or their past selves. Secondly, they compared themselves to a tacit industry standard, which caused them to be concerned about evaluation from colleagues. These can be considered as indirect comparisons and this type of self and other comparison is a novel finding of the present study. Considering direct comparison, participants compared themselves both favorably and unfavorably suggesting a balanced perspective. Self and other comparison is embedded in the careers of classical musicians, due to auditions and orchestral trial periods, which can last months or even years (Noden, 2017). Musicians are in direct competition in auditions, which may encourage individuals to compare their skills (Kegelaers et al., 2022). Considering indirect comparisons and the need to perform in line with professional standards, participants were concerned whether their performances were of a high enough standard and the potential for losing work due to poor performances. Similarly, self-employed musicians reported that musical ability was an important aspect of their reputation (Portman-Smith and Harwood, 2015). Freelance jazz musicians have also described a need to prove themselves during performance (Dobson, 2010b).

Occupational and personal resources (RQ3)

Participants discussed using both personal and occupational resources to cope with the demands they experienced, frequently relying on personal resources. Personal resources included the use of psychological skills, problem solving, performance preparation, emotion regulation, and avoidance. Workplace resources included social support from colleagues, development opportunities, provision of autonomy, and organizational resources. Participants used resources that were appropriate to the type of demand they experienced: for instance, using psychological skills to address performance demands. In this section, the resources referred to most often are considered, including psychological skills, social support, and development opportunities.

Psychological skills used by participants included imagery, mental rehearsal, self-talk, cognitive restructuring, and mindfulness techniques. The results from a systematic review by Ford and Arvinen-Barrow (2019) suggested that psychological skills interventions are effective in supporting musicians to cope with demands and can lead to enhanced performance skills, reduced anxiety, and greater self-efficacy. Participants had developed their psychological skills through formal and informal learning: Adam had received cognitive-behavioral therapy (CBT); Daniel's interest in meditation led him to use mindfulness techniques. Adam perceived the psychological skills he had learnt during CBT as effective for managing performance demands and continued to apply the techniques in performances.

Participants considered social support from colleagues, supervisors, and audiences. Colleague social support and its relevance to professional musicians has been examined in the literature (e.g., Dobson and Gaunt, 2015; Ascenso et al., 2017; Parker et al., 2019). In the present study, participants discussed different types of social support including emotional, esteem, informational, and tangible support, which aligns with the work of Cutrona and Suhr (1992). Popular musicians have reported using informational support in the form of sharing information and skills between band members (Vaag et al., 2014). Musicians also provide tangible support in the form of work opportunities for colleagues and accommodation (Coulson, 2012). Whilst the majority of the participants perceived that colleague social support was available, Daniel described a lack of colleague support and instead relied on his personal resources. Social support from supervisors and audiences was also discussed by participants although less frequently.

Development opportunities were also discussed as an organizational resource. These opportunities allowed participants to work in different settings. Some participants perceived a lack of development opportunities within their roles or that the available opportunities were inadequate. This may be due to the flat organizational structure of orchestras leading to limited opportunities for career progression.

Well-being experiences (RQ4)

Participants reported both hedonic and eudaimonic well-being outcomes. They discussed acute emotional responses at the time of experiencing occupational demands (i.e., positive and negative affect) alongside long-term well-being outcomes (i.e., satisfaction and eudaimonic well-being), which aligns with CMRT (Lazarus, 1999). Considering positive affect, participants experienced enjoyment, excitement, inspiration, and pride due to their musical experiences. Similarly, Ascenso et al. (2017) reported that music-making was an important contributor to positive emotions in classical musicians. Participants also discussed negative affective outcomes in the form of somatic anxiety such as feeling discomfort. Participants reported acute anxiety due to performance scenarios and a large body of literature exists regarding MPA, its prevalence, and possible interventions (e.g., Kenny, 2011; Fernholz et al., 2019).

Participants described experiencing satisfaction and dissatisfaction as an outcome. Satisfaction was reported when performances had gone well, aligning with research which suggests making-music is itself a source of satisfaction for musicians (Coulson, 2012). Participants reported dissatisfaction when either their own performance or the actions of others failed to live up to their expectations. This is similar to research from the occupational literature, which suggests that unmet expectations may have a negative impact on job satisfaction (Murray, 2008; Irving and Montes, 2009).

Alongside hedonic well-being outcomes, participants reported experiencing all six dimensions of eudaimonic well-being. They frequently referred to environmental mastery, which was linked to performance outcomes: positive performance outcomes led to increased environmental mastery; conversely, negative performance outcomes led to decreased environmental mastery. Environmental mastery is similar to the concept accomplishment, which is part of Seligman's (2011) PERMA framework and has been explored in musicians (Ascenso et al., 2017). The experience of environmental mastery may be due to the fulfilment or thwarting of competence, which is a basic psychological need within the framework of Self-Determination Theory (Deci and Ryan, 2000).

Personal growth was discussed by participants in relation to working in new settings and gaining new perspectives on themselves and their work. This finding is echoed in research on critical life events in sport and music where individuals have reported experiencing personal growth through increased maturity, greater self-understanding, and developing perspective on what was important (John et al., 2019). Purpose in life, self-acceptance, and autonomy were discussed less frequently by participants.

Connections between stress and well-being (RQ5)

In this section, connections between the stress process and well-being outcomes are considered. Well-being outcomes related to the type of appraisal participants made. Threat and challenge appraisals related to acute hedonic well-being experiences. Threat was related to the experience of negative affective well-being outcomes and challenge was related to positive affective well-being outcomes. Researchers assessing the role of stress appraisals for employee well-being have reported similar findings. For instance, threat appraisals have been related to higher distress and anger, whereas challenge appraisals have been related to higher positive affect (Searle and Auton, 2015; Tuckey et al., 2015). Tuckey et al. (2015) suggested that threat appraisals may have a negative emotional impact due to the threat to basic psychological needs. Conversely, challenge appraisals may lead to positive affect due to the fulfilment of basic psychological needs.

Longer term well-being outcomes, including satisfaction and aspects of eudaimonic well-being, were related to appraisals of benefit and harm/loss. Satisfaction was also related to positive impacts on eudaimonic well-being experiences (e.g., increased environmental mastery) and was connected with appraisals of benefit. This often related to the effective use of resources, which was associated with successful performance outcomes. Harm and loss appraisals were connected with dissatisfaction and experiences that negatively impacted eudaimonic well-being (i.e., related to ill-being). Such experiences were associated with ineffective use of resources and negative performance outcomes. Additionally, harm and loss appraisals were associated with negative affective outcomes, such as anger, when participants perceived they had been wronged or mistreated. It is important to note the temporal element of appraisals and associated well-being outcomes: challenge and threat appraisals

were made prior to events and affected acute well-being outcomes; benefit and harm/loss appraisals were made following events and led to lasting well-being outcomes.

Implications

Regarding underlying properties of stress appraisal, the results demonstrate that "inadequate preparation" should be revised to "preparation," as participants discussed being both adequately and inadequately prepared. Preparation could be defined as "the extent to which an individual feels prepared for performance." Additionally, self and other comparison could be expanded to account for comparisons with perceived industry standards and be defined as "comparing any physiological, psychological, or social aspect of performance or the associated environment with that of another individual or perceived occupational standards." The comparison to a tacit standard may reflect how classical music is taught. Smilde (2009) suggested that tacit knowledge is often communicated by an experienced individual in close proximity over a number of years. The reliance on tacit knowledge could mean that many aspects of the occupational environment remain unspoken (a hidden curriculum), which could explain why musicians compare themselves to a tacit industry standard rather than agreed and explicit standards.

Practical implications for professional orchestras relate to continuing professional development (CPD) and creating socially supportive environments. Given that participants made challenge appraisals when in new or unusual circumstances, CPD represents one way to provide such experiences. For orchestral musicians, this could be achieved through performing in smaller ensembles, programming concerts, or working in healthcare or educational settings. Findings from qualitative research suggest that working in educational and community contexts positively impacts musicians' well-being and facilitates the development of new skills (Preti and Welch, 2013; Ascenso, 2016; Forbes and Bartlett, 2020a). For such opportunities to be appraised as a challenge rather than a threat, it is important they are adequately resourced. This means musicians need appropriate time, training, and support. For those working in healthcare settings, this could be training to understand specific conditions, introductions to specific models of working, or peer learning sessions (Perkins et al., 2018; Forbes and Bartlett, 2020b; Shaughnessy et al., 2023).

In terms of social support, orchestra managers can provide different types of support, such as informational support (e.g., feedback on performance), tangible support (e.g., finance to attend counselling), emotional support (e.g., talking to musicians about how they are feeling), and esteem support (e.g., acknowledging when tasks are done well; Cutrona and Suhr, 1992). For musicians who frequently work with the same ensemble, regular conversations with section principals, ensemble leaders, or orchestra managers could be established. This could allow musicians to receive feedback in a non-threatening environment and provide an opportunity to discuss CPD. Regular conversations could allow managers to build social connection with musicians, making them more comfortable to discuss issues when they do arise. The results also highlight the importance of social support from colleagues. Increasing musicians' abilities to support each other could be achieved by delivering training on communication and collaboration skills through reflective exercises and group activities (e.g., Jungert et al., 2018). Research from the wider occupational literature suggests that such interventions may be effective for increasing colleagues' abilities to support each other in terms of basic psychological needs, and, in turn, positively impact well-being and motivation (Slemp et al., 2021).

Strengths, limitations, and future directions

This is the first qualitative study to explore the stress process and perceived well-being outcomes from the perspective of CMRT (Lazarus, 1999) in professional classical musicians. Further, this is the first qualitative study to explore appraisals and underlying properties of stress appraisal in this population. The relationship between primary appraisal and well-being outcomes highlights the role of the individual in the stress process and the importance of transactional approaches for assessing stress and well-being in classical musicians. Thatcher and Day (2008) based their underlying properties of stress appraisal on situations perceived as extremely stressful. The inclusion of demands perceived as both positive and negative allowed for further development of the underlying properties of stress appraisal.

However, we acknowledge the limitations of the current study, in which data were collected during the COVID-19 pandemic. To increase the relevance of the results to the broader occupational environment, participants were asked to consider their usual workplace experience, which relied on participants accurately remembering and representing their experiences. Further, due to the idiographic nature of the research the sample was small. Whilst consistent with IPA, the findings are based on the experiences of a few participants.

In future, researchers should consider asking participants to reflect on situations that they perceive both positively and negatively to elicit understanding of the stress process and well-being outcomes rather than focusing on experiences that are considered as detrimental to the individual. Additionally, researchers can use the expanded definitions for preparation and self and other comparison proposed in this study. Including not only inadequate preparation but preparation more broadly provided a better understanding of why different types of appraisal were made. Given the nature of IPA research and focus on small sample sizes, future research could be conducted with a large sample of musicians using quantitative methods. This could include cross-sectional or longitudinal questionnaire studies that assess the different aspects of the occupational stress and well-being process, and the relationships between these concepts.

Considering the evidence presented here, researchers could conduct interventional studies that address occupational stress and well-being in musicians. At an organizational level, interventions could target social support in the workplace and professional development programmes. Given that many musicians work in a freelance capacity, the music industry could create well marketed and funded networks for musicians that support them to develop the resources needed for a thriving career. At an individual level, further intervention studies are required to establish how professional musicians can be taught psychological skills as the majority of research has been conducted with students.

Conclusion

This study took a qualitative approach to assessing occupational stress and well-being in professional classical musicians. Across occupational demands, threat appraisals were most frequent, which suggests that the occupational context of classical musicians can be characterized as threatening. The main threats perceived by participants related to career and employment security. Self and other comparison and preparation were two important underlying properties of stress appraisal. We provided updated definitions for both concepts. Participants described personal resources and organizational resources, often discussing social support. Through using resources, participants often described successful outcomes, particularly in terms of performance. Stress appraisals were seen to relate differentially to well-being outcomes. Threat and challenge appraisals, which are future orientated, related to acute hedonic well-being outcomes in the form of positive and negative affect. Benefit and harm/loss appraisals, which are orientated towards the past, related to satisfaction and eudaimonic well-being.

Data availability statement

The datasets presented in this article are not readily available because they are restricted to the author team in accordance with Cardiff Metropolitan University ethics committee. Requests to access the datasets should be directed to SW, WillisS5@cardiff.ac.uk.

Ethics statement

The studies involving humans were approved by Cardiff School of Sport and Health Sciences Ethics Committee (Cardiff Metropolitan University). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

SW: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. MM: Conceptualization, Formal analysis, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. RN: Conceptualization, Formal analysis, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. DW: Conceptualization, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Personality traits in musicians with different types of music performance anxiety

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Introduction: This study investigated the relationship between personality traits and MPA in the course of a specific performance.

Methods: For this purpose, symptoms of MPA, functional coping with MPA and performance-related self-efficacy of a sample of 393 musicians including 23% professional, 49% non-professional orchestra musicians and 28% singers in amateur choirs were categorized and then used to analyze differences in the personality traits. The questionnaires used were the NEO-FFI and the PQM.

Results: The results showed that professional orchestra musicians had significantly higher openness and conscientiousness than non-professional orchestra musicians and amateur choir singers. Musicians who had few symptoms of MPA, positive coping with MPA and high self-efficacy across a specific performance (Type 1) have low neuroticism in their personality traits. Regarding MPA, the personality traits were correlated with all MPA scales after the performance but less with MPA scales before and during the performance.

Discussion: Results could indicate that personality traits play a particularly important role in the processing of performance experiences after the performance and suggest focusing on the situation after the performance in particular with professional orchestra musicians.

KEYWORDS

music performance anxiety, personality traits, neuroticism, amateur musicians, professional orchestra musicians

1 Introduction

A variety of factors contributes to the experience of music performance anxiety (MPA). MPA is generally described as a state of excitement, which can cause negative symptoms of stress reactions (Spahn, 2015; Guyon et al., 2020), but can at its optimal level also enhance a performance. These factors cover a wide spectrum of personal characteristics and self-perceptions, such as self-efficacy, emotionality, perfectionism, fear of negative evaluation, and manifestations of general anxieties (Kenny, 2011; Spahn, 2015; Osborne and Kirsner, 2022). The personality of musicians in particular is an important factor in the development of MPA (Smith and Rickard, 2004; Chattin, 2019; Rodriguez-Mora and Lopez Diaz, 2020; Herman and Clark, 2023).

To describe personality traits, the multidimensional personality inventory NEO-FFI (1989) developed by Costa and McCrae (1989) was mostly used, with which five essential characteristics, the so-called Big Five, are surveyed according to the five-factor model. These

factors are (1) openness to experience (2) conscientiousness, (3) extraversion (4) agreeableness and (5) neuroticism.

Openness to experience stands for tolerance and interest towards new things (also on an intellectual level), and a positive attitude towards art and culture. Open people are usually inventive, innovative, decent, level-headed and interested (Pervin, 2000). *Conscientiousness* stands for the realization of the goal direction of action. People with a pronounced conscientiousness are well-planned, conscientious, reliable, action-oriented and ambitious (Pervin, 2000). *Extraversion* stands for the passion with which emotions are lived out, on the one hand in contact with one's environment, and on the other hand one's own impulses, such as the expression of joy. Extraverted people are typically talkative, active, powerful, decisive and bold. Introverts are accordingly afflicted with the opposite characteristics (Pervin, 2000). *Agreeableness* stands for helpfulness and selflessness. People with this trait are confident, gentle, collaborative, generous and giving (Pervin, 2000). *Neuroticism* stands for the assimilation and handling of one's own emotionality to external influences. Neurotic people are often impatient, restless, frustrated, sensitive and fickle (Pervin, 2000).

Using the NEO-FFI personality trait questionnaire, a number of studies have investigated the influence of musicians' personality traits on the general manifestation of MPA. Rodriguez-Mora and Lopez Diaz (2020) investigated a sample of 72 musicians between 16 and 54 years old with the KMPAI-E (Kenny, 2011) to measure MPA and with the NEO-FFI to measure personality traits. The results showed a positive correlation between MPA and neuroticism ($p < 0.01$) and a negative correlation of MPA with extraversion ($p < 0.01$) and responsibility ($p < 0.05$).

In line with this, Chattin (2019) found in her study with 55 collegiate music piano majors a significant relationship between the Big Five personality types and levels of MPA. Overall results indicated that certain personality constructs studied in this research do have an impact on MPA. Findings suggest that neuroticism, worry, self-focus and somatic tension affect performers negatively, while openness, conscientiousness, and perceived control likely helped to alleviate MPA. Males reported higher levels of perceived control than females.

Herman and Clark (2023) conclude in their review on MPA that studies consistently report significant associations between MPA and high levels of maladaptive personality traits, neuroticism and MPA being strongly associated (Valentine et al., 1995; Langendörfer et al., 2006; Thomas and Nettelbeck, 2014).

More recently, studies have been conducted to determine whether different types can be described in the way MPA occurs (Papageorgi, 2021; Spahn et al., 2021). Papageorgi (2021) identified three clusters among adolescent instrumental learners with low, medium and high anxiety, who developed adaptive MPA through good self-esteem and positive coping as well as maladaptive MPA in the case of negative self-perceptions.

Spahn et al. (2021) investigated how dispositional MPA relates to performance-specific MPA. Regarding performance-specific MPA, they found three different MPA types across a specific performance. Type 1 describes musicians who have few symptoms of MPA throughout the performance, show functional coping with MPA, and have a stable and well-developed self-efficacy. Type 2 describes musicians who begin their performance with rather high symptoms of MPA but can positively reduce these by the end of the performance and show high values in self-efficacy and in functional coping. Type 3 contains musicians who begin their performance with some symptoms of MPA, which increase to the end of the performance. The values of self-efficacy and functional coping in this type are rather low. Professional musicians were more often distributed in MPA Type 3 than amateur musicians.

The discrimination of the three types of MPA was also found in young amateur brass musicians (Spahn et al., 2023). Most of the musicians were found to be in MPA Type 1. These findings were in accordance with the three clusters found by Papageorgi (2021) by using similar criteria. This shows the reliability of the classification of three MPA types.

The present study aimed to examine for the first time whether musicians in the different performance-specific MPA groups (Spahn et al., 2021) differ in terms of their personality traits.

The objective was to investigate the relationship between personality traits and MPA in the course of a specific performance:

How do personality traits relate with symptoms of MPA, functional coping with MPA and performance-related self-efficacy before a performance, during the performance and after the performance?

For this purpose, symptoms of MPA, functional coping with MPA and performance-related self-efficacy of a sample of musicians were categorized and then used to analyze differences in the personality traits.

2 Material and methods

2.1 Participants

The sample of this study consisted of 393 musicians including 23% professional and 49% non-professional orchestra musicians and 28% singers in amateur choirs (see Table 1). The classification into these musical subgroups was based on the musical level of the orchestras. Professional orchestra musicians had main occupations at radio symphony orchestras or philharmonic orchestras. The non-professional orchestra musicians came from student orchestras and semiprofessional orchestras. The amateur choir singers were amateur singers in semiprofessional choirs. The sample is a sub-sample of the study Spahn et al. (2021).

In total, 59.6% were female musicians. There was a significant distribution difference between the musical subgroups [χ^2 (398, 2) = 27.7, $p < 0.001$] with more females among the choir singers than among the orchestra musicians.

TABLE 1 Characteristics of the sample.

	Professional orchestra musicians	Non-professional orchestra musicians	Amateur choir singers
Amount ($N = 393$)	$N = 89$ (23%)	$N = 195$ (49%)	$N = 109$ (28%)
Gender (% female)	43.2%	56.4%	79.2%
Age (in years, SD)	43.4 (13.2)	25.2 (9.6)	28.7 (13.4)

The mean age of the sample was 30.2 years [SD = 13.6 years]. The professional orchestra musicians were significantly older than the non-professional orchestra musicians and the amateur choir singers [F (2,381) = 74.5, $p < 0.001$], with the latter two being mostly students.

The distribution of the instruments were 45% strings (with 79% in the professional and 57% in the non-professional orchestras), 13% woodwind instruments (with 12% in the professional and 22% in the non-professional orchestras), 29% singers (all in the choirs) and 13% other instruments such as percussions and brass instruments.

2.2 Measures

2.2.1 NEO-five-factor-inventory

For measuring the personality traits, the German version of the NEO-FFI (NEO-Five-Factor-Inventory) was used (Körner et al., 2002). The questionnaire measures Neuroticism, Extraversion, Openness, Agreeableness and Conscientiousness. In the short version with 30 items (Körner et al., 2008) statements regarding the described personality characteristics were rated on a Likert scale from 0 (strongly disagree) to 4 (strongly agree) and a mean scale value was calculated for each personality trait.

2.2.2 Performance-specific questionnaire for musicians

MPA was measured with the Performance-specific Questionnaire for Musicians (PQM, see Spahn et al., 2021). The questionnaire refers to the times directly before, during and after a music performance. It needs to be completed shortly after a performance, whereby the questions relating to the times before and during the performance are answered retrospectively. In total, 33 items need to be answered on a Likert scale between 1 (does not apply) and 5 (fully applies) with 11 items per time point. At each time point, three scales were calculated: functional coping, referring to the positive effects of MPA, symptoms of MPA, referring to physical and mental impacts of MPA, and self-efficacy, which comprises the belief in the personal ability to perform.

With the responses of 532 musicians, three types of MPA have been categorized using a cluster analysis (Spahn et al., 2021). Musicians in Type 1 reported of few symptoms of MPA, showed high functional coping with MPA, and a stable and well-developed self-efficacy across the whole performance. Musicians of Type 2 began the performance with considerable high symptoms of MPA but reduced them by the end of the performance. They also showed high values in self-efficacy and functional coping. Type 3 contained musicians with moderate symptoms of MPA at the beginning of the performance, which increased to the end of the performance. They showed low values in self-efficacy and functional coping. The musicians were classified 50% as Type 1, 27% as Type 2 and 23% as Type 3 (Spahn et al., 2021).

A further seven items were used to assess the self-rated quality of the performance. The items refer to specific musical parameters, such as tempo, intonation, dynamics, and were rated on a Likert scale from 1 (badly) to 6 (excellent). The mean value of all seven items builds a specific judgment score. The higher the score the better the musicians valued their own performance quality.

2.3 Design

After concerts of the orchestras and choirs, the musicians were asked to fill in the questionnaires as pen-and-paper version. The concerts were regular concerts of the music group in line with their normal performance schedule and with standard repertoire. In the off-stage facilities, the musicians were given the questionnaire by an experimenter, who informed them about the study and that participation was completely anonymous and voluntary. The study was granted ethical approval by the Ethics Committee of the University Clinic Freiburg.

2.4 Data analysis

The statistical analyses were performed using SPSS (Version 29, Armonk, NY: IBM Corp.). Descriptive statistics including mean and standard deviation (SD) were calculated for each variable. To analyse distribution differences of non-parametric variables Chi-square (χ^2) tests were performed. Parametric comparisons on the PQM scales and the NEO-FFI personality traits were calculated with multivariate ANOVAs. On significance, *post hoc* analyses with Tukey HSD correction were performed. A canonical correlation analysis (CCA) was conducted using the NEO-FFI personality traits and the PQM scales to evaluate the multivariate shared relationship between the two variable sets. The level of statistical significance was set at 0.05.

3 Results

3.1 NEO-five-factor-inventory

The multivariate analysis of the NEO-FFI scales across the three musical subgroups within the whole sample found significant effects in the scales openness [F (2,390) = 3.38, $p = 0.035$] and conscientiousness [F (2,390) = 3.83, $p = 0.022$] (Table 2). The effect in openness was caused by higher values in the professional musicians

TABLE 2 Mean values of the NEO-FFI scales with standard deviation by musical subgroup (*$p < 0.05$).

NEO-FFI	Professional orchestra musicians (N = 89)	Non-professional orchestra musicians (N = 195)	Amateur choir singers (N = 109)
Neuroticism	1.38 (0.70)	1.51 (0.80)	1.38 (0.77)
Extraversion	2.52 (0.50)	2.60 (0.60)	2.54 (0.55)
Openness	**2.92*** (0.65)	**2.74*** (0.68)	**2.68*** (0.66)
Agreeableness	2.99 (0.58)	2.83 (0.70)	2.91 (0.72)
Conscientiousness	**3.05*** (0.54)	**2.82*** (0.66)	**2.90*** (0.71)

compared to the choir singers [Post-Hoc, $p = 0.035$] and in conscientiousness by higher values in the professional musicians compared to the amateur musicians [Post-Hoc, $p = 0.016$].

There were also significant main effects for gender in the neuroticism scale [$F(1,383) = 6.32$, $p = 0.001$] and in the agreeableness scale [$F(1,383) = 15.66$, $p < 0.001$] with higher values for the female musicians in both scales. However, there were no significant interaction effects for gender and musical subgroup.

3.2 Performance-specific questionnaire for musicians

The mean values of the PQM scales for each musical subgroup are listed in Table 3. The multivariate analysis across the three musical subgroups found several significant main effects. Before the performance, in the scale symptoms of MPA [$F(2,390) = 6.24$, $p = 0.002$] the non-professional musicians were significantly higher than the professional musicians [Post-Hoc, $p = 0.037$] and the choir singers [Post-Hoc, $p = 0.004$] and in the self-efficacy scale [$F(2,390) = 5.11$, $p = 0.006$] the choir singers were significantly higher than the professional [Post-Hoc, $p = 0.013$] and the non-professional orchestra musicians [Post-Hoc, $p = 0.016$]. During the performance, in the scale functional coping [$F(2,390) = 2.19$, $p = 0.02$] the choir singers were significantly higher than the non-professional musicians [Post-Hoc, $p = 0.016$], in the scale symptoms of MPA [$F(2,390) = 10.68$, $p < 0.001$] the non-professional musicians were significantly higher than the choir singers [Post-Hoc, $p < 0.001$] and the professional musicians [Post-Hoc, $p = 0.013$] and in the self-efficacy scale [$F(2,390) = 5.98$, $p = 0.003$] the choir singers were significantly higher than the professional [Post-Hoc, $p = 0.006$] and the non-professional orchestra musicians [Post-Hoc, $p = 0.008$]. After the performance, in the scale functional coping [$F(2,390) = 15.91$, $p < 0.001$] the choir singers were significantly higher than the professional [Post-Hoc, $p < 0.001$] and the non-professional orchestra musicians [Post-Hoc, $p < 0.001$] and in the scale symptoms of MPA [$F(2,390) = 7.83$, $p < 0.001$] the choir singers were significantly lower than the professional [Post-Hoc, $p < 0.001$] and the non-professional orchestra musicians [Post-Hoc, $p = 0.003$].

3.3 Correlations between NEO-five-factor-inventory and performance-specific questionnaire for musicians

The canonical correlation analysis (CCA) yielded five functions with 59.5% explained variance for the full model across all functions with the first three functions being significant. Since the first function [$F(45,1,698,5) = 4.81$, $p < 0.001$] already explained 55.4% of the variance shared between the variable sets, only this function was considered for further analysis. In this function, the questionnaires correlated with Pearson's $r = 0.498$ with each other (see Figure 1). The explained variance for the NEO-FFI questionnaire was 32.7% and for the PQM 35.9%.

For the analysis of the individual predictor variables, only correlation coefficients above $r = 0.5$ were considered. The results showed that neuroticism, extraversion and conscientiousness were the primary contributors for the prediction on the NEO-FFI side and the self-efficacy scales at all performance times as well as all scales after the performance on the PQM side. While extraversion and conscientiousness were positively related, neuroticism was negatively correlated. For the PQM scales, self-efficacy and functional coping showed positive and symptoms of MPA negative correlation coefficients.

The correlations between the NEO-FFI personality traits with the self-assessed judgment score of the performance quality found significant correlation coefficients only for neuroticism [$r = -0.22$, $p < 0.01$] and extraversion [$r = 0.23$, $p < 0.01$]. These correlations are moderate to low. The negative correlation of neuroticism describes that musicians with higher neuroticism rated their performance lower. Musicians with higher values of extraversion rated their performance as better.

3.4 Types of MPA

The types of MPA were distributed to 52% in Type 1, 23% in Type 2 and 24% in Type 3. In a multivariate analysis, extraversion,

TABLE 3 Mean values of the PQM scales with standard deviation by musical subgroup (*$p < 0.05$ and **$p < 0.01$; in bold: highest value if significant).

PQM	Professional orchestra musicians	Non-professional orchestra musicians	Amateur choir singers
Before the performance			
Functional coping	4.21 (0.68)	4.19 (0.75)	4.29 (0.73)
Symptoms of MPA	1.92 (0.94)**	**2.20 (0.91)****	1.86 (0.78)**
Self-efficacy	3.79 (0.71)**	3.84 (0.69)**	**4.07 (0.71)****
During the performance			
Functional coping	4.21 (0.82)*	4.16 (0.70)*	**4.41 (0.75)***
Symptoms of MPA	1.76 (0.83)**	**2.05 (0.79)****	1.64 (0.72)**
Self-efficacy	3.98 (0.71)**	4.04 (0.67)**	**4.28 (0.69)****
After the performance			
Functional coping	4.06 (0.71)**	4.30 (0.73)**	**4.60 (0.57)****
Symptoms of MPA	1.77 (0.76)**	1.68 (0.70)**	**1.40 (0.72)****
Self-efficacy	3.98 (0.81)	4.02 (0.81)	4.20 (0.84)

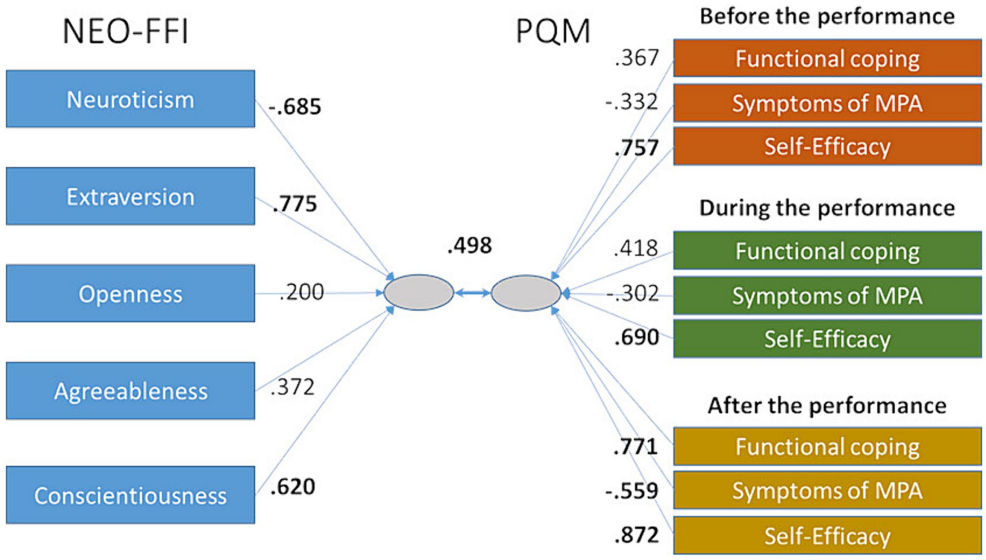

FIGURE 1
Outcome of the CCA between NEO-FFI and PQM showing the canonical correlation coefficients (in bold: relevant correlations).

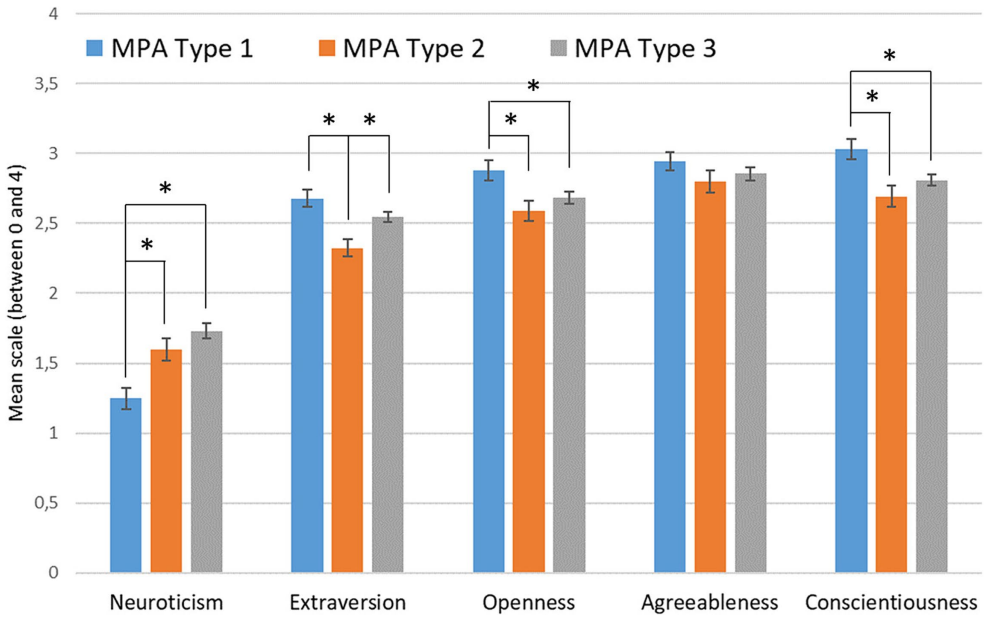

FIGURE 2
Mean values of the NEO-FFI scales (error bars show standard error of the mean) by MPA Type (*$p < 0.05$).

openness, neuroticism and conscientiousness showed significant main effects across the three types of MPA [F (2,390) > 7.0, $p < 0.01$] (see Figure 2).

The detailed comparisons showed that musicians of MPA Type 1 had significantly lower mean values in the neuroticism trait than the musicians of the other Types [Post-Hoc, $p < 0.01$]. Furthermore, the musicians of MPA Type 1 had also significantly higher values in the extraversion scale than the musicians of Type 2 [Post-Hoc, $p < 0.01$] but not of Type 3. Here, the musicians of Type 2 had significantly lower values than of Type 3 [Post-Hoc, $p = 0.017$]. For the openness, musicians in Type 1 were significantly higher compared to musicians in Type 2 [Post-Hoc, $p = 0.002$] and in Type 3 [Post-Hoc, $p = 0.047$]. Musicians of the MPA Type 1 were also higher in the conscientiousness trait than musicians of Type 2 [Post-Hoc, $p < 0.01$] and of Type 3 [Post-Hoc, $p = 0.015$]. Except for the extraversions scale, the mean values of the musicians in Type 2 and 3 did not differ significantly in the personality traits.

4 Discussion

This study investigated the relationship between personality traits and performance-related MPA in professional and non-professional orchestra musicians and amateur choir singers.

4.1 Personality traits

In the NEO-FFI personality traits, the three musical subgroups differed only in openness and conscientiousness. Professional orchestra musicians showed significantly higher openness and conscientiousness than non-professional orchestra musicians and amateur choir singers.

This is in contrast to the results of Kuckelkorn et al. (2021), where the other personality traits did also differ significantly between professional and non-professional musicians. Using the NEO-FFI personality trait questionnaire, Kuckelkorn et al. (2021) found differences between professional and amateur musicians with higher values in openness and neuroticism as well as lower values in agreeability and conscientiousness in professional musicians compared to the amateur musicians.

Our results appear comprehensible due to the different situation and requirements in which professional musicians find themselves compared to non-professional musicians and choir singers. For example, professional musicians must be more conscientious in order to meet professional standards. At the same time, being open to new experiences is particularly well suited to the profession of orchestral musician, especially as a high degree of flexibility is required in the music profession.

Female musicians in our study showed higher values in neuroticism and agreeableness than male musicians. This was found similarly in other studies (Herman and Clark, 2023).

4.2 Performance-related MPA

In the evaluation of the PQM scales, the amateur choir singers stood out in comparison to professional and non-professional orchestra musicians with the highest self-efficacy before and during the performance. Amateur choir singers were best able to cope with MPA during the performance and had the fewest symptoms of MPA after the performance. Ryan and Andrews (2009) were also able to show that choir singers suffer from MPA, but that performances in instrumental ensembles triggered stronger MPA than choir performances.

Possibly due to less experience and playing skills than the professional orchestra musicians, the non-professional orchestra musicians showed the strongest symptoms of MPA before and during the performance. Interestingly, the professional orchestra musicians had the lowest self-efficacy at all three time points of the performance and remained at the same level of symptoms of MPA, especially after the performance. As self-efficacy can be influenced by high expectations and perfectionism, these lower values among professional orchestra musicians can be linked to this. From the perspective of musicians' medicine, it could be important for professional orchestra musicians to consciously relax in the situation after the concert and improve their self-efficacy through positive self-assessment.

4.3 Correlation between personality traits and MPA

The results of our study show a positive correlation between self-efficacy and extraversion in relationship to MPA. These results were generally supportive of the theoretically expected relationships between personality traits and MPA in particular and are in accordance with Rodriguez-Mora and Lopez Diaz (2020).

Similarly, the findings on the correlation of higher levels of neuroticism and stronger MPA in other studies (Valentine et al., 1995; Smith and Rickard, 2004; Langendörfer et al., 2006; Thomas and Nettelbeck, 2014; Chattin, 2019) were confirmed. Additionally, musicians with higher neuroticism rated their performance lower. Musicians with higher values of extraversion rated their performance as better.

The relation of personality traits and aspects of MPA at a performance differed between amateur and professional musicians. Interestingly, among the professional musicians, neuroticism was only associated with the post-performance situation. This could indicate that personality traits play a particularly important role in the processing of performance experiences after the performance and would again focus in particular on the situation after the performance with professional orchestra musicians.

4.4 Types of performance-specific MPA and personality traits

The musicians were divided into three MPA types according to Spahn et al. (2021) and in accordance with Spahn et al. (2023) and Papageorgi (2021). Musicians of Type 1 differed significantly from musicians of the other two Types 2 and/or 3 in the personality traits by higher extraversion, openness and conscientiousness and lower values for neuroticism.

In particular, Type 1 differed from the other two types in that openness and conscientiousness were stronger here. Chattin (2019) also found both personality traits to be able to reduce MPA. This could be interpreted to the effect that these musicians have more flexibility in the performance situation while at the same time being more conscientious in their preparation.

The correlations between low neuroticism and adaptive MPA from previous studies (Smith and Rickard, 2004; Chattin, 2019; Rodriguez-Mora and Lopez Diaz, 2020; Herman and Clark, 2023) are thus also confirmed with regard to a specific performance situation. The proximity between anxiety and neuroticism also makes it possible to relate the present results to the study results of Papageorgi (2021).

4.5 Limitations of the study

Even though the present study is based on a large sample, it should be borne in mind that the sample is rather heterogeneous, consisting of professional and non-professional musicians, as well as orchestra musicians and choir singers. The results obtained here should therefore be replicated in large, homogeneous samples.

Furthermore, the PQM was applied for each musician only once and for one performance. It might be interesting to investigate how

personality traits may affect more than one performance of the same person.

5 Conclusion

The present study shows that musicians who have few symptoms of MPA, a positive coping with MPA and a high self-efficacy regarding performance have lower neuroticism and higher openness and conscientiousness in their personality traits. This indicates an influence of personality traits on the performance practice of musicians. The results confirm the findings of previous studies and emphasize the importance of identifying musicians who are less advantaged by their personality traits and providing them with long-term support in the form of appropriate techniques and measures to improve their self-efficacy and coping with MPA.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Committee of the University Clinic Freiburg. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because the study was completely anonym and the participants read a study information with all necessary data protection information. With filling in the questionnaire, they agreed for participation. The study was reviewed and approved by Ethics Committee of the University Clinic Freiburg.

Author contributions

CS: Conceptualization, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. FK-H: Data curation, Methodology, Writing – review & editing. JH: Conceptualization, Formal analysis, Writing – review & editing. AI: Conceptualization, Methodology, Writing – review & editing. MN: Conceptualization, Formal analysis, Methodology, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1398095/full#supplementary-material

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Questioning evidence-based practice in physiotherapy: a philosophical reflection. *The example of physiotherapy with musicians*

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Introduction: In the late 1990s, evidence-based medicine (EBM) emerged, emphasizing the conscientious use of current best evidence in medicine and ensuring the best care for each individual. Thus, applying evidence-based practice (EBP) in physiotherapy is complex due to sparse research, distinct challenges, and unsuitable tools. This is particularly relevant considering musicians' health since the literature is very limited.

Part I: The first part advocates for EBP and explain how it ensures both the best care and adherence to ethical principles (beneficence, non-maleficence, respect for autonomy, and justice), for both caregivers and patients.

Part II: The second part discusses the common pitfalls often encountered by healthcare professionals, and especially as physiotherapists for musicians, when applying evidence at the patient's bedside, again from both perspectives, healthcare professionals and patients.

Part III: Finally, this third part aims to open the discussion by considering various perspectives, such as values-based practice or the importance of qualitative research, to reshape EBP in physiotherapy.

Conclusion: This work highlights the prevalent existence of *grey zones* encountered by healthcare practitioners with musicians. While conducting more research to help understand them, physiotherapists must learn to navigate these waters.

KEYWORDS

evidence based practice (EBP), musicians' health, physiotherapy, ethics, performance

Introduction: evidence-based practice with musicians, a philosophical issue

Evidence-based medicine was defined in the late 1990s as the "conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients" (Sackett et al., 1996). Paramedical professions adopted this approach, and to avoid excluding these professions, we prefer the use of "evidence-based practice" instead of medicine, which now seems inappropriate and limited.

In his *princeps* paper (Sackett et al., 1996), David Sackett states that the philosophical foundations of the evidence-based approach date back to at least mid-19th century Paris, likely referring to French positivism and experimental medicine. The Evidence-Based Medicine Working Group (1992) has described EBM as being a "paradigm shift," clearly referring to Kuhn (Kuhn, 1983) and his conception of changes in scientific paradigm, discussing the importance of the "development of clinical instincts" (regarding what cannot be tested) and the understanding of "certain rules of evidence," important for the well-read and implementation of the proof with our patients. Evidence-based practice (EBP) was therefore defined under the famous shape of the following tryptic: the combination of research evidence, clinical expertise and patient preferences (Haynes et al., 2002). Since then, this tryptical definition has been reshuffled due to much criticism, mainly the lack of a clear relationship between the three circles which are theoretically of equal value (Bizouarn, 2019).

Moreover, five principles have been described, highlighting the relationship between EBM and our daily clinical practice (i.e., second principle, "secondly, the clinical problem – rather than habits or protocols – should determine the type of evidence to be sought") (Davidoff et al., 1995). The connection between EBP and clinical practice requires deeper description. In *The Birth of Clinic* (Naissance de la Clinique), Michel Foucault (French philosopher, 1926–1984) describes the different paradigms that followed one another regarding medicine and its main object: illness. Foucault described how the medical sight on the individual has permitted "a scientifically structured discourse" by removing "the old Aristotelian forbidding," and thought the "singular colloque" of the care relationship to be one with an asymmetrical power balance, using sarcasm and phrases like the "the doctor-patient couple" (Foucault, 2003).

If EBP promoters consider it a foundational necessity in clinical practice, this contrasts with Maël Lemoine's (contemporary French philosopher) view. He argues that the clinic should be considered as a very specific procedure to medicine, binding observations (joining Foucault here) and explanations. In that respect, the clinic cannot be merely equated to proof integration. In his work "The disunity of medicine," Lemoine explains how medicine consists of different fields not specific to medicine (i.e., physics, chemistry, biology), and therefore, different explanations coexist (Lemoine, 2011). For Lemoine, the only specific approach in medicine is the clinic, which cannot be confused with the traditional evidence-based approach since it is only a statistical explanation of medicine, or with EBP since it is only an "evaluation approach of one aspect of clinical practice (therapeutic decision), based on statistical methods which in medicine belong rather to the epidemiological subfield" (Lemoine, 2011).

The use of scientific evidence in medicine is not new. In the 19th century, after the decline of anatamo-pathological medicine, Claude Bernard's approach of experimental medicine experienced an impressive rise. And in the mid-20th century, Hill theorized the randomized controlled trial (RCT) (Hill, 2011), which is now a pillar of the evidence hierarchy. EBP classifies and ranks evidence based on quality and inherent risk of bias: at the top of the pyramid, we find RCTs, systematic reviews, meta-analyses and overviews (Howick et al., 2011). However, while RCT minimizes bias through randomization and blinding, it does not allow researchers to open the "black box" of underlying physio-pathological mechanisms (Rogers and Hutchison, 2017). This may explain why the external validity of RCTs, and their applicability to clinical practice in populations or conditions outside of those tested, is disputable. This element of external validity and applicability is what makes the treatment of musicians using EBP difficult. Can we really apply exercises described for swimmers to violinists lacking scapular stabilization (Tawde et al., 2016) or understand low back pain in pianists by comparing them to office workers?

Moreover, this primarily concerns the clinical questions which have been investigated in research. How is it possible to apply evidence with double bassists while specific research on this instrument is scarce, if not non-existent (Levenderis and Rennie-Salonen, 2022)? One might also wonder about the relevance of the tools used in many studies: is the Rated Perceived Exertion Scale the most appropriate to evaluate musical performance (McCrary et al., 2016), or Rapid Entire Body Assessment for investigating playing postures? (Valenzuela-Gómez et al., 2020). To this day, to the best of our current knowledge, no one has undertaken to reflect on evidence-based practice at the musicians' bedside, by mobilizing both scientific references and philosophical insights to better understand what is at stake.

Thus, here is the question we are asking: in the specific context of musician's health, does EBP provide the best guarantee of care, or is it a chimera (an unattainable ideal) or a straightjacket?

Methodological considerations

This philosophical research work is conceived in three parts. Two contradictory theses about the implementation of evidence-based practice and its pragmatic approach in the context of musicians' physiotherapy are presented in part one and two, considering treatment and prevention. The third part consists of a synthesis of these two opposing arguments and provides perspectives for both clinicians and researchers, who may recognize themselves in the question raised throughout this reflective paper. This cannot be considered as a standardized literature review but rather as a cross-reading of a selected *corpus* consisting of scientific research and philosophical works.

Part I: evidence-based practice, a guarantee for best healthcare

For professionals, providing the best healthcare

EBP evaluates the best available evidence on treatments or diagnostic tools and, depending on the pathology and individual case, seeks to provide the best solution for healthcare practitioners. This is a reassuring approach for caregivers, particularly for younger caregivers who cannot rely on their own clinical expertise. In that respect, the difference between knowledge and practice must be emphasized – knowing the evidence is not enough to know how to apply them. This is where the clinical experience enters the scene and how the two circles of the triptych overlap. This is apparent when examining trained professionals in the McKenzie method, who have more reliable abilities to classify low back pain patients than those who are not trained (Garcia et al., 2018).

In addition, being familiar with best and latest scientific evidence also means being able to communicate them to our patients and argue with our peers. This competence allows to effectively explain to other healthcare practitioners who may advise injured musicians to abruptly interrupt their instrument practice, that this sudden stop may not be beneficial in the long term (Stanhope and Weinstein, 2021).

Finally, basing clinical practice on evidence requires an acknowledgement of, and adherence to, biomedical ethics principles (Beauchamp and Childress, 2013). First, this approach facilitates equity in healthcare access: evidence-based healthcare for all. Then, as previous studies have highlighted both the effectiveness and harmlessness of the treatments in question, professionals are certain to respect beneficence and non-maleficence. Finally, since patients' choices cannot be followed without full information first and consent later, EBP is also responsible for respecting patients' autonomy.

For patients, receiving the best healthcare

Without reiterating here all the beneficial aspects that EBP provides for patients, a few key points should be enumerated. First, knowing that the healthcare professional one may face knows and uses the best evidence is extremely comforting for patients and constitutes probably one of the best ramparts against quackery. Moreover, as patient choices assume an important role, EBP respects the patients' right to information, free will, and autonomy (Greek, *autos*: oneself and *nomos*: law), in the Kantian sense of the word and of his "*sapere aude*!" (dare to know) (Kant, 1991).

This new "epistemic share of knowledge between caregiver and care receiver" (Stiegler and Alla, 2022) transforms the therapeutic relationship, especially as patients, in addition to the information they receive from professionals, are also now much more informed through the internet. For musicians, considered as patients, the situation is positively changing: while they often express a lack of knowledge (Rousseau et al., 2020), this could progressively change.

As a result of a second paradigm change concurrent to EBP, namely the emergence of a biopsychosocial model in place of the biomedical one, we now know to take care of our patients much more holistically, considering not only their physiological situation but the social and physiological factors may influence their health.

Evidence-based practice on a social scale

Incorporating the highest evidence in our clinical practice serves to be beneficial for humanity and bodes well for social justice. According to utilitarians but also to John Rawls in his *Theory of Justice* (Rawls, 2005), it is our duty to fight against injustice and inequality [since it cannot be considered as a "fact of nature" (Spitz, 2011)], in this context unequal healthcare access. Theoretically, our French healthcare system entitles all individuals to the best healthcare, most of them being refunded by national solidarity, regardless of their life or work habits. Smoking does not mean that someone's cancer will not be treated using the best level of evidence or cost more compared to someone who has never touched a cigarette. Having chosen to become an orchestra musician does not mean that they may be considered responsible for work-related ear issues.

Moreover, in its more recent definitions, the concept of healthcare resources has been added to EBP (Rogers and Hutchison, 2017), considering the sanitary context. Together, EBP and *New Public Health* inform the QUANGOs (QUasi Non-Governmental/QUasi-Autonomous National Government Organisations) that disseminate guidelines and assess practices. However, it should be mentioned that these recommendations are often designed for very frequent pathologies, not considering specific cases such as musicians' common injuries.

Part II: evidence-based practice, between straightjacket and pipe dream

Combining clinic and research: does the "healthcare practitioner-researcher" exist?

While the evidence-based approach strives provide the best healthcare, it is highly complex. The question remains: how can we adapt the protocols of RCTs, which are carried out on drastically different populations to our patients? And how do we cope with the *grey zones*, "where the evidence about risk–benefit ratios of competing clinical options is incomplete or contradictory," that we particularly face with musicians (Naylor, 1995)? How do we answer our clinical questions to tackle focal dystonia when evidence is lacking?

Also, although the theoretical borders of EBP have been thoroughly described, articulating the three circles of the triptych is still left to one's interpretation. Moreover, integrating the highest evidence level in clinical practice requires donning the researcher's three-piece costume: find, read, and appraise. But to put it on, you have to own it, and many barriers to EBP have been highlighted in literature. Such barriers include reading in English (for non-native speakers), mastering scientific methods (i.e., statistical tools, methodological bias) or simply having access to literature and being able to perform searches (Da Silva et al., 2015). For example, it is essential to have access to peer-reviewed journals such as the *Medical Problems of Performing Artists* journal in order to apprehend a great number of issues about musicians' health. It would be dishonest not to mention the dramatic time-consuming nature of reading papers, when most of healthcare practitioners already experience the downward spiral of their entangled professional and personal lives.

The RCT, being at the top of the evidence hierarchy in EBP, provokes questioning. RCTs have been criticized for several reasons, including their mediocre external validity (and an excellent internal validity), therefore limited applicability to real-world practice, their inadequacy to certain practices such as physiotherapy (contrariwise to pharmaceutical trials), and their ignorance of the *black box* and the contextual elements of interventions (Rogers and Hutchison, 2017). For example, if prevention programs for playing-related musculoskeletal disorders may have a significant effect on performance or on injury prevalence, this does not answer the following question: why they do have an effect? And in the context of musicians, it is difficult to conduct an adequately powered trial due to

the limited number of participants. This leads researchers toward conducting epidemiological studies, the results of which must be considered with extreme caution.

Limited samples are especially an important issue in studies of risk factors. Indeed, few existing systematic reviews (Baadjou et al., 2016; Kok et al., 2016) have concluded that there is too much heterogeneity in the data among primary studies, whether regarding the populations of musicians studied (professionals, students, amateurs) or the used definition of PRDMs. This led other research teams to work on risk factors in a different way, in order to describe them while being very cautious about how to interpret their significance in the development of these disorders. Chan and Ackermann (2014) in their literature review provide details about non-modifiable and modifiable risk factors. Rousseau et al. (2021) in their study combining narrative review and interviews (conducted with orchestra musicians and specialized healthcare professionals) provide a comprehensive theoretical model describing nine categories (individual characteristics, posture, biomechanics, injury management, workload, physical activity, life habits, environment and psycho-social factors). Current research is already evolving the definition of PRMDs (Zaza et al., 1998), moving toward a more comprehensive definition of "performance-related pain" (Zão et al., 2024) and an associated questionnaire, which may help researchers to better investigate risk factors and provide brighter comparisons between their different works.

Patient of the *Lumières*: the "know and decide" injunction

Although the first part describes how patients could endorse the role of the "patient of the *Lumières*" (referring to the eighteenth-century Age of Enlightenment), informed and deciding for himself, it should be noted the place from which the patient speaks. As Susan Sontag has written, "illness is the night-side of life, a more onerous citizenship" (Sontag, 1978). Talcott Parsons has theorized the moral obligation of being a "good patient" in the eyes of society. Thus, although solidly informed, patients may struggle in formulating their own choices and decisions – "*sapere aude*!" (Kant, 1991) is a difficult injunction to satisfy. Moreover, is it reasonable to expect that scientific literature search and reading, already a difficult task for healthcare professionals, can be easily and adequately performed by our patients? Despite all our goodwill, it is almost impossible to erase this asymmetrical power that resides in the therapeutic relationship, as emphasized by Foucault. This brings to mind an anecdote: the situation of Rémi, a 14-year-old violinist, striving to become a professional musician. Suffering from an injury to his right wrist for several months, his rheumatologist, after having recommended to him to stop instrumental practice first for 2 weeks, then 1 month, advised him to stop playing the violin and change to another instrument. However, after a few weeks of postural rehabilitation and strengthening exercises, Rémi was able to play to pre-injury levels. What exactly happened between Rémi and his rheumatologist which almost resulted in the sudden break of a career that had barely begun?

Finally, since patients are the ontological object of research, it seems important to mention the crucial role that patients themselves could play in the development of trial protocols to identify and answer the clinical questions that are most meaningful to them. This integration of the patient perspective into study design leads to identification of cellists as musicians who would like to play on adaptable chairs (and thus evaluate the effects on their posture and performance) or orchestra musicians as ones who would like to have their own stand instead of sharing it. Example is research done by Spahn et al. (2014) in which standing and sitting position have been investigated in upper string players ($n = 16$) using posturography and 3D motion analysis. Results show that musicians report a preference for the standing position rather than the sitting position, reporting better weight distribution while standing, as well as greater freedom of movement. However, this does not reflect their professional daily life in the orchestra, as instrumentalists play most of the time seated. Spahn et al. (2014) highlighted that being seated on the right or on the left of the music stand impacted the weight distribution in a contralateral way (e.g.: loading the right side more than the left one while sitting on the left side of the stand). Although these conclusions should be considered with caution, they are interesting for reconsidering the working environment of musicians and collaborating with them to maximize the prevention of PRMDs.

Globalization and control: evidence-based practice to the test of society

Some of the major promoters of EBP, including John Ioannidis, claim it has been "hijacked" (Ioannidis, 2016). A vivid example of this is the pharmaceutical bias, which is still often overlooked and poorly corrected. A clinical trial funded by the pharmaceutical industry will be three to four times more likely to be published than its public counterpart. Also, Ioannidis warns us about the use of big data in research which, according to him, could gradually overwhelm the scientific method.

Evidence is also a political, cultural, and social entity (Goldenberg, 2010), and we need to bear in mind the "power relationships internal to the world of scholars" which Bernard Lahire (French sociologist), while prefacing and commenting Norbert Elias' work (German sociologist), describes as both "cooperation and competition relationships" (Lahire, 2016).

Mirroring the evidence crisis, the clinic faces tremendous challenges. As described by Stéphane Velut in his essay "Hospital, a new industry," the clinic is flooded by consulting firms (Velut, 2020) and finance-based medicine (Ioannidis, 2016), converting the stock-hospital to a flow-hospital. It must be acknowledged that musicians do not represent a large "market share."

Finally, it appears particularly relevant for musicians, whose professional lives vary considerably from one to another, that ignoring social factors while assessing health in individuals (which is much more difficult to investigate and evaluate compared to psychological factors) opens the door to potential therapeutic failure. As an example, advising orchestra musicians to increase their breaks number and duration could be considered as a tremendous idea from a physiological standpoint and it is often advocated (Chan and Ackermann, 2014), but it is unrealistic in practice when you have to rehearse and perform with both the orchestra and conductor.

Part III: evidence-based practice, a worthwhile approach

In this last part, few hypotheses will be discussed to remedy the previously mentioned challenges in the EBP of musicians.

Values-based practice

First, we would like to consider the *values-based practice* as our primary hypothesis (Fulford, 2004). This concept does not reject scientific evidence; instead, it emphasizes that many therapeutic failures stem from value conflicts and that it is essential to view the clinical practice as an alliance between evidence and values. Fulford, an American psychiatrist, highlighted language and communication as mediums through which we can better understand patients' values and encompass those of healthcare professionals. A *values-based practice* shows great promise in facilitating better dialog between these two perspectives, which often struggle to comprehend each other. For example, injured musicians often delay seeking help because they fear being told to interrupt their instrumental practice (Stanhope and Weinstein, 2021).

Reconsider the psychosocial factors

As previously mentioned, the well-named biopsychosocial model (Engel, 1977) attempts to merge the biological causes of diseases with the psychological and social factors that can influence their onset or chronification. However, while psychological factors are very often investigated in research and assessed in the clinic, social ones do not share the same fate, despite their undeniable importance. We are convinced that social factors are critical, but in most cases, it is impossible to take any action to alter them. Consider the orchestra musician: apart from his personal practice, nothing falls within his personal agency – in his position in the orchestra or his practice breaks, there is no room for manoeuver. The same can be said of other professions such as home support or delivery workers and this heart-breaking "Sorry we missed you" by Ken Loach, in Manchester suburbs (Sorry we missed you, 2019).

Give clinical expertise its due

Finally, healthcare practitioners and researchers face a great challenge: the imperative to reintegrate clinical expertise. It appears that conducting qualitative studies – that is to say, exploring life experiences, emotions and feelings of both patients and professionals – may contribute to be achieve success in this endeavor. This approach has been undertaken several times in specialized literature in musicians' health, such as studies investigating the lived experience of musicians with playing-related injuries (Guptill, 2011) or representations of body and health (Schoeb and Zosso, 2012). In both these studies, attention is focused on the individual experiences of musicians: one concerning their life with their injury and their often difficult care journey (Guptill, 2011), the other on their awareness (or lack thereof) of the importance of the human body in serving instrumental performance (Schoeb and Zosso, 2012). Questioning individuals on their proper life allows one to refute the mind–body dualism, as both Dewey (1916) or Canguilhem (1966) have done previously, to travel to the ends of the biopsychosocial model, and to capture all the aspects of the "vicissitudes of life."

Conclusion

According to the EBM working group's explicit notion that "the new paradigm puts a much lower value on authority," it may appear medical paternalism is vanishing. However, one form of authority must not hide another, and the use of evidence must not become a dogma. When treating musician patients, while research is still scarce and methods sometimes unsatisfactory, physiotherapists and other specialized healthcare professionals may often find themselves navigating across the *grey zones* of clinical practice (Naylor, 1995). This paper highlights the importance of conducting further research on musicians' health and well-being, as it is supported by reviews and clinical trials, aforementioned in this manuscript, but also the meaning and significance of being *uncertain* while facing specific disorders or health conditions. Both uncertainty and autonomy, along with the possibility of therapeutic failure, are philosophical concepts that merit more extensive discussion in the initial training of healthcare professionals, particularly when in the context of caring for underrepresented populations in current research.

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Acceptance and commitment coaching for music performance anxiety in adolescent singers

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Introduction: Most of the anxiety disorders, particularly social anxiety, seem to develop either during childhood or adolescence. Adolescent singers who experience physical, mental and emotional changes along with voice change are particularly prone to the development of MPA. However, adolescence also seems to be an opportune time to instil healthy behaviours in singing students as they are more likely to remember these coping strategies, owing to the release of dopamine and the 'reminiscence bump'. As this period of a singer's life is wrought with inevitable anxiety development, the additional aim of the study was to develop a coaching framework which can be used by singing teachers in their practice. Mindset training for adolescents seems crucial to help them continue singing through puberty so they do not drop out of singing lessons or choir during voice change and identity development.

Methods: The study aimed to determine if Acceptance and Commitment coaching could be used with adolescent singers with MPA and to record and analyse rich qualitative data in the form of semi-structured participant interviews and questionnaires.

Results: When their perception of MPA symptoms and physiological and psychological arousal before a performance changed, their behaviour and reactions changed accordingly. The change took place over a period of time, which was characterised by discoveries about themselves, confusion in understanding new concepts and letting go of old habits. Interestingly, by the end of the coaching sessions, their preoccupation with pleasing the audience and appearing perfect on stage was replaced by a new-found delight in pursuing values and goals related to their singing. Along with this came the acceptance of themselves and others as individuals with the potential for growth and change and the capacity to learn from mistakes.

Discussion: This study marks the first investigation into the effectiveness of using of ACC as an intervention for MPA in adolescent singers undergoing puberty by a singing teacher. The results are promising and suggest that ACC is an effective MPA intervention for adolescent singers to cope with inevitable development-related anxieties and keep them engaged in the activity of singing during their pubertal years.

KEYWORDS

adolescent singers, puberty, performance anxiety, performance enhancement, flow

1 Introduction

Puberty in adolescence represents a period of physical upheaval and transformation (Sweet, 2015). The physical and emotional health of the singer is inextricably connected and the pedagogy of the adolescent singing voice needs to consider several aspects for the healthy development of the singer (Gebhardt, 2016). Music Performance Anxiety, with its symptoms of persisting, distressful apprehension, has been seen to be widespread among adult singers (Kenny, 2011; Patston and Osborne, 2015). Although MPA has been noticed in children, its origins have not been studied in detail (Patston and Osborne, 2015). While it is expected that students would become more comfortable with performing with an increase in expertise and familiarity with teaching methods, research shows that MPA increases throughout adolescence, peaking at the age of 15 years (Patston and Osborne, 2015). The average age of onset has been observed to be falling worldwide, with the current age of onset around 12.5 years for boys and 10 years for girls, compared to 14 years for boys and 12 for girls in 1950 (Andrews and Summers, 2002; Gackle, 2014; Williams, 2019). Pubertal timing or going through puberty earlier, later or at the same time as one's peers seems to have an effect on the development of psychopathology, which may well persist into adulthood (Graber, 2013). Early-maturing girls and late-maturing boys may be more prone to developing depressive disorders and social anxiety (Graber, 2013). Males who begin voice change earlier than their peers may not perceive themselves as good singers and avoid participating in middle school choir (Fisher, 2014). Although the changes observed in girls are gradual in comparison to the drastic and tumultuous changes observed in the male larynx, female adolescents show characteristic changes such as breathiness, huskiness, insecurity of pitch, decreased range and voice cracking (Gackle, 2014; Sweet, 2015). Young female singers reported a loss of vocal confidence with the onset of voice change, and this was usually accompanied by a loss of confidence in other areas of their lives as well (Gackle, 2014).

Apart from the changes in the body related to puberty, the adolescent brain is also changing during this time and continues to do so into the twenties (Mills and Anandakumar, 2020). These brain changes manifest in behavioral changes such as the desire to explore and form new friendships and social bonds (Mills and Anandakumar, 2020). Development of an organized and coherent sense of identity or a sense of self is considered as the key task in adolescence (Crocetti et al., 2008). Musical identity development in children is influenced by the family, predominantly the parent's beliefs about the child's musical talent and how they regard the child as a musician (Davidson and Borthwick, 2002). Adolescents who are highly invested in their musical identities might find it difficult to separate their self-esteem from their musical self-efficacy (Kenny, 2011). Such adolescent singers may be more prone to anxiety because failure as singers could be interpreted as failure as people (Chesky and Hipple, 1997). The fear of failure, which has its origins in childhood, could be due to high parental expectations, where the child defines failure as unacceptable and have negative implications for their self-worth and relational security (McGregor and Elliot, 2005). Thus, the child seeks to actively avoid achievement situations such as sports or music as they are vigilantly trying to avoid failure. For adolescents high in fear of failure, achievement situations such as music performance are not opportunities for improving but could be threatening and potentially shameful, thus creating a self-perpetuating cycle which maintains and exacerbates this fear (McGregor and Elliot, 2005). With regard to music learning, adolescents may be frustrated by motor skills which take time to develop and may lack the motivation to practice and perform due to fear of failure (McGregor and Elliot, 2005). This situation could be exacerbated by the fact that they are also learning to adjust the motor coordination of their rapidly growing bodies (McGregor and Elliot, 2005). However, if they avoid practice and performance opportunities, they miss out on important parts of their learning.

The adolescent brain also gains heightened sensitivity to mundane events because of the increased release of dopamine during this period of growth (Gebhardt, 2016). When released with strong emotions such as shame or fear, dopamine makes it possible for ordinary events to become engrained in the memory (Gebhardt, 2016). Psychologists refer to this as a 'reminiscence bump' as it involves the ability to recall experiences between the ages of 10 and 18 more clearly than any other period of life (Gebhardt, 2016). A majority of adult musicians in a study indicated that their first memories of music performance anxiety were from adolescence, and they could recall these memories with great detail as if they had happened just the day before (Kenny and Osborne, 2006). In the case of adolescent musicians, many of whom are forced into performance situations early in life owing to their giftedness in musical development, anxiety responses can lay down templates for subsequent reactions to music performance situations throughout life (Kenny, 2011). Thus it is evident that embarrassing or shameful performance-related situations in childhood and adolescence may have a way of staying deeply ingrained in a person's memory and may potentially guide behavior and career choices in the future.

Young adolescents also show an increased sensitivity to evaluation or criticism in this stage of life (Slee, 1993; Hoxter, 2017). This is due to a change in their thinking and reasoning abilities, where the teenager has an "imaginary audience" constantly monitoring and assessing them (Slee, 1993; Kenny, 2011). This leads to heightened self-consciousness and peer-group conformity, with the changes happening to them taking center stage in their personal thoughts (Kenny, 2011). They also believe that others are concerned about their appearance and behavior as much as they are (Slee, 1993; Vartanian, 2000; Kenny, 2011). It seems that adolescents who may be prone to social anxiety could develop music performance anxiety co-morbidly along with maladaptive perfectionism (Dobos et al., 2019). Female high school musicians reported higher performance anxiety symptoms, corresponding with research showing higher shame and social anxiety symptoms in this gender in adolescence (LeBlanc et al., 1997; Ranta et al., 2007; Williams, 2019). MPA and Perfectionism also has a steeper and more intense developmental trajectory in females than males (Patston and Osborne, 2015). While social-phobics would rather avoid social situations, musicians with social phobia need to perform in public in order to excel and this could in turn lead to intrapersonal tension (Dobos et al., 2019).

Music performance anxiety develops as a result of genetic predisposition and the individual's learning history (Barlow et al., 2004; Mineka and Zinbarg, 2015; Patston and Osborne, 2015). Teachers who provide positive and supportive guidance to children and adolescents during singing lessons and performance situations, choosing repertoire that is appropriate to the developmental stage of the adolescent are more likely to contribute to a positive learning history (Osborne and Kenny, 2005). The style of singing lessons and the temperament of the singing teacher are expected to affect the

young student's enjoyment of singing and also their learning outcomes (Patston and Osborne, 2015). Teachers are also seen to contribute to the development of perfectionism and anxiety in their students if they themselves have these tendencies and unwittingly pass them on to their students (Patston and Osborne, 2015). Additionally, research shows that musicians suffering from MPA are more likely to seek help from their teachers rather than a clinical therapist (Williamon and Thompson, 2006). While it seems that adolescents were prone to the development of social anxiety and MPA, it also seems possible that this might provide a unique window of opportunity to instill healthy behaviors and coping strategies in singing students (Gebhardt, 2016). It might be crucial for the singing teacher to provide interventions during this period of life alongside singing lessons to avoid the development of maladaptive coping strategies.

As most of the research on MPA interventions has been undertaken in clinical settings, there is very little teacher-led coaching research done for adolescents (Shaw et al., 2020). The present study aims to research and deliver a coaching course for adolescent singing students dealing with MPA in the private voice studio setting, while addressing the specific developmental needs of teenage singers (Patston and Osborne, 2015).

2 Acceptance and commitment coaching as a treatment for MPA in adolescent singers

One of the strategies gaining popularity in clinical and coaching settings is Acceptance and Commitment Therapy (ACT), a newer third-wave intervention framework (Eifert and Forsyth, 2005; Juncos and de Paiva Pona, 2018; Hill and Oliver, 2019). ACT is based on the philosophy that thoughts and emotions need not be managed in order to live a valued and meaningful life (Eifert and Forsyth, 2005). Instead of controlling our internal private world, ACT focuses on accepting unwanted thoughts and feelings, whose occurrence and disappearance cannot be controlled, and on commitment and action toward living a.

valued life (Eifert and Forsyth, 2005). In the case of Music Performance Anxiety (MPA), ACT suggests that anxiety need not stand in the way of doing what one loves, in this case, music performance (Eifert and Forsyth, 2005; Juncos et al., 2017). Experiential avoidance, or the individual's attempts and efforts to avoid, suppress or alter negatively perceived body sensations, thoughts, worries and memories, is considered to be at the core of all anxiety disorders (Eifert and Forsyth, 2005). ACT principles aim to allow the individual to overcome rigid and inflexible patterns of experiential avoidance by allowing them to approach fear and anxiety more fundamentally and deeply (Eifert and Forsyth, 2005).

The ACT Hexaflex Model is a visual representation of the six core processes of Acceptance and Commitment Therapy (ACT). The six core processes are.

1 Acceptance (the willingness to experience difficult thoughts and emotions).
2 Cognitive Defusion (Separating ourselves from our thoughts and emotions).
3 Being Present (Engaging fully with the present moment).
4 Self as Context (Recognizing that we are not just a product of our thoughts and feelings).
5 Values (Beliefs and principles that guide our behaviors).
6 Committed Action (Choosing to engage in behaviors which align with our values).

The core processes are interconnected and mutually reinforcing and contribute to the development of psychological flexibility in the coachee.

ACT has been used with adolescents in clinical and school settings in areas such as chronic pain, chronic fatigue, depression, stress, obesity and anxiety (Livheim et al., 2014; Kemani et al., 2018; Kallesøe et al., 2020; Zetterqvist et al., 2020; Clery et al., 2021; Guerrini Usubini et al., 2022; Petersen et al., 2022) The results of these studies have been promising, with participants showing a significant decrease in psychological inflexibility and also in symptoms (Livheim et al., 2014; Kemani et al., 2018; Kallesøe et al., 2020; Zetterqvist et al., 2020; Clery et al., 2021; Guerrini Usubini et al., 2022; Petersen et al., 2022). Online interventions in group settings have also been developed in order to increase the accessibility of ACT among adolescents, with results showing benefits such as symptom reduction in clinically diagnosed youth (Puolakanaho et al., 2018; Keinonen et al., 2021; Lappalainen et al., 2021). ACT has been used in MPA studies in university music students with clinically significant improvements in psychological flexibility along with symptom reduction (Juncos and Markman, 2015). Although used so far in clinical settings and administered by performance psychologists, ACT has been recommended to be used as an evidence-based model of care by music teachers and practitioners over the other available options (Juncos and De Paiva Pona, 2018). ACT is also seen to be a promising intervention for vocal students affected by physical MPA symptoms (Juncos et al., 2017).

Acceptance and Commitment Coaching (ACC) is a model of coaching based on the principles of Acceptance and Commitment Therapy (ACT) (Hill and Oliver, 2019). ACT, Mostly used in clinical settings for a range of issues like psychosis, depression, anxiety, addiction, and chronic pain, has an extensive body of research demonstrating its effectiveness in helping people make changes in their lives (Hill and Oliver, 2019). Due to this evidence base and versatility, ACT has been adopted by coaches in several settings like sports, music and the workplace (Bond et al., 2008; Blonna, 2010; Skews, 2018; Hill and Oliver, 2019). In one study, ACC appears to be a promising MPA intervention that can be administered by a music teacher in non-clinical settings (Shaw et al., 2020). Therefore, ACC could be an effective intervention that music teachers can use for adolescents experiencing MPA in individual and group settings, either through online or in-person sessions.

2.1 Aims of this study

This study aimed to be the first application of ACC in which a singing teacher administered the interventions directly to individual adolescent singers undergoing puberty and experiencing MPA. The research question to be answered was: Can ACC be used as an effective intervention for adolescent singers with MPA by a singing teacher who has no training in psychotherapy? It was hypothesized that there would be a significant improvement in the singer's psychological flexibility after receiving 6 sessions each with the singing teacher. In

addition, it was hypothesized that ACC could improve the experience of flow during practice and performance, which would encourage the singers to keep returning to the activity of singing during their pubertal developmental years.

The study's main aim was to determine the changes in the participant's self-perception of MPA symptoms and whether the ACC intervention could motivate the adolescent singer to continue pursuing the activity of singing during the pubertal years. No attempt was made to interfere with or record the change in quality of the actual singing performances before and after the intervention.

3 Materials and methods

3.1 Participants

The participants were 4 singers (3 male and 1 female) between the ages of 13 and 17 years. They were recruited through word-of-mouth advertising through the researchers' teaching contacts. None of the singers were the researcher's singing students. The participants filled out the KMPAI-A questionnaire in order to ascertain if they had MPA and were hence eligible to participate in the study.

3.2 Coach

AP is an independent voice coach and choral trainer. She was trained as a western classical singer and has performed as a soloist and along with renowned choirs both in her hometown Chennai, India and internationally. She became interested in the topic of MPA after she noticed the occurrence of MPA in her singing students and wished to find effective evidence-based strategies which could be used in the teaching studio in tandem with singing lessons. As part of her M.A. in Voice Pedagogy, she conducted an in-depth literature review on the effects of voice change and puberty on the development of MPA in adolescent singers. She concluded that adolescence would be a unique window of opportunity to train young musicians to cope with inevitable developmental anxieties.

Institutional review board (IRB) for this research was given by the University of Wales Trinity St David's (UWTSD) ethics board. AP conducted this research with the Voice Study Center, Ltd., a provider of postgraduate voice pedagogy study that is affiliated with the UWTSD. AP was supervised by the third author (DW) in securing ethics board approval and in ensuring that AP provided the intervention as a coach and not as a psychotherapist to the participants.

3.3 Procedure

3.3.1 Training

AP received training in ACC from the second author (DJ), a clinical and performance psychologist with more than 15 years' experience in treating anxiety disorders and specific expertise in using ACT with musicians to enhance performance and treat MPA. Materials for AP's training and the participant's coaching were taken from three books: Acceptance and Commitment Training for Musicians by Juncos and de Paiva Pona (2018), Acceptance and Commitment Coaching by Hill and Oliver (2019) and ACT for Treating Children by Tamar Black (2022).

3.3.2 Coaching intervention

AP met each participant individually over Zoom for six sessions between March and June 2022. The sessions ranged between 45 to 60 min each depending on the participant. The participants performed regularly either as vocalists with bands or in choirs or in karoake and stage shows. The two older participants, both 17 years old at the time, enjoyed the mindfulness exercises which were either 'eyes-closed' or body-scan observations. However, the two younger participants (13 and 14 years) required mindfulness exercises that were activity-based. There were no fixed coaching plans for all the participants, rather the ACT Kidflex based on Black's book was used to explain concepts of acceptance and commitment to performance values and to develop psychological flexibility in the participants. It is also important to note that not all participants required training in all the 6 core processes.

As this study was focused on delivering coaching interventions to individuals, AP had to take into account the age and personality of the participants while deciding the appropriate exercises and metaphors for the participants. Participant A, a 17-year-old male, was able to understand abstract ideas and metaphors well. He was also seen to ask questions and reflect and process thoughts verbally. He was the only participant who liked the eyes-closed or focus-based mindfulness exercises. AP began with the core processes of Being Present followed by Cognitive Defusion, Values and Committed Action. Participant B, a 14-year-old male, did not enjoy discussing his thoughts and feelings verbally. He also did not enjoy eyes-closed mindfulness exercises. However, AP found him deeply engaged in written/painting activity-based mindfulness exercises, with some of his finished work being elaborate and descriptive of his MPA-related thoughts and symptoms. AP also found it easy to connect the ACT Hexaflex principles to his current superhero character. AP began with the core process of Self as Context followed by Acceptance, Being Present, Cognitive Defusion and Committed Action. Participant C, a 13-year-old male, did not always have the appropriate words to describe his feelings. With this participant, AP found it challenging to understand if he had grasped the Hexaflex concepts. As he was not yet able to understand abstract concepts, AP used exercises meant for children, which he then responded to very well. The core processes used with him were Being Present, Values and Committed Action. Participant D, a 17-year-old female, struggled with shifting her attention away from her MPA symptoms, which included extreme tremors in her hands and voice when she went up to sing and accompany herself on the piano. AP began with values-related exercises with her, rather than mindfulness exercises. The core processes used with this participant were Values, Committed Action, Self as context and Cognitive Defusion.

As a common theme, all the participants were primarily preoccupied with how their peers and audience viewed them and their performances. During the initial sessions they found it difficult to understand the concepts of acceptance of anxiety symptoms as they felt they needed to get rid of the symptoms in order to have enjoyable performances. By the end of the sessions they came to accept the symptoms as something normal and as part of their performances.

The participants completed questionnaires and gave semi-structured interviews both before and after the coaching intervention sessions.

The questions which were asked in the pre-coaching questionnaire were

1 What are the symptoms or feelings that you are aware of before of while you sing?
2 Do these symptoms/feelings interfere with your singing?
3 Have you ever tried to make these symptoms go away? How?
4 What is it about singing for an audience (of any number) that scares you the most?
5 What would your ideal performance feel like?

Questions included in the post-coaching questionnaire were

1 What have you learnt during the coaching sessions?
2 How are you going to use what you have learnt?
3 What have you learnt about yourself during the coaching sessions?
4 What is your current outlook on singing performance? Has it changed or remained the same after the coaching sessions?
5 What are you most looking forward to as a singer and performer?

3.4 Semi-structured interview questions

3.4.1 Pre-coaching

1 Before you go up to sing or while you perform, what kind of symptoms do you experience?
2 While you are singing what do you often think about?
3 What does nervousness feel like in your body?
4 How long before the performance do these sensations appear? Days? Hours? Minutes before?
5 Does the intensity of these sensations change during the performance?
6 How do you practice or prepare for an upcoming performance?
7 Describe a performance that went really well
8 Describe a performance that did not go so well, if any.

3.4.2 Post-coaching

1 What was the most helpful/useful part of the coaching sessions for you?
2 What was the least helpful/useful part of the coaching sessions for you?
3 How do you feel it went over Zoom rather than in-person?
4 What do you feel about the length of the course and the duration of each session?
5 Do you feel your peers and other performers talk about MPA? Would you talk about your MPA with them? Why or why not?
6 Is there anything in the sessions that you struggled with? Anything you found difficult to understand or wished we had spent more time on?
7 Would you recommend these sessions to other singers you know who may or may not be struggling with MPA?
8 Do you feel equipped to continue using the exercises and principles which you learnt during the sessions?
9 What do you think of the exercises? Were they fun/difficult/boring/interesting?
10 Is there any way that the content of the coaching sessions could be improved?
11 What did you learn about mindfulness/acceptance of MPA symptoms and pursuing valued actions over the last few weeks?

Exercises used for different ACT processes used during the coaching sessions:

(The exercises were taken from 'ACT for Musicians by David Juncos and Elvire de Paiva e Pona and ACT for Treating Children by Tamar Black)

3.4.3 Being present

1 Scanning a Picture frame with your eyes open
2 Mindfulness of the body

3.4.4 Acceptance

1 Tug of war with anxiety monster
2 The Willingness Dial
3 The Pen Exercise

3.4.5 Cognitive defusion

1 Thought labeling
2 Word Repetition to form new associations
3 Thanking your mind for your thoughts

3.4.6 Self as context

1 Clouds in the sky
2 Chessboard

3.4.7 Values

1 Heart exercise
2 Two roads
3 Writing mission statements

3.4.8 Committed action

1 Specifying Performance-related goals

4 Findings

AP set out to conduct this study in order to ascertain whether ACC would be a feasible intervention which can be used by private singing teachers with their adolescent singing students who experience MPA. AP also wished to understand the experiences of teenagers who have MPA. Adolescents, due to natural growth processes are prone to the development of MPA along with or independent from social anxiety (Kenny, 2011). Since this is the beginning stage of MPA, which is then maintained through to adulthood, it was necessary to find an intervention which singing teachers, who are not trained in psychotherapy, can use in their private teaching practice.

The findings revealed a definite change in the participants and that change began with their way of thinking about MPA. When their perception of MPA symptoms, physiological and psychological arousal before a performance changed, their behavior and their reactions changed accordingly. The change took place over a period of time which was characterized by new discoveries about themselves, confusion in understanding new concepts and letting go of old habits. Interestingly, by the end of the coaching sessions their preoccupation with pleasing the audience and appearing perfect on stage was replaced by a new-found delight in pursuing values and goals related to their singing. Along with this came the acceptance of themselves and others as individuals with potential for growth and change and the capacity to learn from mistakes.

The following themes emerged.

5 Theme one: we're going on a roadtrip!

5.1 The starting point

5.1.1 Going in circles

As in every journey that is undertaken, unless there is clarity on where the traveler intends to go, there is a lot of time and energy wasted on going in circles and stopping at or passing through unplanned destinations. Before the start of the coaching sessions the participants had a vague idea about what they wanted from a good performance. They depended more on feelings to tell them if the performance had gone well. There was a common idea that a good performance would also feel good. However, when they encountered feelings of discomfort from singing in front of people and because they depended on good feelings to evaluate their performance, they either shamed themselves for feeling that way or tried different strategies to get rid of the discomfort before moving on in their singing journey. But, the more they tried the strategies, the more frustrated they became. The older two participants seemed especially confused that they were not able to get rid of this discomfort and other nervous symptoms, despite their singing experience. The participants ultimately decided that the best solution for their MPA was more practice before a performance, as this might make them feel more confident before they went on stage. But they could never decide how much practice was enough.

They all had had at least one good performance in the past, when they had experienced a good feeling before they had gone on stage. They had practiced and rehearsed before those performances and hence had concluded that in order to produce the same good feelings before a performance, long practice sessions had to be the key to unlock these good feelings. However, during interviews the participants also confessed to not practicing at all or practicing only if there was a performance coming up in the near future. This contradicted with their beliefs regarding practice affecting performance.

Some of the participant responses are shown below. The core process which may need to be trained has been indicated in brackets.

Participant A (PA) - (Self as context, Cognitive Defusion)

> "If there's like a good feeling"

> "Be very, very well prepared"

> "I thought the more I performed, it will get lesser. It's not happening"

Participant B (PB) - (Cognitive Defusion)

> "Feel proud of myself"

> "Satisfaction which I feel"

Participant C (PC) - (Values)

> "How I feel at the end"

> "The applause"

> "If I mess up what's gonna happen?"

Participant D (PD) (Self as Context, Cognitive Defusion, Acceptance)

> "Should feel very relaxed"

> "Should have no nervousness or goosebumps"

> "Still takes place each time"

5.1.2 Audience

The participant's journey was also overly dependent on the real and imaginary audience. The participants felt they were moving forward only if the audience approved their performance. Even while preparing for their performance, the imaginary audience was always consulted with regard to repertoire selection. The participants also tried to modify their behavior based on how they felt the audience was reacting to them. Irrespective of the number of the audience, the presence of known or unknown people triggered varying reactions in the participants. Audience opinion was very important just before, during and even after the performance had ended, with participants actively scanning the audience's facial reactions while singing. The level of audience applause was deemed as the feedback needed to assess if the performance had gone well or not. The participants seemed to vacillate between depending on good feelings and audience approval, making performance evaluations entirely on these criteria, thereby ignoring their singing values.

PA (Cognitive Defusion)

> "Kind of avoid making eye contact"

> "Appeal to the audience"

> "We will look at how the audience reacts in like, the first 30 seconds"

PB (Being present)

> "Scared that the audience will lose interest"
>
> "What they are looking for"

PC (Self as context)

> "It's like a weight on my mind"
>
> "Audience plays a very important part"

PD (Being present, Cognitive defusion)

> "Will everyone like it?"
>
> "The energy was different. They were hard to engage. I panicked"

5.2 The crisis/turning point

During the initial sessions, the participants seemed resistant to the ACT principles. Instead they wished to learn quick fixes to get rid of their uncomfortable feelings. When they began to understand the point of the exercises, they essentially got over their boredom in doing them. But this took between three to five sessions, depending on the participant. As they were given choices between different exercises they ended up choosing the ones they liked best to practice between sessions. They also pressed through confusing and sometimes very different ways of thinking about their MPA symptoms, anxiety triggers and their reactions.

The first signs of change were seen after 2–3 sessions. The ACT core processes which were being trained have been indicated in brackets.

PA (Acceptance)

> "So the aim of these exercises are not for it to be fun or something you enjoy or anything. It is work. It's to build your focus and attention and all that. So yeah …"
>
> "Even though you can practice as much as you want, you can be as confident as you want. There are certain things you can't account for on the day of the performance. You are bound to get nervous and all that and that is fine."

PB (Committed action)

> "I kind of got over the boring feeling because I realized that it was necessary; it was helpful. And so I will admit that when I do the exercises, I do get a little bored. But I kind of think about how it's benefitting me."
>
> "After the first two sessions, I think I was a little bit confused, like what we had been talking about, but then eventually, they kind of got a little more in detail. And ironically I was able to understand it better."

PC (Acceptance)

> ""I found that staring into one thing was difficult for me. Apart from that everything was interesting. Yes"
>
> "I learned that I can't just get rid of negative thoughts. I just have to change the way of thinking."

PD (Cognitive defusion, acceptance)

> "So it definitely.it is helpful. But it was slightly boring. But I found that noticing the thoughts when they passed by you. I found that interesting."
>
> "We have to live with anxiety. That is one of the most key points I learned"

Once the participants learnt to face their feelings and accept them, values were clarified and they were given a chance to indulge in metacognition, or the act of thinking about their thinking. They recognized what they were used to believing about themselves and their performance. Toward the last few sessions, they learned to defuse from beliefs that did not serve them and focus on values-related beliefs instead. They had the opportunity to re-affirm their values related to singing.

PA (Values)

> "I subconsciously avoid uncomfortable situations such as singing in front of large audiences. I've learnt that I'm a good singer and performer, and there is no need to feel any different."

PB (Self as context)

> "I can be very quick to judge myself and it can often be demotivating. I have learnt that it is necessary to be firm but not harsh as well"

PC (Committed action)

> "I'm not such a shy person actually and can achieve my goals. I will appreciate everything I am and will be "

PD (Cognitive defusion, self as context)

> "I have learnt that the way I think changes my performance"

5.3 The journey continues

Clarifying values in turn gave the participants a clear picture on where they intended to go. The shift was seen from dependence on feelings and audience approval to focusing on steps to take toward valued behavior. They were also able to assess how far they had strayed from the path toward their destination. Different exercises helped them assess and visualize where they were currently. Course

correction was necessary. Participants also realized that the journey they had undertaken was like a one way journey facing due north. Milestones had to be acknowledged and celebrated along the way but the journey was always ongoing. Rather than looking at performances as potentials for rejection and criticism, they were beginning to be viewed as opportunities to have fun while pursuing valued behavior. More importantly, mistakes which were earlier considered unacceptable and shameful became potential areas for future improvement.

PA (Values, committed action)

> "Looking forward to playing outside my comfort zones. I want to keep singing and performingwith my band and just enjoying playing with them. Seeing myself grow as a singer and performer"
>
> "I want to keep singing"
>
> "I subconsciously avoid uncomfortable situations"
>
> "These sessions have like helped to identify areas where I may not be as confident"

PB (Values, acceptance)

> "Looking forward to be a better singer and performer"
>
> "learn from mistakes"
>
> "I'm very quick to judge myself"
>
> "I think that I was constantly trying to like bottle up the emotions"
>
> "Your mind is like a muscle, you have to train it..like, it constantly needs like substance."

PC (Acceptance, values)

> "I will happily accept whatever comes"
>
> "train the mind"
>
> "I am hoarding unnecessary anxiety"
>
> "I realized how far I was from my goal. Now I am a little more closer."
>
> "Singing is not just a showcase of your talents. It's an adventure."

PD (Values, committed action)

> "Get to a level where I can sing with maximum confidence"
>
> "learning about me"
>
> "I'm not so far from my goal. I have been accomplishing things"
>
> "If there is no mistake then it will be boring. There won't be anything to accomplish in the next performance"

5.4 Theme two – how the journey changed me

5.4.1 Accepting myself

Participants realized that the journey changed them in several ways. The highlight of this journey was that they no longer saw anxiety and its symptoms as something strange but as an aspect to be expected when something of value is attempted by them. Mistakes in performance previously seen as an extension of themselves as people were no longer feared but seen as opportunities to improve in future performances. All the participants exhibited the core process of Acceptance.

PA

> "It is normal to feel nervous before or during a performance"

PB

> "Making mistakes or feeling nervous is normal"

PC

> "Anxiety can be faced"

PD

> "Anxiety is part of being a singer"

5.4.2 Accepting others

Along with accepting themselves, participants also empathized with other singers and realized the futility of setting impossible standards and being critical of themselves and others. There was a shift from viewing fellow performers as just singers. They are now viewed as humans with flaws and imperfections who sing and create art. Participants also understood why their peers refused to talk about or acknowledge MPA because they had been that way before the coaching sessions. They understood that talking about it and accepting that one might have uncomfortable feelings associated with singing might ruin their social image and reputation.

Singing requires the singer to be vulnerable in front of the audience, causing adolescents, especially males, to choose to play instruments and stay at the back of the stage but still be part of the performance. This is pertinent as singers who face MPA are different to instrumentalists who face MPA with different things at stake.

PA

> "Everyone is human being. They are going to face it."

PB

> "A lot of performers do get nervous"

PC

> "Tell them that what you're feeling is normal"

PD

> "Everyone will face it"

5.4.3 It's all about me now

Participants wished to bring their uniqueness into their performances. The core processes of Values and Committed Action were very stronly seen by the 5th and 6th sessions. PB accepted that it might mean choosing the right audience who will appreciate his music. Once values were clarified, there was no going back to simply pleasing the/any audience. Performances were now intrinsically motivated for one's pleasure and having fun rather than to prove their worth to others and themselves. Because of this, participants looked for more opportunities to sing in situations outside of their comfort zones. They also looked forward to honing and nurturing their talents and saw It as a progressive journey. The participants believed that the audience and their peers would be influenced by the music they created.

5.4.4 Change in symptom levels

At the beginning of the sessions, the participants were keenly aware of their symptoms, keeping track of when they began and how they changed or stayed the same during and after their singing. In the exit interviews, the participants reacted to their symptoms in various ways.

Two participants (B and D) noticed that their symptoms had reduced. One of them (D) noticed the usual beginning of the symptoms, but she learnt to defuse from the usual response to the trigger and consequently noticed that the symptoms reduced during performance.

PA could not tell what happened to his symptoms. Either he had not noticed because he had been focusing on task-related details, or his symptoms might have reduced. This participant had mainly cognitive symptoms. Hence, being mindful and staying present while performing could have shifted his focus off his obtrusive thoughts during singing. PD remarked that he did not notice the symptoms which had bothered him earlier. It is also unclear in this case whether the symptoms disappeared. It was clear that irrespective of whether the symptoms reduced, disappeared or stayed the same, the participants were no more concerned about getting rid of the symptoms. Instead, they chose to focus on their performance and be aware of what was happening in the present moment.

The pre-coaching questionnaire and interviews focused mostly on the symptoms and perceived nervous states before performance. However, the post-coaching interviews and questionnaires focused more on the learning and the future application of the learning. This was done on purpose to determine the change in the level of pre-occupation with symptoms.

5.4.5 I want to tell my peers about this

While earlier, the participants had been shy about talking about their MPA to their peers, the coaching changed that aspect in several ways. All of them indicated that they were more open to talking about it because they no longer saw it as an extended imperfection of themselves as people. They also wished to spread this good news to fellow performers.

Participants (D & A) who saw mistakes as the worst thing that could happen during performances now welcomed them as a way of improving and learning. The bigger picture of artistic development was being taken into consideration. This helped them commit to regular practice schedules irrespective of whether there was a performance.

With the change in perception of self and self-conscious feelings of shame and guilt due to the development of the core processes of Cognitive Defusion and Self as Context, participants seemed willing to talk about their thoughts related to MPA. Participants also wanted these benefits for their peers and other performers as well. They could think of several people in their circle who would benefit from ACC. The participants also felt that ACC had helped them in other areas of life apart from singing. Along with accepting themselves and others as humans, participants also wished for other performers also to be able to do their best. PC, who had been the only one who said that his peers confided freely about their MPA to each other, felt that they should also know that help is available.

6 Discussion

The current study sought to examine whether Acceptance and Commitment Coaching (ACC) would be a feasible intervention that can be used by singing teachers to alleviate Music Performance Anxiety (MPA) faced by adolescent singers. Additionally, the study aimed to examine whether the use of ACC had the potential to help adolescent singers cope with inevitable development-related anxieties and keep them engaged in singing during their pubertal years. Based on the suggestion that flow states are a good antidote to MPA and for keeping an individual returning to an activity, the study used a positive psychology approach to coaching adolescents using the ACT framework (Csikszentmihalyi, 1975; Hill and Oliver, 2019).

Results showed evidence of an increase in psychological flexibility in the participants as well as the ability to defuse MPA-related thoughts and accept their MPA symptoms. This is consistent with results from a previous ACC study by a singing teacher on a university student (Shaw et al., 2020). The results are similar to ACT psychotherapy for MPA studies with seven vocal students (Juncos et al., 2017). It appears that the adolescent participants learnt to de-fuse from their MPA-related thoughts and accepted their MPA symptoms, behaving more flexibly in the presence of these symptoms, similar to the results seen in the previous studies on older vocal students. The results of this study are also in keeping with the previous study on ACC being an effective coaching framework that can be used by a singing teacher with no training or education in psychotherapy (Shaw et al., 2020). This change in behavior due to psychological flexibility was not seen immediately but took between 4 to 6 weeks. During this time the participants went through stages of confusion, boredom and restlessness, mainly at not being able to focus for a long time and also frustration at not being able to complete an exercise. However, they were motivated when they began to see changes in their ability to focus, thus helping them move on to the next step. They also realized that change takes time and hard work. The neuroscience of habit and subsequent behavioral changes is especially important for the coach to know, in order to be able to recognize the typical characteristics of the change process and to

be sensitive to the feelings of confusion and impatience expressed by the participants (McKay and Kemp, 2018).

Findings revealed that among the biggest concerns of adolescent singers was the presence of an audience, both real and imaginary. This is in keeping with previous studies done on the effect of audience presence on performance (Slee, 1993; LeBlanc et al., 1997), the capacity for adolescents for increased abstract thinking (Steinberg, 2005) and the concern that other people are constantly judging and assessing them (Vartanian, 2000). Additionally, there was evidence of fear of failure, making mistakes and maladaptive perfectionistic tendencies that showed that achievement situations such as music performance were not viewed as opportunities for improvement but as threatening and potentially shameful. These findings align with previous studies in these areas (McGregor and Elliot, 2005). The participants also showed a lack of motivation to practice on a regular basis, which could be attributed to frustration in adjusting motor coordination of their rapidly growing bodies (McGregor and Elliot, 2005). Participants were also seen to avoid uncomfortable performance situations which further exacerbated their fears (McGregor and Elliot, 2005). The older participants also showed hints of shame at having MPA symptoms, which is in line with studies which show the increasing trajectory of shame along with the increased potential for abstract thinking (Orth et al., 2010; Mojallal et al., 2021).

After the completion of the ACC sessions, the participants reported not only psychological flexibility in the presence of MPA symptoms, and defusion from MPA-related thoughts in combination with values-based action, but they also began to normalize the making of mistakes during the performance, instead seeing them as ways to improve in their future performances. Mistakes and failure as singers were no longer seen as an extension of themselves but as a natural part of them. This could be a clue that ACC can be used to alleviate perfectionistic tendencies and fear of failure in adolescent singers. However, more longitudinal studies are needed in this regard to assess the long-term behavioral change in them. As dimensions of MPA shift over time in relation to performance context and development of the limbic system of the brain, it is also necessary to conduct studies to assess changes in adolescent MPA over an extended period of time (Patston and Osborne, 2015).

The participants also showed increased acceptance of negative feelings like nervousness and anxieties being part of them. This is in keeping with previous studies which show the importance of experiences in the development of self-identities and self-concepts, which are considered the key tasks in adolescence (Markus and Wulf, 1987; Crocetti et al., 2008). Since the audience for these participants comprised mainly of their schoolmates and their families, there seemed to be a higher risk involved with regard to public performances, which is the fear of judgment and exclusion by their peers, in addition to fears involved with performing for any audience in general. With regard to peers being the audience, the participants faced the potential risk of rejection and evaluation by their own friends who would be part of the audience. The three older participants also mentioned that MPA was not discussed freely within their peer groups. These findings are in keeping with studies which showed the following: adolescence is a critical time to form and maintain interpersonal relationships (Baumeister and Leary, 1995), the development of a social identity during adolescence (North and Hargreaves, 1999), high risk for social anxiety development during this period (Zimmer-Gembeck et al., 2021), the presence of a small peer group seen to increase MPA in high school music students (LeBlanc et al., 1997), young adolescents increased sensitivity to evaluation or criticism (Slee, 1993; Semper et al., 2016; Hoxter, 2017), development of maladaptive schemas due to experiences of shame (Mojallal et al., 2021), development of a negative self-concept during adolescence in response to shame experiences (Ogilvie, 1987), young people rarely seeking help for their phobias for fear of being ostracized (Dobos et al., 2019) and the heightened importance of peer group inclusion in middle school (Flanagan et al., 2008). By the end of the ACC sessions, the participants showed an increased acceptance of themselves and their peers and the idea of being human with flaws. This could be a potential benefit of using ACC on adolescent singers as it could help with the developmental need of forming a healthy social identity. Further studies are needed to investigate how psychologically flexible adolescents could impact their peer groups.

The older participants also mentioned experiencing flow-like states in their performances toward the end of the ACC sessions. While earlier they had trouble focusing on their song, they could now be in the moment and focus on various aspects like lyrics, expression and communicating the song because they had defused from MPA symptoms and focused on their values instead. This is in keeping with the study that it is possible for non-expert singers to experience flow (Barlow et al., 2004; Broomhead, 2010). Experiencing flow could motivate adolescents to keep coming back to the activity of singing owing to the release of dopamine while indulging in pleasurable and rewarding activities (Cohen and Bodner, 2019). It is unclear whether the younger participants experienced these flow states. It is possible that low levels or lack of increase in flow in the younger adolescents in this study were due to the absence of perceived skill/challenge balance in them, similar to studies conducted by Cohen and Bodner (2019) and Cohen and Bodner (2019). Overall, ACC has the potential to help adolescent singers cope with inevitable development-related anxieties.

6.1 Study limitations

This study is not without limitations. Given it was a qualitative study with four participants, direct conclusions about ACC's effectiveness in helping adolescent MPA cannot be made. It is possible that the participants' improvements related to psychological flexibility were due to a demand characteristic that positive change was expected, which threatens the validity of the study. However, the pattern of results is similar to those of the vocal students of Shaw et al. (2020), Juncos et al. (2017) and Juncos and Markman (2015). These trends across studies strengthen the possibility that the changes and psychological flexibility in the participants were due to ACC interventions. The study was also conducted over Zoom, disrupting the conversation flow with participants with poor internet connectivity. While all the participants felt this was a minor inconvenience in comparison to other benefits like being in the comfort of one's home and being able to participate from other locations, it would still be useful to conduct a similar study using in-person sessions. It must also be noted that there was no attempt to record the changes in performance quality itself. It would be beneficial to include this aspect in future studies with adolescent singers.

6.2 Future recommendations

There is a need for more studies on using ACT with child and adolescent singers and ACC by singing teachers for this age group. This would help in customizing and refining the ACT principles for these age groups with special considerations based on their cognitive and physical development. The participants also indicated that they were willing to talk about their MPA after undergoing the sessions. In particular, they indicated they were keen to talk to their peers about it and help them. It would be interesting to look into the impact of peer influence by psychologically flexible adolescent singers.

Parents and singing teachers seemed to play an important part in the singer's microsystem, potentially influencing the adolescent's psychological flexibility and contributing to the development of their musical identity (Lamont, 2017). It has been suggested that the parents also undergo ACC so that they can not only help their child between sessions but also prevent any conflicting coping strategies being reinforced or advocated by them (Black, 2022). However, no study has been conducted to date on including parents in MPA coaching using ACC. I believe future research evaluating this aspect is much needed.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statement

The studies involving humans were approved by Research Ethics committee of the University of Wales Trinity St David. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

AP: Writing – original draft, Writing – review & editing. DJ: Supervision, Writing – review & editing. DW: Supervision, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Playing-related musculoskeletal disorders among Chinese conservatoire piano students: prevalence, risk factors and preventive interventions

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Introduction: Both professional musicians and conservatoire students are at significant risk of developing playing-related musculoskeletal disorders (PRMDs) during their career life. With the growing number of students pursuing a conservatory degree and graduating from music conservatory in China, the aims of this study were: (1) to identify the nature of PRMD and explore the prevalence of PRMD in Chinese conservatoire students; (2) to determine the relevant risk factors with the presence of PRMD among Chinese conservatoire students; and (3) to suggest preventive interventions for young pianists at their early career stage.

Methods: A self-reported online survey study was conducted among 363 Chinese conservatoire students who majored in piano performance.

Results: Of all respondents, 82.6% reported having had at least one PRMD. The wrist was proved to be the most affected body site, followed by the shoulder, finger and arm. Respondents who experienced PRMD reported "pain," "fatigue," and "stiffness" as the most frequent symptoms. The main risk factors associated with PRMD included gender, years of playing experiences, practice hours, warm-up habits before practice, and break-taking during practice.

Discussion: Female students, those with longer year of playing experience, those who practice longer hours, those who do not warm up before practice, and those who do not take breaks during practice were found to have more PRMD symptoms and higher level of severity. This study highlights the need to increase awareness of PRMD among conservatoire students and to understand the occurrence of PRMD; it is helpful for young pianists to prevent severe musculoskeletal disorders and implement preventive measures at early career stages. Further studies are suggested to follow up on music students who have had at least one PRMD at different stages of professional musical training.

KEYWORDS

piano, musculoskeletal disorders, playing-related injuries, conservatoire students, prevalence, risk factors, preventive interventions

1 Introduction

Throughout the career life of a musician, it is common to experience mild aches and pains during playing and after playing. These symptoms, known as playing-related musculoskeletal symptoms (PRMS), are generally milder than playing-related musculoskeletal disorders (PRMD) (Brandfonbrener, 2003; Ranelli et al., 2011). PRMDs are a common issue among

musicians during their whole career life (Brandfonbrener, 2003; Zaza, 1998), including pains and symptoms that affect the ability to play the instrument as usual (Zaza and Farewell, 1997). For professional musicians, these occupational-related symptoms can result in a loss of performing opportunity, leading to decreased income, social stigma, and psychological and emotional challenges associated with being unable to engage in music-making (Guptill, 2011).

The high prevalence of PRMDs among professional musicians has been attributed to chronic musculoskeletal conditions that were overlooked and improperly treated during their younger years (Bejjani et al., 1984; Savvidou and Stanek, 2019). Most existing studies regarding PRMDs have focused primarily on professional musicians (Ackermann et al., 2011; Hoppmann and Patrone, 1989; Steinmetz et al., 2015), often neglecting the early pain experiences of musicians in their younger ages. This gap in the literature is significant because conservatoire students, who are at the early stages of their professional careers, are also susceptible to PRMD. More recent studies have started to highlight the equivalent prevalence of PRMD among conservatoire students (Brandfonbrener, 2009; Cruder, 2020; Steemers et al., 2020). Understanding and addressing these early pain experiences is crucial for preventing chronic issues in later professional life as a musician.

Research has provided insight into the nature and prevalence of PRMD in musicians across different disciplines. Performing arts and medical research approach the study of PRMDs with different focuses and measurements. Performing arts literature tends to categorize PRMDs based on instruments and/or playing positions, often using less standardized definitions (e.g., Dawson, 2002; Sakai, 2002; Taddey, 1992). This can lead to a wider range of disorders being included and thus a higher reported prevalence rate, especially when mild symptoms and pains are classified as disorders. Occupational medicine literature, though more limited, groups PRMDs by medically confirmed diseases that meet the established diagnosis standards in the late 1980s (Wilke et al., 2011). Consequently, some unconfirmed disorders might be overlooked in these studies.

Existing literature shows varied results regarding the prevalence rates of PRMD due to differences in research methods (e.g., questionnaires, interviews, or physical examination), measurements (i.e., number of musicians experiencing PRMDs at a specific point in time, or over a specific period such as a month or a year), instruments and small sample sizes. Reported prevalence rates of PRMD range from 40 to 60% among professional musicians (Zaza and Farewell, 1997; Fry, 1986), 9 to 90% among tertiary music students (Fry, 1987; Zetterberg et al., 1998), and 20 to 70% among children learning instrumental music (Brown, 1997; Grieco et al., 1989; Roset-Llobet et al., 2000). In the systematic review conducted by Zaza (1998), the prevalence rate of PRMD among professional musicians ranged from 39 to 87%.

The prevalence of PRMD among keyboard players was significantly higher compared to that of percussionists (Sandell et al., 2009). However, within the group of keyboard players, pianists exhibited the lowest prevalence of PRMD (Ranelli et al., 2011). Among tertiary music students, those playing strings, woodwind, brass, and keyboard were reported to have a high prevalence of PRMD (Zetterberg et al., 1998; Pratt et al., 1992).

In medicine literature (Biro et al., 1983; Buescher, 2007; Caldron et al., 1986; Hochberg et al., 1988; Konczak and Abbruzzese, 2013; Larsson et al., 1993; Newmark and Hochberg, 1987; Sataloff et al., 1991; Zeuner and Molloy, 2008), four main PRMDs were identified: overuse syndrome, temporomandibular joint disorders, focal motor dystopias and joint hypermobility. Overuse syndrome is defined as painful conditions induced by long and hard use of a limb beyond biological tolerance (Fry, 1986; Fry, 1993). It is often used generically to include conditions such as tendinitis, tenosynovitis, dystonia, and related conditions that are not currently defined as specific disorders (e.g., Altenmüller, 2003; Altenmüller et al., 2012; Fry, 1986; Marsden, 1991). As a result, the diagnosis of symptoms is generally based on the doctor's own clinical experience (Bejjani et al., 1996). These conditions are also related to the instrument played or the position of playing, which aligns with the findings in performing arts literature.

Although much research has been done to explore the prevalence of PRMD in different instrument players and factors associated with musicians' occupational-related injuries (e.g., Bejjani et al., 1993; Papandreou and Vervainioti, 2010), limited is focused on the specific group of conservatoire piano students. While a professional career is not necessarily the goal of every conservatoire student, avoiding PRMD should be a priority at any level of professional piano training. The risk factors contributing to PRMD in musicians are multifactorial, including individual factors (such as age, gender, previous injuries, anthropometrical characteristics of the musician, and psychological distress) (Ranelli et al., 2011; Cruder et al., 2021; Pfalzer and Walker, 2001; Warrington et al., 2002; Yoshie et al., 2009), instrument-related factors (such as weight of the instrument, techniques, and training of playing) (Mikimoto et al., 2004), playing conditions (e.g., time spent playing the instrument) (Fry, 1987; Fotiadis et al., 2013; Ranelli et al., 2011; Robitaille et al., 2018), and the interactions between these factors.

To simultaneously address the gap in existing literature and a lack of evidence for the population of Chinese pianists, this study aims: (1) To ascertain the prevalence and symptoms of PRMD in Chinese conservatoire students majoring in piano performance; (2) To determine any risk factors of the appearance of PRMD. Based on existing literatures, we hypothesized that age, gender, years of playing, practice hours, practice habits and strategies would be associated with PRMD; (3) To suggest interventive preventions for conservatoire piano students.

2 Materials and methods

This study adopted a self-reported online questionnaire. This questionnaire was structured based on an existing survey by Ling et al. (2018); therefore, the validity of the questionnaire was already established.

Participants were recruited through contacts with conservatoires in China. Recruitment was done in three ways. Firstly, an invitation email to participate in this study was sent to their teaching staffs of piano studies, and then the link to questionnaire was shared with their students. Secondly, online advertisements via social media platforms were published. Thirdly, we utilized the word-of-mouth strategy by asking for referrals from people who have participated in previous surveys.

This study aims to recruit piano students because the research aim is to examine the prevalence of PRMD among Chinese Conservatoire Piano students. Therefore, Chinese students majoring in piano performance at undergraduate or postgraduate level are considered.

At the beginning of the questionnaire, a brief introduction of the study, including its purpose and procedure, was given. Furthermore, the level of confidentiality, which would be upheld throughout the project, and the voluntary nature of participation were demonstrated. Participants were informed that personal information would be kept anonymized and confidential. Due to the voluntary nature of the self-reported online questionnaire, informed consent was obtained before participants answered the questionnaire by having them tick a consent box. Contact details of the two researchers were provided at the end of the questionnaire if participants have any further enquiries.

2.1 Questionnaire design and procedure

The questionnaire was structured into three sections, and it took approximately 7 to 10 min to complete. The design of this questionnaire was informed by the existing survey used by Ling et al. (2018), as their survey was designed specifically for pianists and closely aligned with the research objectives of the current study. The reliability and validity of the questionnaire were already established in their studies. The first section collected respondents' demographic information (gender, age, age started playing the piano, number of years learning the piano). In the second section, participants were asked about their practice habits, such as years of playing experiences, weekly practice hours, break-taking during practice and warm-up exercises. In the third section, participants were required to indicate their experiences of PRMD during their entire piano training. Only participants who had experienced any symptoms before were included. The list of injury locations included finger, wrist, arm, neck, shoulder and back. A blank space was also provided for participants to identify discomfort in any other parts of the body. For each discomfort, they were asked to describe the discomfort in the body parts that they have experienced using checkboxes (allowing for multiple selections).

Participants were further asked to rate the level of discomfort they have experienced. The level of discomfort was used to categorize the severity of PRMD on a scale of 0 to 7 (as shown in Table 1). Levels 0 to 2 were regarded as relatively mild discomfort, and thus, only those who had rated severity at level 3 and above were considered experiencing PRMD. According to Ling et al. (2018), respondents who rated pain at levels 0 to 2 were not considered as having PRMD. Thus, respondents declared a PRMD at level 2 and below were excluded from being classified as having PRMD in the analysis.

The questionnaire was translated and adapted in Chinese. To ensure that the adapted version was valid for the current context and to test the validity of translation, a pilot study was conducted among a convenience sample of conservatoire students. Their feedback was incorporated into the final design of the questionnaire used in this study. Feedback included the need to provide an approximate length of time required to complete the questionnaire. A copy of the final questionnaire is available in the Supplementary material.

2.2 Data analysis

All the data was analyzed using SPSS 26.0. Descriptive statistics are presented for the prevalence rates of PRMD among Chinese piano students, with the prevalence rate calculated as a percentage of reported PRMD of the whole sample. To determine the relationship between the occurrence of PRMD and several variables, analyses of variances, Chi-square and regression analyses were conducted. These analyses were adopted based on their suitability for identifying statistical differences between groups and for exploring associations between variables. In the following sections, the results quantifying the effects of gender, years of playing experience, practice hours, the habit of warm up before practice and break-taking during practice are described. A significance level of $p < 0.05$ was used for reporting.

TABLE 1 Level of severity of signs and symptoms of pain among pianists.

Level	Signs and symptoms
0	No pain during and after playing the piano.
1	Feeling tired during and after playing the piano, but no pain or other symptoms.
2	Pain occurs while playing the piano, or for a short period of time (< 2 days) after playing the piano. You are still able to play the piano normally.
3	Pain occurs while playing the piano and persists for a longer period (>2 days) after playing the piano. However, playing is not yet restricted.
4	Pain progresses. You have to change playing techniques and reduce playing time. Pain resolves after the alteration.
5	Pain occurs once you start to play the piano. Changing techniques and shortening playing time do not relieve pain. Some daily activities are affected.
6	Pain persists even when you are not playing the piano. Many daily activities are affected. You have to stop playing completely until recovery.
7	Pain persists. No recovery. You are not able to play the piano anymore.

3 Results

The total number of participants was 363 piano performing students drawn from five Chinese conservatoires, including the Central Conservatory of Music, Shanghai Conservatory of Music, Sichuan Conservatory of Music, Zhejiang Conservatory of Music and Xinghai Conservatory of Music. The average age of the sample was 22.3 (min-max = 18–27; $SD = 2.2$). More respondents identified their gender as female ($n = 241$, 66.4%), and other responses were male ($n = 122$, 33.6%). In general, participants had an average of 16 years of playing experience on the piano (min-max = 8–22; $SD = 2.24$). The average age at which they started learning the piano was 8.24 (min-max = 4–13; $SD = 1.69$). The weekly hours spent practicing the piano were reported as 1-5 h ($n = 30$, 8.3%), 6-10 h ($n = 21$, 5.7%), 11-15 h ($n = 22$, 6.1%), 16-20 h ($n = 71$, 19.6%), 21-25 h ($n = 93$, 25.6%), 26-30 h ($n = 80$, 22%), and 30+ hours ($n = 46$, 12.7%).

Of all respondents, 82.6% (300/363) reported having at least one PRMD. The prevalence figures reported in this study refer to lifetime PRMDs experienced by respondents during their entire piano-playing experiences. Participants also reported having experienced multiple signs and symptoms and in more than one body site. The reported symptoms were associated with the upper body. The wrist ($n = 183$, 50.4%) was found to be the most affected body site, followed by the

shoulder ($n = 150$, 41.3%), finger ($n = 132$, 36.4%), arm ($n = 98$, 27%), back ($n = 72$, 19.8%) and neck ($n = 55$, 15.2%). Pain ($n = 211$, 58.1%), fatigue ($n = 188$, 51.8%), and stiffness ($n = 153$, 42.15%) were the most cited symptoms. The average severity rating was highest in the shoulder (M = 5.33; $SD = 3$), wrist (M = 4.69; $SD = 3.49$), finger (M = 4.37; $SD = 3.84$) and arm (M = 3.92; $SD = 3.42$). Figure 1 provides the prevalence of PRMD by body site. Figure 2 presents the distribution of severity ratings, including data for those at severity level 1–2 who were excluded in further analyses, for descriptive purposes. Most respondents (77.6%) reported having symptoms, and among these respondents, 68.6% ($n = 249$) reported having had severe signs and symptoms rated between levels 4 and 6 (see Figure 2 for the distribution of the maximum severity reported).

This study identifies significant associations between PRMD prevalence and various factors, however definitive causals conclusions regarding these relationships were not drawn. The results have shown that there was a statistically significant difference between females and males. Females (M = 3.7, SD = 0.96) were more likely to report more PRMD than males (M = 2.9, SD = 1.17). In addition, females (M = 4.8, SD = 2.24) reported a significantly higher level of severity than males (M = 4.2, SD = 2.62). The year of playing experiences of piano students were found to be significantly related to their prevalence and maximum severity of PRMD. There was potentially a complex relationship between the prevalence of PRMD and years of playing experience (as shown in Figure 3). To test the relationships, linear regressions were carried out between years of playing experience and the maximum severity of injuries. A statistically significant positive linear relationship between the maximum severity of injuries and years of playing experience was found ($B = 0.71$, $p = 0.03$*), suggesting that longer years of playing experience were associated with higher severity.

Practice hours of the students were highly correlated to their PRMD prevalence (r = 0.101 [−0.006, −0.126], $p = 0.013$*) and maximum severity of PRMD ($r = 0.096$ [−0.126, −0.113], $p = 0.021$*). As shown in Figure 4, the relationship between practice hours and the severity of PRMD was complex. In order to further explore relationships between students' practice hours per week and their prevalence and severity of PRMD, a series of multiple linear regressions were conducted. A positive linear relationship between the maximum severity of injuries and practice hours was found and the result was significant ($B = 1.35$, $p = 0.00$*), suggesting that overall longer practice hour was associated with injuries of a higher level of severity.

There were significant associations between students' practice habits and their PRMD prevalence and severity. Participants were asked to indicate whether they had the habit of warming up before practice and taking breaks during practice. According to their responses, the group that has the habit of warm up before practice showed lower prevalence and severity of PRMD than the other group that has no habit of warm up (results are presented in Table 2). Furthermore, there was a statistically significant difference in PRMD, and severity based on the habit of break- taking during practice: one group that reported the habit of taking break during practice and the other had no habit of taking break during practice. In general, the latter group showed higher prevalence of PRMD and higher severity level of PRMD (results are presented in Table 3).

4 Discussion

This study aimed to (1) ascertain the prevalence of PRMD in Chinese conservatoire piano students; (2) determine any predicting risk factors associated with PRMD, and (3) evaluate relevant preventive interventions. One advantage of this study is its inclusion of a substantial sample size of Chinese conservatoire students majoring in piano performance.

Of the 363 participants, 82.64% reported having had at least one PRMD during their entire piano-playing experiences, a figure slightly lower than that reported in recent studies (e.g., Savvidou and Stanek, 2019). Although this study has limitations regarding the validity of the severity data, since respondents may have rated injuries that occurred many years ago, introducing potential recall bias, findings are consistent with comparable studies which have reported PRMD prevalence rates

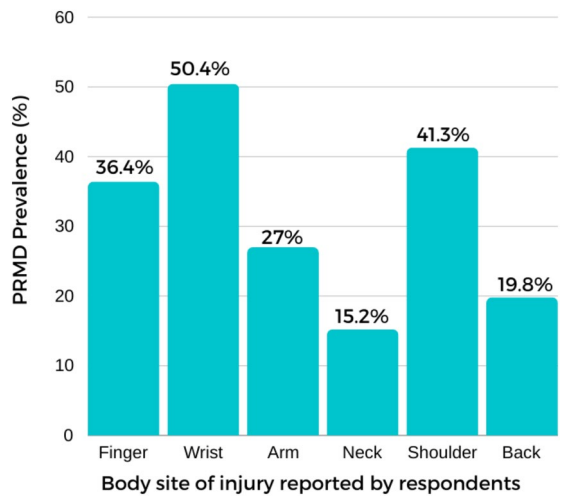

FIGURE 1
The prevalence of PRMD by reported body site.

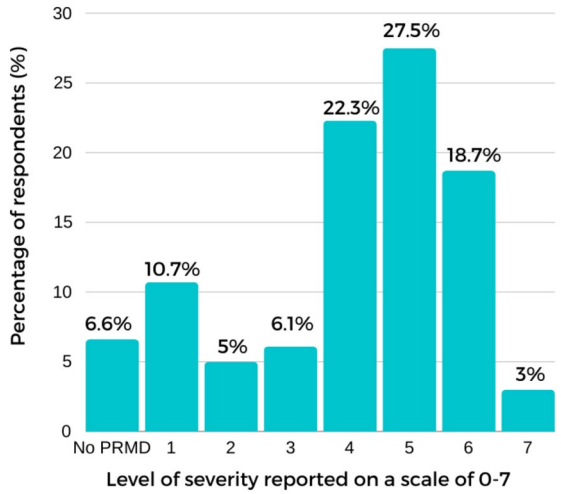

FIGURE 2
The percentage of respondents for each level of severity reported (on a scale of 0–7).

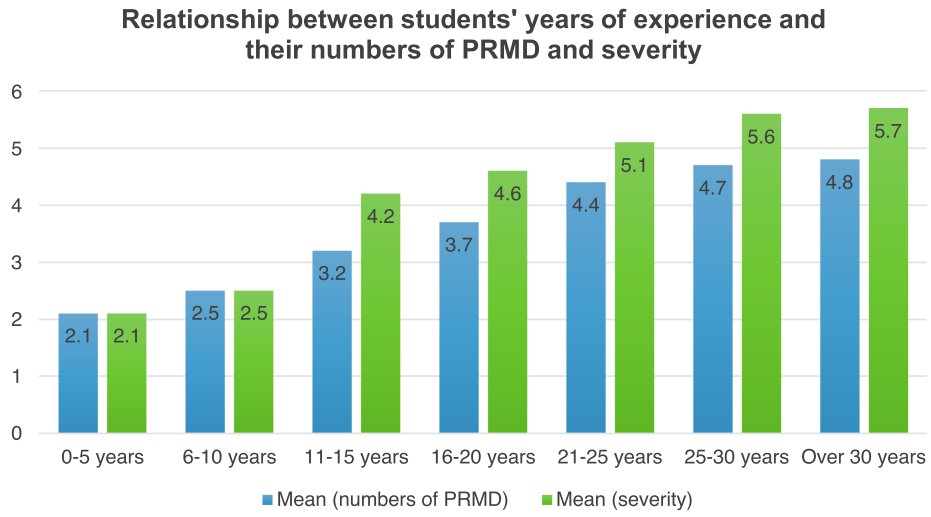

FIGURE 3
Relationship between students' years of experience and their numbers of PRMD and severity.

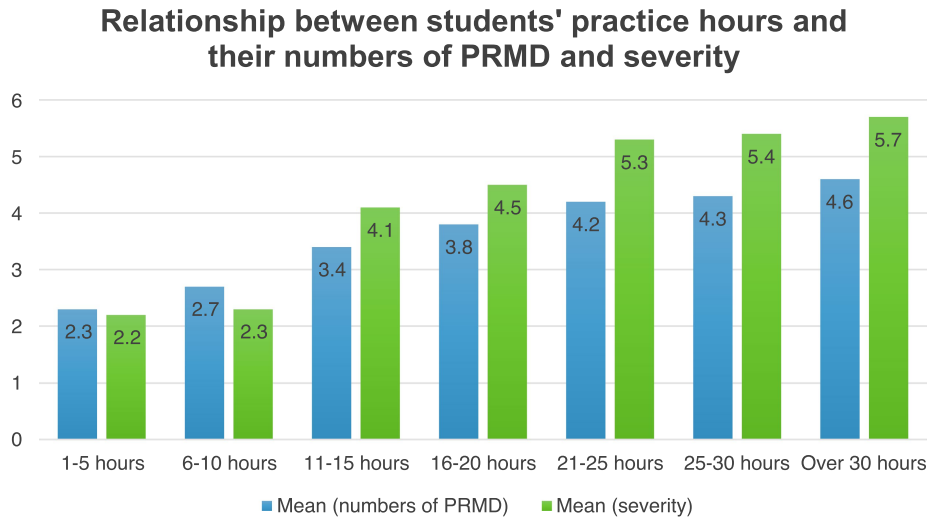

FIGURE 4
Relationship between students' practice hours and their numbers of PRMD and severity.

among musicians of between 39 to 87% (Zaza, 1998; Baadjou et al., 2016; Berque et al., 2016). The results also align with piano-specific PRMD rates previously reported by Sandell et al. (2009). A majority of participants had experienced severe signs and symptoms: 71.5% reported at least one PRMD rated 4 and higher.

The most common body site of injuries in this study was found to be wrist (including all severity level 0 to 7). In general, disorders associated with the wrist have been reported to be common among instrument players (Brandfonbrener, 2000; Fry, 1986; Hochberg et al., 1983; Grieco et al., 1989; Sandell et al., 2009; Ranelli et al., 2011). Disorders associated with the wrist have also been proposed to be the most reported problems among pianists, as a result of overuse or misuse (Grieco et al., 1989; Ranelli et al., 2011; Shoup, 1995). Furthermore, shoulder, finger, arm and neck were reported to be the most common affected body sites among piano students, which confirms previous findings (Barr et al., 2005; Buckle and Devereux, 2002; Rigg et al., 2003; Roset-Llobet et al., 2000; Siivola et al., 2004; Zaza, 1995). Previous performing arts literatures that categorize PRMD based on playing position and postures, PRMD associated with the upper extremities (hand, arm and shoulder) and neck were reported to be the most common injury body sites among musicians (e.g., Dawson, 1988; Dawson, 2002; Farias et al., 2002).

Gender was identified as one of the risk factors in this study, echoing to previous studies. Gender has been widely investigated as an individual condition factor that may associate with PRMD and the consensus has been reached: female musicians were more likely to report a PRMD than their male counterparts (Pak and Chesky, 2001; Fjellman-Wiklund et al., 2003; Lim and Altenmüller, 2003; Ranelli

TABLE 2 Students' ANOVA test and effect size for the who has the habit of warm up before practice and who has no habit of warm up before practice.

	Group 1: who has the habit of warm up before practice		Group 2: who has no habit of warm up before practice		*t*	*p*
	M	SD	M	SD		
Numbers of PRMD	3.7	1.3	4.3	1.9	56.32	0.001
Severity level	4.5	2.7	5.2	2.3	52.67	0.001

TABLE 3 Students' ANOVA test and effect size for the who take break during practice and who does not take break during practice.

	Group 1: who take break during practice		Group 2: who does not take break during practice		*t*	*p*
	M	SD	M	SD		
Numbers of PRMD	3.9	1.2	4.7	3.3	58.32	0.005
Severity level	4.4	1.9	5.3	2.2	22.18	0.017

et al., 2011). In addition, female musicians reported higher severity level than males, and the effect is statistically significant.

Unlike the individual condition factors and instrument-related factors which are less modifiable, many factors associated with PRMD have been found to be related to the musician's playing behaviors that are adjustable. Two types of playing behaviors were found to contribute to a higher risk of PRMD: misuse and overuse. Misuse includes inappropriate use of the body, which is in relation to practice habits, including playing techniques, movement techniques and postures (Lippmann, 1991). As instruments have their own shapes and weights, wrong positions and body postures can lead to injuries (Brandfonbrener, 2000). Similarly, Guptill and Zaza (2010) argue that all instrument players need to maintain the natural curvatures of the spine (both in sitting and standing) during playing; otherwise, it can lead to PRMD. For instance, the common slouching of shoulders and the hyperextension in the lower spinal of musicians during playing can cause unnecessary tension and pain in the lower and mid-back among musicians (Guptill and Zaza, 2010; Harreby et al., 1995). Also, Lippmann (1991) suggests that the PRMD of pianists were related to misuse of the body and improper practicing habits, including motor skills and movement techniques. For instance, the extreme ranges of movement during playing (Fry, 1986) and wrist postures working against gravitational force (Allsop and Ackland, 2010) have been evidenced to be misuse factors that can lead to overuse syndrome.

The other type of playing behavior that can lead to PRMD is overuse, which includes repetitive movements (Rozmaryn, 1993), long hours of practice and playing, long years of playing experiences, and a sudden increase in practice intensity. Performing and practicing instruments pose significant musculoskeletal pressure on musicians (Kok et al., 2016; Quarrier, 1993), as they often involve intensive repetitive and striking motions that are primary sources of PRMD (Lederman and Calabrese, 1986). Similarly, Guptill and Zaza (2010) argue that the use of repetitive moves during extended hours of practice could be an important risk factor of PRMD. Overuse occurs when muscles, tendons, ligaments or fascia are stressed beyond the individual's biological limits (Dawson, 2008; Philipson et al., 1990). For pianists, overuse is common, since the fundamental skills in playing the piano are motor skills, which involve enormous movements of hands, fingers, wrists and arms and lead to overuse (Sakai, 2002). Brandfonbrener (2000) criticized repetitive techniques involved in complex repertoires and the needed force applied to keys to cause overuse problems among pianists. Lim and Altenmüller (2003) argued that heavy workloads and non-flexible work schedules were responsible for overuse among musicians. The results of this study confirmed that longer years of playing experience and longer practice hours can contribute to PRMD rate and severity.

The group of participants with the habit of warm-up before practice showed lower PRMD frequency and severity than the group of no warm-up habit. Having warmups before practice can be helpful for pianists to reduce PRMD. Before playing, both musical and physical warm-ups are needed. The importance of musical warm-up that aims to prepare the body and mind for performance has been noted by musicians, and some musical warm-up strategies have been developed and deployed. Slow and comfortable playing can help pianists to prepare themselves musically before performance. It may include starting with moderately paced scales and arpeggios or easy repertoires (Guptill and Zaza, 2010), which, on the one hand, can help pianists get into music quickly and, on the other hand, can prepare the relevant muscles for continued playing. Meanwhile, physical warm-ups such as body stretching can also be helpful, as they can enhance muscle flexibility and benefit quick-speed movements by improving the strength of the musculotendinous unit (Page, 2012). Specific warm-up exercise of stretching is involved in different muscles and body sites. To reduce the risk of overuse syndrome of hands or wrists, Guptill and Zaza (2010) encouraged pianists to turn their palms upward and extend their wrists and fingers.

The risk of overuse syndrome can also be reduced through necessary breaks. It has been found in this study that participants who take breaks during practice showed lower prevalence rate of PRMD and lower severity than those who do not have the habit of break-taking. Taking regular breaks can be beneficial to reduce the occurrence of PRMD. Guptill and Zaza (2010) argued that two types of breaks are needed: micro-breaks during practicing and breaks away from playing. Micro-breaks during playing can be a stop for several seconds or counting rests (*ibid*), which allow for muscle recovery. Breaks away from playing involves longer breaks after a long time of playing. Although many teachers advocate a five-minute break for every thirty-minute practice (Tubiana and Amadio, 2000), no specific studies investigating the time and frequency a musician need to reduce the risk for playing-related injuries. Pianists need to determine the time and frequency of breaks based on their own conditions.

Smart practice techniques can help to reduce the overuse syndrome through reduced practicing hours and repetitions. Less effective practice techniques, for instance, returning to the beginning of the section when a mistake is made and repeating the same section

all over again (Renwick and Mcpherson, 2002; Williamon and Valentine, 2000). As a result, smart practice techniques that avoid unnecessary work could be essential to prevent overuse syndrome of hands or wrists for pianists. First, modern technology (e.g., recording applications) can be used to identify errors during practice. After identifying the error, the pianist should practice the error areas slowly and repeatedly rather than returning to bar 1 and practicing the whole repertoire. Secondly, incorporating cognitive practice without the instrument (such as practicing fingering on the table) into daily practice routines can be an effective strategy for reducing the force applied to the keys during piano performance. Other useful cognitive practice techniques include getting familiarized with the structure, phrasing, and interpretation of the repertoire through listening to recordings before playing, visualizing successful performances by other musicians, and imagining the process of playing through the piece mentally (Guptill and Zaza, 2010). These strategies can be helpful in enhancing efficiency and reducing repetitions (Bandura, 1986). Thirdly, developing a structured practice plan helps pianists to manage their practice hours effectively and avoid sudden increases in practice time and frequency that could lead to the occurrence of overuse syndrome.

It is important for musicians, including pianists, to adopt correct postures and playing positions since wrong postures can cause unnecessary tension for muscles and thus lead to a higher risk of playing-related disorders. For pianists, the proper sitting position is shown in Figure 5, typically involving the maintenance of normal curves of the spine when sitting at the piano (Guptill and Zaza, 2010). According to Guptill and Zaza (2010), the recommended piano-playing position is designed to minimise strain on various body sites including hands, wrists and arms. This recommended position facilitates easy and unrestricted movements of the hands and wrists, thereby reducing the risk of playing-related injuries, including overuse syndrome in these body sites.

The position of the wrist during piano playing is crucial for the overall well-being of the pianist. Oikawa et al. (2011) highlight the significance of minimizing forearm burden to decrease the likelihood of related disorders. Recommendation for pianists could include maintaining a neutral wrist position during playing (see Figure 6). Incorrect position of wrists (such as those shown in Figures 6B,C) may cause an additional burden for the forearm and wrists, as they require extra muscle activities of the wrist's extensors and flexors (Oikawa et al., 2011). Adhering to proper wrist positioning is essential for pianists to reduce the risk of musculoskeletal issues and promote a healthier playing experience for pianists.

5 Conclusion

In summary, this study highlighted a high prevalence of PRMDs among Chinese conservatoire piano students, with 82.64% of participants reporting at least one PRMD. The wrist was identified as the most influenced body site of injury, followed by the shoulder, finger, and arm, with pain, fatigue, and stiffness was found to be the most frequently cited symptoms. Key risk factors contributing to the development and severity of PRMDs included gender, years of playing experience, practice hours, and practice habits such as warming up and taking breaks. Female students, those with longer playing experiences, those practicing for extended hours, and those neglecting warm-ups and breaks were more likely to suffer from PRMDs.

By focusing on the specific population of conservatoire students majoring in piano performance, the research contributes to a more nuanced understanding of the potential challenges faced by piano students in their career life. These insights could potentially inform preventive interventions and strategies aimed at mitigating the risk of PRMD among pianists. The results and findings of this study confirm and build upon existing knowledge regarding PRMD among piano students,

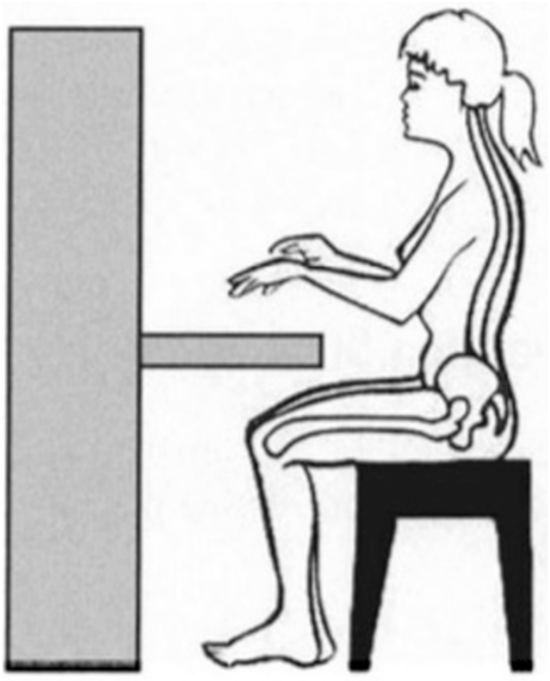

FIGURE 5
Proper sitting position for piano-playing recommended by Guptill and Zaza (2010, p.30). Adapted from Adalbert (2000).

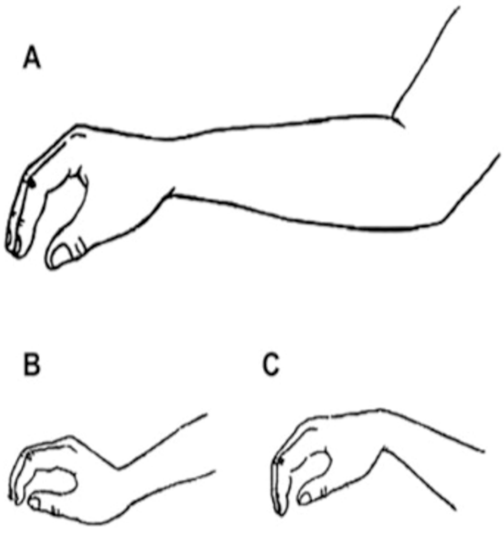

FIGURE 6
The proper and wrong positions of the wrist during piano-playing suggested by Oikawa et al. (2011). Adapted from (Mikimoto et al., 2004).

suggesting the need for extended research to include professional pianists and longitudinal follow-up studies on music students experiencing PRMDs. Moreover, this study adds to the growing body of literature on PRMD in musicians with a different sample and highlights the importance of addressing these issues to support the physical health and overall well-being of pianists at their early musical career stages.

Despite the valuable insights this study provides into the prevalence and risk factors of PRMDs among Chinese conservatoire piano students, several limitations and challenges must be acknowledged. First, this study relied on self-reported data through an online questionnaire, which may introduce recall bias, leading to insufficient reporting. Participants were asked to recall and rate the severity of injuries that may have occurred many years ago, which could affect the accuracy of the responses. The collection of past events of injury may vary between individuals, and the severity of past symptoms might be over- or under-estimated. This limitation highlights the need for objective measures of PRMD severity, such as clinical assessments or longitudinal data collection. This study employed a cross-sectional design where the data was collected at one point of time. While this approach is useful for identifying the prevalence of PRMDs, it fails to capture changes in PRMD symptoms over time or the progression of disorders. A longitudinal study could make the tracking of PRMD development possible, offering more comprehensive insights into the nature and course of these disorders. These limitations may limit the generalizability of the findings to students from other music schools, or musicians who engage with instruments beyond just the piano. Further research should explore PRMDs across a broader range of musical disciplines and geographical regions to understand the wider applicability of these findings. Additionally, the sampling method might lead to potential sampling bias. The sample might overrepresent individuals who were more engaged with social media or those who have stronger connections with the researchers' networks. Although the sample size ($n = 363$) is substantial for understanding the prevalence of PRMD among Chinese conservatoire piano students, the recruitment approach may limit the generalizability of the findings to the broader population of musicians. Future studies could aim to employ randomized or stratified sampling techniques to ensure greater representativeness of the sample. Lastly, this study overlooked the importance of other factors influencing the occurrence of PRMD, such as playing posture, psychological stress, and access to ergonomics education for understanding the issue more comprehensively.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Hangzhou Zhijiang Experiment Mid. School, China. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

LZ: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. YW: Data curation, Project administration, Resources, Validation, Visualization, Writing – review & editing, Writing – original draft. ZZ: Resources, Validation, Writing – review & editing.

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Exploring motivational patterns in high-performing pianists: evidence from Cliburn competitors' biographies

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This research examines the motivational patterns of high-performing classical pianists, characterized by a combination of implicit motives (i.e., non-conscious preferences for specific incentives). Utilizing the Linguistic Inquiry and Word Count (LIWC) software, I analyzed textual data from biographies of 107 pianists (i.e., Juniors aged 13–17: $n = 38$; Professionals aged 18–30: $n = 30$; Amateurs aged 35 and older: $n = 39$) participating in the prestigious 2022–2023 Van Cliburn Competitions. My results showed distinct profiles of implicit motives among pianists compared to non-pianists, with significantly higher need for achievement and need for power. While professional pianists exhibited the lowest level of need for power, junior pianists demonstrated the highest level of need for affiliation. Gender and age predicted part of pianists' implicit motives. Male pianists demonstrated higher need for achievement than females. Finally, age negatively predicted need for affiliation. These findings highlight the motivational patterns within the classical piano community, offering theoretical implications for understanding implicit motives and practical applications for pianist education. Study limitations and future research directions are discussed.

KEYWORDS

implicit motives, motivational pattern, the Cliburn, biographies, linguistic inquiry and word count

1 Introduction

Pianists hold a pivotal position within the classical music sphere, serving not only as performers but also as collaborators (e.g., Katz, 2009) and educators (e.g., Duckworth, 1965). Their contributions extend beyond the concert hall, shaping the cultural landscape and fostering musical appreciation worldwide. While previous research has explored the psychological profile of high-achieving pianists (e.g., NEO Five-Factor in Chmurzynska, 2012), less attention has been paid to the deeper, motivational drivers that underpin pianists' aspirations, behaviors, and actions.

Understanding pianists' underlying motivation is crucial for several reasons. Firstly, it allows us to gain insight into the driving forces behind their dedication to their pianistic craft, shedding light on the intrinsic and extrinsic factors that fuel their pursuit of musical excellence (*cf.* Amabile, 1996). Secondly, insights into pianists' motivations can inform pedagogical approaches (Gerelus et al., 2020), career development strategies (Zhukov and Rowley, 2022), and performance enhancement techniques (Chaffin and Lemieux, 2004; Osborne et al., 2020), ultimately benefiting both individual pianists and the broader classical music community. Furthermore, understanding pianists' motivational dynamics can facilitate the cultivation of supportive environments that nurture their artistic growth and well-being (Koehler et al., 2023), thereby ensuring the continued vitality and sustainability of the classical music ecosystem.

Despite the significance of understanding pianists' motivational profiles, there persists a notable gap in our understanding of their implicit motives (e.g., McClelland, 1987; Schultheiss

and Brunstein, 2010). Operating outside an individual's conscious awareness, implicit motives are motivational predispositions based on affective responses to rewards and punishments that facilitate the pursuit of specific types of incentives and the avoidance of certain disincentives (Schultheiss and Köllner, 2021). Studying implicit motives can provide distinctive insights into individuals' genuine passions, values, and enduring aspirations, which may not always align with their explicitly stated goals or objectives (Köllner and Schultheiss, 2014; Rawolle et al., 2013; Schultheiss and Köllner, 2021).

1.1 Implicit motives

David McClelland's Implicit Motives Theory (McClelland, 1987; Schultheiss and Brunstein, 2010) posits that implicit motives direct and drive individuals' behavior towards emotionally charged or affectively "hot" stimuli (Schultheiss, 2008; Schultheiss et al., 2010). Since the 1950s, research on implicit motives has predominantly focused on "big three" fundamental motivational needs: need for achievement (*n* Achievement), need for power (*n* Power), and need for affiliation (*n* Affiliation). Below, I outline the definitions of these motives, their psychological and behavioral correlates (see Schultheiss and Köllner, 2021, for a recent comprehensive review), and their relevance to pianists.

1.1.1 Need for achievement

Need for achievement is "the capacity to derive satisfaction from the autonomous mastery of challenging tasks" (Schultheiss and Köllner, 2021, p. 385). *n* Achievement drives individuals to excel in challenging tasks and seek personal accomplishment (McClelland et al., 1953). Understanding pianists' level of *n* Achievement can provide insights into their drive for mastery (Schultheiss and Brunstein, 2005), goal-setting behaviors (Brunstein, 2010), and responses to feedback (Brunstein and Maier, 2005). Pianists with high *n* Achievement may demonstrate a preference for challenging repertoire, set ambitious performance goals (e.g., Yuja Wang's 2023[1] marathon Carnegie concerts featuring Rachmaninoff's five works for piano and orchestra), and persist in the face of setbacks (Neumann and Schultheiss, 2015). In contrast, those with lower *n* Achievement may exhibit less ambition and persistence in their musical pursuits (McClelland, 1987; Schultheiss and Brunstein, 2010). By understanding *n* Achievement among pianists, piano educators and researchers can tailor training and support interventions to enhance achievement motivation and facilitate their artistic development.

1.1.2 Need for power

Need for power refers to "a capacity to derive pleasure from having physical, mental, or emotional impact on other individuals or groups of individuals and to experience the impact of others on themselves as aversive" (Schultheiss and Köllner, 2021, p. 387). *n* Power predicts an individual's assertiveness (e.g., Veroff, 1982), leadership (e.g., Steinmann et al., 2015), and competitiveness (e.g., Winter, 2010). Pianists with a high *n* Power may be more inclined to seek opportunities for solo performance, assert their artistic vision, and engage in competitive contexts such as competitions and auditions. Understanding the interplay between *n* Power and musical outcomes can inform strategies for fostering healthy competition, enhancing leadership skills, and navigating interpersonal dynamics within collaborative settings (*cf.* Ditlmann et al., 2017).

1.1.3 Need for affiliation

Need for affiliation is "a capacity to derive satisfaction from establishing, maintaining, and restoring positive relationships with others and to experience separation as aversive" (Schultheiss and Köllner, 2021, p. 386). *n* Affiliation is related to interpersonal relationships, social connections, and collaborative behaviors (e.g., Dufner et al., 2015). Pianists with a high *n* Affiliation may prioritize building supportive networks (e.g., Dufner et al., 2018), seek opportunities for ensemble playing, and thrive in cooperative musical environments. By contrast, those with lower *n* Affiliation may gravitate towards solo performance or struggle with interpersonal challenges in ensemble settings. By understanding the role of *n* Affiliation among pianists, pianist educators and researchers can develop interventions to promote positive social interactions, foster collaborative skills, and enhance the sense of community within the classical music scene.

1.2 Research questions

Exploring each of McClelland's implicit motives among pianists offers valuable insights into their motivational profiles. Previous research on implicit motives has highlighted that effective leaders often exhibit a specific motivational pattern known as the "leadership motive pattern" (LMP) (McClelland and Boyatzis, 1982; McClelland and Bunham, 1976; Winter, 1973; Winter, 1991). The LMP is characterized by a combination of high *n* Power, low *n* Affiliation, and a high level of activity inhibition (AI), or "a stable tendency to refine and regulate the behavioral expression of motives" (Steinmann et al., 2015, p. 168). In this study, I aim to explore whether high-performing Cliburn pianists possess a distinct combination of implicit motives, which I refer to as a musicianship motivational pattern (MMP). Consequently, I focus on three primary research questions (RQs):

> RQ1: *How do the implicit motives of high-performing pianists compare to those of non-pianists*?
>
> RQ2: *Do the implicit motives of high-performing pianists differ across distinct competitive settings*?
>
> RQ3: *How do pianists' sociodemographic* variables, *such as gender and age, relate to their implicit motives*?

2 Method

2.1 Research setting: the Van Cliburn competition (2022–2023)

The Van Cliburn Competition offers a rich and multifaceted research context for understanding the motivational profiles of high-performing pianists. As one of the most prestigious piano competitions globally, it attracts top-tier pianists from around the world, ensuring

1 https://www.carnegiehall.org/About/History/Performance-History-Search?q=yuja%20wang%20philadelphia&dex=prod_PHS&event=68959

a pool of participants who have demonstrated exceptional dedication and talent in their pursuit of piano mastery. This concentration of elite performers provides a unique research context to study individuals who have already achieved a high level of musical success and competence, offering valuable insights into the motivational factors driving drive their continued pursuit of excellence.

The competitive nature of the Cliburn Competition replicates the high-stakes performance environments that professional pianists and musicians regularly encounter in their careers. The intense pressure and scrutiny involved in the competition setting, though beyond the scope of this research, allow researchers to observe how different motivational factors may predict performers' behavior and performance outcomes under stressful conditions. Understanding how these motivations manifest in competitive settings can offer valuable insights into the psychological processes underlying high performance and achievement.

Moreover, the Cliburn Competition's multi-dimensional structure, encompassing junior, professional, and amateur editions, provides with diverse contexts to explore motivational profiles across various stages of pianists' development and levels of expertise. By comparing and contrasting the motivational dynamics of emerging talents, seasoned professionals, and enthusiastic amateurs, I can gain a comprehensive understanding of the factors that drive individuals to pursue excellence in piano performance across different career stages.

The junior edition of the Cliburn Competition provides insights into the early developmental stages of high-performing pianists' careers, offering valuable opportunities to examine how motivational factors influence the trajectories of emerging talents. Given its role as a pinnacle event in the classical music world, the professional edition of the Cliburn Competition serves as a particularly compelling research context. Winners of the competition often go on to enjoy international recognition and prestigious concert engagements, making it an ideal setting to explore the motivational factors that contribute to long-term success and sustained excellence in piano performance. Finally, the amateur edition of the Cliburn Competition offers a unique perspective on the motivational profiles of non-professional pianists, who bring their own diverse array of motivations and goals to the competition. By studying the motivational dynamics of these enthusiastic amateurs, I can gain insights into the distinctive motivational factors that drive individuals to pursue the piano, even outside their professional realms.[2]

2.2 Textual analyses on Cliburn competitors' biographies

In this study, I utilized the Linguistic Inquiry and Word Count (LIWC) software (Pennebaker et al., 2015) to analyze the implicit motives of 107 pianists (juniors: $n = 38$, including 24 competitors and 14 festival artists; professionals: $n = 30$; amateurs: $n = 39$[3]) participating in the 2022–2023 Van Cliburn piano competitions. Operating an internal default word dictionary to quantify the frequency of words within a given text file, the LIWC can be used to assess a wide range of psychological constructs, including "beliefs, fears, thinking patterns, social relationships, and personalities" (Pennebaker et al., 2015, p. 1). Previous research (e.g., Schultheiss, 2013) has demonstrated the utility of LIWC in detecting implicit motives through the analysis of word frequencies in text.

To ensure the replicability of my LIWC analysis, I obtained all biographies from the "Competitors" pages of the Cliburn official website,[4] retaining only the main biographical text. I removed content such as repertoire[5] (listed for all competitors), occasional mentions of prizes (e.g., "Bernice Gressman Meyerson First Prize Winner" in S. Hong's biography, specific to junior competitors), and stand-alone occupational titles not presented within the main biographical text (e.g., "President and CEO – Advisory Investment Management" in E. Santiago's biography, specific to amateur competitors). This pre-processing step ensures that irrelevant textual data, which could unintentionally confound the frequencies of the "big three" motives of interest, is removed. Critically, the LIWC calculates word frequencies as percentages of the total word count in each text passage, allowing for standardized comparisons across texts despite significant differences in the average word counts of biographies between the three competitor cohorts (junior: $M = 372.05$, $SD = 66.83$; professional: $M = 281.47$, $SD = 104.63$; amateur: $M = 151.69$, $SD = 19.78$), $F(2, 104) = 98.66$, $p < 0.001$.

I employed LIWC2015 (Pennebaker et al., 2015), which includes a default dictionary consisting of 41 categories of psychological constructs, such as drives, affect, and cognition. I focused specifically on the "drives" category, which encompasses the "big three" motives, namely, achievement, power and affiliation. Example words from each category include "win," "success," and "better" for achievement; "superior" and "control" for power; and "ally," "friend," and "social" for affiliation (Pennebaker et al., 2015, p. 11). The LIWC2015 manual also provides base rates for word usage across various text types (e.g., blogs, novels, Twitter), based on over 231 million words from more than 80,000 writers and speakers.

2 My insights into pianists' motivational patterns have been informed by my own experiences as an amateur pianist and a management scholar in the field of subconscious motivation, particularly through my recent participation in and reflection on the 8th Cliburn International Amateur Competition (2022) and PianoTexas International Festival & Academy (2022 and 2023).

3 The 2022 Cliburn amateur competition also included 15 additional pianists who participated as non-competing festival participants, but no biographies were provided on the Cliburn website.

4 Biographies of junior, professional and amateur competitors were obtained from https://cliburn.org/2023-junior-competitors, https://cliburn.org/2022-competitors, and https://cliburn.org/2022-amateur-competitors-3, respectively (all retrievable as of September 25, 2024).

5 The repertoire choices of pianists during competitions, along with factors such as judges' evaluations, performance quality, and performance contexts, could significantly influence competition outcomes. However, these factors fall beyond the scope of the current analysis and warrant future empirical investigation.

3 Results

3.1 Pianists vs. non-pianists

RQ1 examined how the implicit motives of high-performing Cliburn pianists compare to those of non-pianists. The LIWC2015 manual reports the base rates (in %s) for achievement, power, and affiliation motives range from 0.91 to 1.82 ($M = 1.30$, $SD = 0.82$), 1.72 to 3.62 ($M = 2.35$, $SD = 1.12$), and 1.39 to 2.53 ($M = 2.05$, $SD = 1.28$), respectively (Pennebaker et al., 2015, p. 11). In this study, I compared the motive scores extracted from the Cliburn biographies relative to these base rates. The results from a series of independent samples t-tests reveal notable differences between Cliburn pianists across all competition categories (i.e., Junior, Professional, and Amateur) and non-pianists in implicit motives.

With regard to *n* Achievement, compared to non-pianists, Cliburn pianists displayed notably elevated levels across all competition categories (Junior: $M = 3.77$, $SD = 0.66$, $t(37) = 22.99$, $p = 0.000$; Professional: $M = 3.98$, $SD = 1.47$, $t(29) = 9.92$, $p = 0.000$; Amateur: $M = 3.45$, $SD = 1.44$, $t(38) = 9.33$, $p = 0.000$) (see Figures 1a–c).

Regarding *n* Power, Cliburn pianists demonstrated significantly higher levels across all categories (Junior: $M = 4.97$, $SD = 0.65$, $t(37) = 24.95$, $p = 0.000$; Professional: $M = 3.59$, $SD = 1.32$, $t(29) = 5.12$, $p = 0.000$; Amateur: $M = 4.58$, $SD = 1.56$, $t(38) = 8.97$, $p = 0.000$) (see Figures 2a–c).

However, in the realm of *n* Affiliation, there was no significant difference observed between Junior pianists ($M = 2.19$, $SD = 0.63$) and non-pianists, $t(37) = 1.36$, *n.s.* (see Figure 3a). Both professional [$M = 0.86$, $SD = 0.54$, $t(29) = -12.03$, $p = 0.000$] and amateur pianists ($M = 1.10$, $SD = 1.06$, $t(38) = -5.56$, $p = 0.000$) exhibited significantly lower *n* Affiliation scores than non-pianists (see Figures 3b,c).

Therefore, compared to non-pianists, Cliburn pianists across all competition cohorts demonstrated heightened levels of *n* Achievement and *n* Power. However, unlike junior pianists, adult pianists, regardless of their professional status, were associated with diminished *n* Affiliation.

3.2 Junior vs. professional vs. amateur

RQ2 explored whether the implicit motives of high-performing pianists vary across different competitor categories. The findings revealed no significant differences in *n* Achievement across competitor categories, $F(2, 104) = 1.59$, $p = 0.21$ (see Figure 1d).

A significant effect of competitor category was observed on *n Power*, $F(2, 104) = 10.92$, $p = 0.00$ (see Figure 2d). Specifically, professional pianists ($M = 3.59$, $SD = 1.32$) displayed significantly lower *n* Power compared to both amateur pianists ($M = 4.58$, $SD = 1.56$) ($p = 0.003$, $d = -0.68$) and junior pianists ($M = 4.97$, $SD = 0.65$) ($p = 0.00$, $d = -1.46$). No other differences in *n Power* across competitor categories were found, indicating that professional pianists displayed the *lowest* level of *n* Power.

Moreover, a significant effect of competitor category was observed on *n* Affiliation, $F(2, 104) = 28.17$, $p = 0.00$ (see Figure 3d). Specifically, junior pianists ($M = 2.19$, $SD = 0.63$) displayed significantly higher *n* Affiliation compared to both professional ($M = 0.86$, $SD = 0.54$) ($p = 0.00$, $d = 2.27$) and amateur pianists ($M = 1.10$, $SD = 1.06$) ($p = 0.00$, $d = 1.29$). No other differences in *n* Affiliation across competitor categories were found, indicating that junior pianists demonstrated the *highest* level of *n* Affiliation.

3.3 Gender and age

RQ3 explored the relationship between pianists' sociodemographic variables, such as gender and age, and their implicit motives. Regarding *n* Achievement, male pianists ($n = 80$, $M = 3.89$, $SD = 1.27$) scored significantly higher than female pianists ($n = 27$, $M = 3.20$,

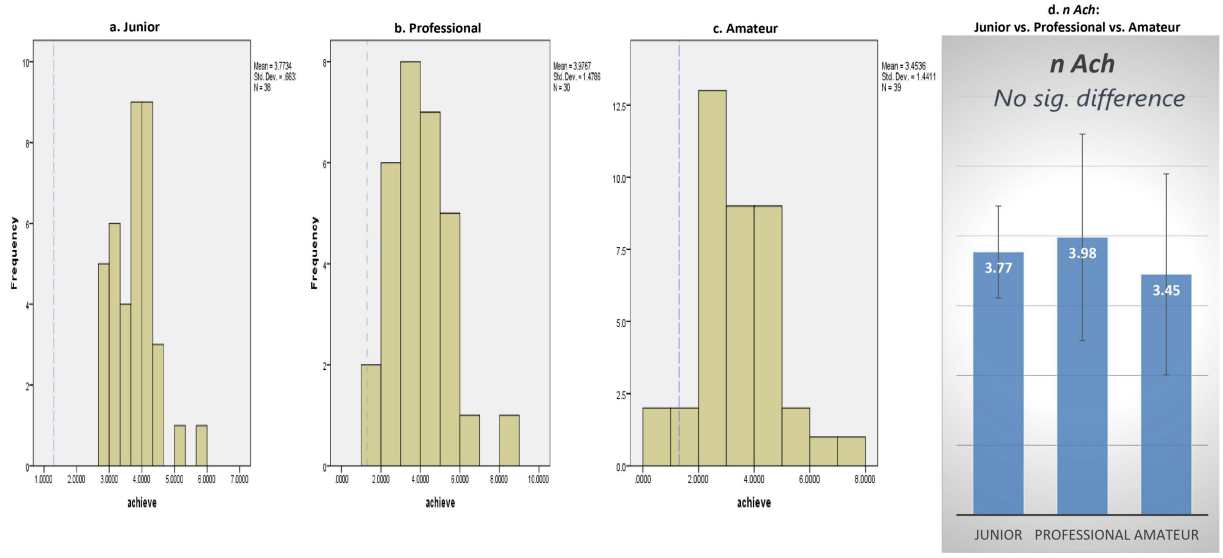

FIGURE 1
Need for achievement.
Note: Blue dotted line in **(a–c)** denotes a grand mean of 1.30 for achievement motive **(d)** is of no concern (Pennebaker et al., 2015).

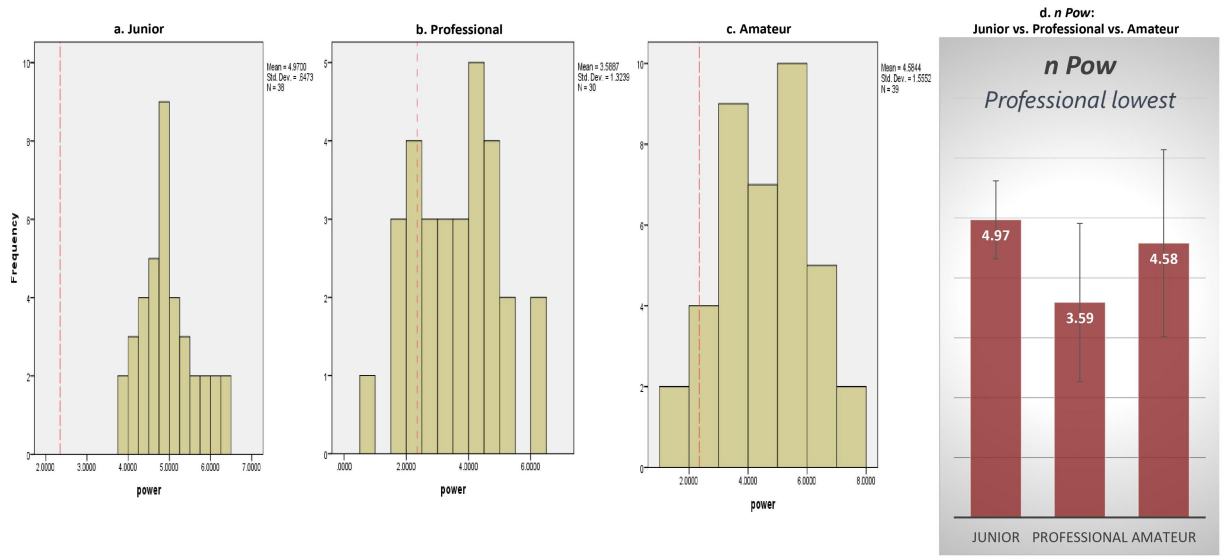

FIGURE 2
Need for power.
Note: Red dotted line in **(a–c)** denotes a grand mean of 2.35 for power motive **(d)** is of no concern (Pennebaker et al., 2015).

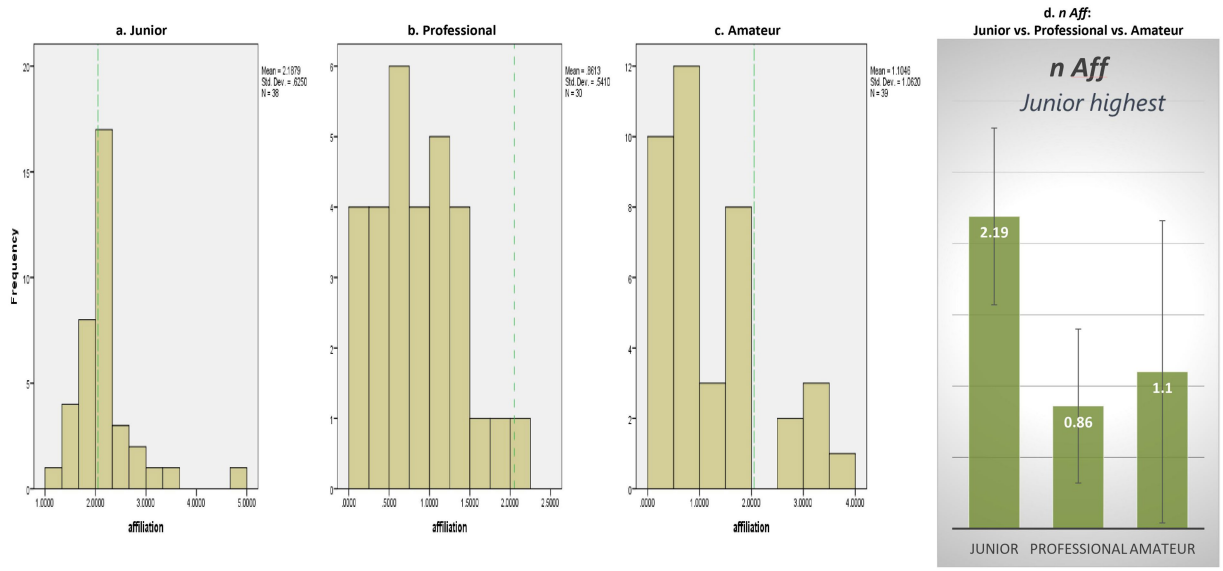

FIGURE 3
Need for affiliation.
Note: Green dotted line in **(a–c)** denotes a grand mean of 2.05 for affiliation motive **(d)** is of no concern (Pennebaker et al., 2015).

SD = 0.99), $F(1, 105) = 6.58$, $p = 0.012$. The regression model, which included both age and gender as predictors, was significant, $F(2, 104) = 3.54$, $p = 0.033$, explaining 6.4% of the variance in *n* Achievement. Gender was a significant predictor [$\beta = -0.25$, $t(104) = -2.56$, $p = 0.012$], while age was not [$\beta = -0.13$, $t(104) = -1.34$, *n.s.*].

For *n* Power, neither age [$\beta = -0.040$, $t(104) = -0.41$, *n.s.*] nor gender [$\beta = 0.011$, $t(104) = 0.12$, *n.s.*] were significant predictors, and the overall model was non-significant, $F(2, 104) = 0.08$, *n.s.* This indicates that neither demographic factor contributed meaningfully to variations in *n* Power.

In terms of *n* Affiliation, age was a significant predictor [$\beta = -0.311$, $t(104) = -3.35$, $p = 0.001$], with increasing age associated with a decrease in *n* Affiliation. Gender, however, was not a significant predictor for *n* Affiliation [$\beta = 0.115$, $t(104) = 1.23$, *n.s.*]. The overall model for *n* Affiliation explained 10.6% of the variance, $F(2, 104) = 6.17$, $p = 0.003$.

These findings suggest that gender significantly predicts *n* Achievement, with males scoring higher than females, while age significantly predicts *n* Affiliation, with older pianists showing lower levels of affiliation motivation. Neither age nor gender significantly predicted *n* Power.

4 Discussion

4.1 Need for achievement

The present findings indicate distinct motivational profiles between pianists and non-pianists. Specifically, compared to non-pianists, pianists demonstrate significantly higher levels of *n* Achievement, indicating a stronger drive for mastery, accomplishment, and success in their musical endeavors. This heightened *n* Achievement among pianists underscores their dedication and persistence in mastering their craft, consistent with the demands of rigorous piano training and performance (Ericsson et al., 1993).

My analysis uncovers gender differences *only* in *n* Achievement among pianists. While both male and female pianists exhibit high levels of *n* Achievement, males tend to demonstrate higher levels compared to females. Although Drescher and Schultheiss' (2016) meta-analytic evidence showed that men and women did *not* differ in their *n* Achievement ($N = 2{,}235$, $k = 13$, $d^* = 0.14$, 95%$CI = [-0.03; 0.30]$), the present finding suggests that male pianists may be particularly driven by the pursuit of mastery and accomplishment in their musical pursuits, contributing to a more nuanced understanding of gender dynamics in the context of pianistic motivation.

Moreover, I found that age did not predict *n* Achievement, contrasting Denzinger et al.'s (2016) result that higher age corresponded with lower *n* Achievement ($n = 736$ adults aged 20–80 year). This result suggests that pianists' drive for personal excellence, artistic mastery, and goal accomplishment remains strong throughout their lifespan and careers. Unlike other broader professional domains where *n* Achievement might decline with age as career goals shift or diminish, classical music emphasizes lifelong pursuit of artistic perfection, where even seasoned musicians strive for continued improvement and artistic growth (Ericsson et al., 1993).

4.2 Need for power

This study reveals that pianists also exhibit significantly higher levels of *n* Power compared to non-pianists. This suggests that pianists are more assertive, ambitious, and inclined towards *influencer* roles within their musical communities. The elevated *n* Power among pianists reflects their willingness to assert themselves and strive for opportunities in the highly competitive classical music landscape. However, the study shows that neither age nor gender predicted *n* Power. Drescher and Schultheiss' (2016) meta-analysis shows that men and women do *not* differ in *n* Power between men and women ($N = 2{,}493$, $k = 15$, $d^* = -0.19$, $95CI = [-0.44, 0.05]$). Consistent with this finding, the present results reflect the pianistic domain where individual mastery and aesthetic expression are central, and thus pianists' desire for influence is *not* differentially shaped by gendered social roles. However, in contrast to Denzinger et al.'s (2016) finding that age negatively correlated with n Power, the present results show that age was not a significant predictor of *n* Power. This discrepancy may suggest that pianists' desire to influence others does not diminish with age as it might in other fields. Evan as they age, classical pianists' desire for performance impact and external recognition remains strong throughout their careers. The sustained *n* Power could be tied to the nature of the classical music profession, where personal influence and artistic legacy often grow with experience and artistic maturity (*cf.* Ericsson et al., 1993).

4.3 Need for affiliation

The analysis of *n* Affiliation among pianists yields nuanced results. While adult pianists, both professional and amateur, demonstrate significantly lower levels of *n* Affiliation compared to non-pianists, there is no significant difference observed among junior pianists (relative to non-pianists). Moreover, I found that competitors' age was a significant, negative predictor of *n* Affiliation. These results suggest that the social orientation of pianists may evolve with age and experience, with adults prioritizing individual achievement over social affiliation, whereas juniors may place a greater emphasis on social connections and collaborative experiences in their developmental stage.

In addition, I found that gender was not a predictor of *n* Affiliation, contrasting earlier findings that females typically score higher than males on this motive (Denzinger et al., 2016; Drescher and Schultheiss, 2016). This discrepancy may suggest that the gender differences in *n* Affiliation observed in broader populations may not manifest as strongly within the domain of classical pianists. Given that the piano career often requires networking and collaboration, both male and female pianists might experience similar levels of need for social connection and approval from audiences, peers, and mentors. The focus on individual performance and the shared pursuit of artistic excellence may minimize the typical gender-based differences in *n* Affiliation.

4.4 Toward a construct of musician motivational pattern (MMP)

This study reveals distinct musician motivational patterns (MMP) among different Cliburn pianist cohorts (junior, professional, and amateur). Juniors exhibit high levels in all three implicit motives. Professionals demonstrate high levels in *n* Achievement, alongside low levels in both *n* Power and *n* Affiliation. On the other hand, amateurs display high levels in *n* Achievement and *n* Power, while exhibiting low levels in *n* Affiliation. In essence, adult pianists, both professional and amateur, share a similar MMP characterized by high *n* Achievement and low *n* Affiliation, while *n* Power serves as a distinguishing factor between professionals and amateurs, with professionals (amateurs) showing lower (higher) *n* Power. Overall, the MMP emphasizes the primacy of *n* Achievement across pianist cohorts, with *n* Power less prevalent among professionals and *n* Affiliation more prominent among juniors.

5 Theoretical and practical implications

Theoretically, the study's contributions to our understanding of implicit motives in the classical music world can inform broader discussions around the role of motivation and individual differences in *competitive* professional contexts. The major theoretical contributions of this study are at least four-folds: (1) providing insights into the implicit motives of pianists relative to those of non-pianists, (2) delineating the musicianship motivational patterns of pianists in different competing settings and levels (juniors, professionals, amateurs), (3) documenting the association between demographic variables such as gender and age and implicit motives, and (4) offering

valuable insights into how pianists can be better supported and motivated in their professional endeavors based on their individual implicit motives and developmental stages. A recent review (Denzinger and Brandstatter, 2018) suggests that implicit motives adapt to life circumstances. The present findings may inform future research on "the trainability of implicit motives" (Denzinger and Brandstatter, 2018) and its associated processes and outcomes both within and beyond the context of classical musicians.

Practically, by understanding the unique motivational patterns of pianists and musician at large, scientist-practitioners can tailor interventions and support strategies to enhance their performance, promote their development, well-being, and success in the dynamic world of classical music. Identifying the implicit motives of pianists at different levels can inform the development of targeted motivational strategies for individuals, tailored to their unique needs and desires. Music educators can tailor their pedagogical strategies to align with a student's dominant motivational patterns (*cf.* McClelland, 1987; Schultheiss and Brunstein, 2010). For example, pianists high in *n* Achievement are likely to thrive in structured environments with clear goals, regular feedback, and challenges focused on refining technical mastery. In contrast, pianists with higher *n* Affiliation may benefit from collaborative settings (e.g., ensembles, collaborative piano), where interpersonal connections foster their motivation. However, when a particular motivational pattern becomes counterproductive, educators can help students reframe their motivations. For instance, a student driven by *n* Power might focus excessively on competition or external validation, hindering their creativity. In such cases, educators can guide them toward intrinsic rewards, such as artistic expression, personal growth, and the joy of learning, rather than seeking extrinsic recognition (see "Intrinsic motivation principles of creativity" in Amabile, 1996). Still, as an individual's motivational profile reflects an *organic* combination of the "big three" motives, interventions should not be overly *mechanistic*. When designing support strategies for musicians, it is important to consider how these motives, along with others unexamined (such as the "aesthetic motive" [6] discussed below), may interact to shape artistic processes and behavior. This understanding can inform a more holistic and systematic approach to interventions.

6 Limitations and future research directions

While this research illuminates the motivational patterns in high-performing classical pianists, several limitations warrant attention. Firstly, the focus of this study was on exploring the implicit motives of pianists participating in the junior, professional, and amateur editions of the 2022–2023 Cliburn competitions. Theoretically, the sole reliance on McClelland's (1987) "big three" motives may not encompass other significant drives, such as an aesthetic motive central to the artistic pursuits of classical performers like Arturo Benedetti Michelangeli whose obsessive perfectionism in the pursuit of sound quality may be motivated by a deep commitment to artistic ideals that go beyond the "big three." Future research should incorporate broader motivational frameworks that include aesthetic dimensions to allow for a more nuanced understanding of the motivational landscape and aesthetic process in musicianship (e.g., Cupchik and László, 1992; Christensen, 2018; Juslin and Sloboda, 2010). A promising avenue for future research would be to test and extend Amabile's (1996) "intrinsic motivation principles of creativity" in the context of musical pursuits. Empirically, the current sample from the Cliburn competitions does not fully represent the diversity of pianists worldwide, underscoring the importance of future research incorporating broader samples. Nonetheless, this sampling approach enables the current research to take a rare initial step in analyzing the motivational dynamics of musical achievement in high-stakes competitive environments. Future studies examining motivational profiles across different instrumentalists and performance contexts could offer a more comprehensive understanding of motivational dynamics in musical performance and achievement. A pertinent question for future research could inquire: *What constitutes the musicianship motivational pattern across various performance contexts?*

Moreover, the current study employed a typological approach, utilizing dichotomous configurations of motives (e.g., high vs. low *n* Power). Steinmann et al. (2015) employed a dimensional approach through regression analysis with interaction terms to investigate whether the leadership motive pattern (i.e., high *n* Power, low *n* Affiliation, and high AI) predicts managerial performance. Future research could adopt this dimensional approach to examine the relationships between various motive patterns and psychological processes, affective and motivational states, and musician outcomes (*cf.* Chen and Yu, 2016). This prompts a fundamental research question: *How do motivational patterns, or combinations of implicit motives, relate to musicians' psychological processes and outcomes, and ultimately, their pursuit of musical excellence and fulfillment?*

A third limitation of this research is its focus solely on establishing the association between gender, age, and the implicit motives of pianists, leaving the roles of other critical sociodemographic variables in implicit motives unexplored. Given that piano pursuit is a global phenomenon involving diverse populations, further research is warranted to investigate the interaction between implicit motives and cultural contexts, shedding light on the intricate interplay between internal psychological drives and external socio-cultural factors influencing pianists' motivation and goal pursuits. Future studies could examine how these motivational patterns interact with societal expectations and cultural norms to shape musicians' experiences, career trajectories, and professional and personal outcomes. Additionally, comparative research across different cultural contexts could elucidate variations in motivational dynamics across societies and inform culturally sensitive approaches to music education and performance. While implicit motives are individual-level variables, music education and performance are collective endeavors (*cf.* Chen, 2007). Therefore, future research could explore: *How do collective artistic pursuits emerge from the cultivation of individuals' desires and motives?*

Lastly, a fourth limitation lies in the reliance on cross-sectional data collected within the 2022–2023 Cliburn competitions, which precludes causal inference and limits our ability to assess temporal relationships between motivational factors and pianist outcomes. Future longitudinal designs could offer valuable insights into the developmental trajectories of pianists' motivations, career paths, and well-being, thereby providing a deeper understanding of the factors influencing long-term success in the classical music industry. Another promising research avenue is to address the causal effects of implicit

6 The author thanks Reviewer 2 for their theoretical insights into the role of an aesthetic motive in the pianistic realm.

motives through experiments involving the technique of priming(e.g., Bargh, 1994, 2006). Priming involves subtly influencing individuals' behaviors, thoughts, or decisions by exposing them to certain stimuli or cues (e.g., photographs, Chen and Latham, 2014) without their conscious awareness of the influence (Bargh and Chartrand, 1999). This technique has been widely employed to study and modify behaviors, including motivation and performance (e.g., Dijksterhuis and Van Knippenberg, 1998; Hart and Albarracín, 2009). Past studies have demonstrated the causal effects of priming on need for achievement (e.g., Chen, 2012; Chen and Latham, 2014; Hart and Albarracín, 2009; Shantz and Latham, 2009). More recent meta-analytic reviews (e.g., Chen et al., 2021; Latham et al., 2023) have established the causal effects of priming goals in the subconscious on both need for achievement and human performance. Future research in the realm of musicianship motivational pattern can leverage this new knowledge to inform the design, development, testing, and validating of effective motive interventions and motivational support systems aimed at fostering musicians' behavior, performance, and personal and professional development.

In summary, by tackling these research limitations, future research hold promise for advancing the comprehension of the intricate interplay among implicit motives, individual differences, cultural influences, interventional techniques, and performance outcomes across a broader spectrum of performing professionals beyond classical pianists.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/ participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

XC: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Exploring the lived experience of performance-related health and wellbeing among flautists

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Introduction: The study has investigated the lived experience of flautists, focusing on their experiences and perceptions of performance-related physical discomfort, injury and related mental health challenges that they might have encountered in practice and performance. The aims of the research have been to provide flautists with an opportunity to reflect on any physical or psychological performance issues in their own words, and to understand the subjective meaning of these experiences.

Methods: A basic qualitative approach was used for gathering data. All the fieldwork was undertaken during or immediately after the Covid-19 pandemic. Consequently, the participating flautists were deliberately selected using professional networks on the basis of their answers to a pre-interview initial questionnaire related to the characteristics of their personal backgrounds and their experiences, as well as being able to participate remotely. There have been two data collection phases. Phase 1 was a specially designed pre-interview questionnaire drawing on themes from appropriate literature. Phase 2 built on the pre-interview questionnaire responses and was designed as semi-structured interviews, undertaken on Zoom, and included a 'River of Flute-playing Experience' activity during the interview. The 'River of Experience' method is an autobiographical research tool in which participants were asked to annotate key biographical experiences and challenges at various points along their drawing of a meandering river. The combined data analyses drew on thematic analysis.

Results: The eight participants reported a personal history of performance-related health and wellbeing challenges that they had faced at some point in their lives. The findings reveal that flautists encounter health-related challenges associated with their practice and performances, and the data suggest that they each require an understanding of likely performance-related health challenges and supportive resources to assist them in managing these challenges.

Discussion: The participants' diverse experiences highlight the importance of managing health and the value of supportive social connections. They cope with health challenges by integrating passion, resilience, and adaptability into their lives, finding ways to grow and continue to thrive in their flute-playing journey. The study underscores the need for comprehensive health education and support resources for flautists, emphasising the significance of resilience and adaptability in fostering health, wellbeing, and success.

KEYWORDS

performance-related health, flautists, lived experience, COVID-19 pandemic, river of experience

1 Introduction

Reports of musicians' performance-related health and wellbeing issues have been increasing in recent years (Papageorgi and Kopiez, 2012). Musicians, particularly at an elite level, can experience health and wellbeing challenges in making and performing music as a direct outcome of the strenuous physical and psychological requirements of their profession (Zaza et al., 1998). For example, musicians often require long hours of practice and rehearsal, which may cause physical problems and even long-term damage (e.g., Llobet et al., 2007; Jabusch and Altenmüller, 2006). Such activities not only make physical demands, but also often need tremendous concentration, which can be mentally tiring. Practice, rehearsal and performance require the body to deal with the effort of playing, and the pressure of seeking to improve performing ability and quality (Llobet et al., 2007). Overall, such demands imply that professional musicians are required to have a comprehensive training in technique.

Professional musical activities have been associated with reports of general psychological ill-health in musicians (e.g., Kenny, 2011; Steemers et al., 2020). For example, Papageorgi and Kopiez (2012) discuss the 'psychological and physiological demands of learning to play a musical instrument' (p. 731). Because playing music puts high demands on the musculoskeletal and nervous system, personal competence in health maintenance needs to be taken seriously by all musicians. One of the most common psychological problems encountered by musicians is performance anxiety (e.g., Kenny, 2011; Mazzon et al., 2023).

Playing-related physical injury has been discovered to have a vital influence on psychological health (Ascenso et al., 2018) and has been linked with high levels of general psychological ill-health among musicians who perform at a professional level. It is also reported that the psychological features of musicians' injuries often include an ignorance of the significant demands that playing makes on their bodies, and that an acceptance of pain is a part of music-making (Paull and Harrison, 1997). For example, a study of symphony orchestras in Denmark argued that 'musicians reported higher emotional demands, lower job satisfaction, lower decision latitude, lower social support and lower sense of community' (Ascenso et al., 2018, p. 3), and with a higher degree of perceived stress among female musicians.

However, in contrast, in considering the mapping of 'core' elements of happiness and wellbeing, Seligman (2011) theorised that musicians can score relatively highly on each of the five components of his 2002 PERMA model (Positive Emotion, Engagement, Relationships, Meaning and Accomplishment) and that this is higher than in the general population (Ascenso et al., 2018).

Despite the rapid rise of research in the field of performing arts medicine (*cf* Burwell, 2012; Sataloff et al., 2010), there is limited previous research that has examined flautists' lived experiences of health and wellbeing issues (e.g., Fain, 2010; Ackermann et al., 2011; Lonsdale et al., 2014). It is unclear how flautists identify themselves as being injured, and how they might address such concerns. Consequently, the aims of the current research have been to provide individual professional flautists with an opportunity to reflect on any physical or psychological performance issues in their own words, and to understand the subjective meaning of these experiences for the participants. The research explores flautists who self-identify as healthy, as well as those who have experienced performance-related health issues in the past, and those who are currently facing such issues. It seeks to shed light on the challenges that flautists face within flute learning and performance.

A related aim of the study has been to examine the resources that flautists require and make use of in order to address any performance-related health issues and the challenges that are associated with practice, rehearsal and performance.

2 Methodology

2.1 Theoretical framework

Aaron Antonovsky came up with the concept of '*salutogenesis* – of the origins (*genesis*) of health (*saluto*)' (Antonovsky, 1979, preface vii), which was derived from his efforts to research health rather than disease. One underlying question concerned the origins of health. During his investigations, he uncovered the following response: 'The origins of health are to be found in a sense of coherence' (Antonovsky, 1979, preface vii). For him, 'A Sense of Coherence' (SOC)

> *'…is a dispositional orientation that allows individuals to be more resilient to stressors in daily life, stay well and improve their health. It includes three components: comprehensibility, manageability and meaningfulness.'* (Antonovsky, 1993, p. 727).

Antonovsky's salutogenic model refers to an approach that focuses on factors that promote human health and wellbeing, as opposed to factors that contribute to disease. His model demonstrates how personal, social, and environmental resources may be utilised to address difficulties and to contribute to the development of an individual's health. His question and its answer together make up the basis for his *Salutogenic Model of Health* (SMH). The important conceptual elements within the SMH are related to stress, breakdown, resources, a Sense of Coherence (SOC), and health (Vinje et al., 2017). These are explained below.

Sense of Coherence (SOC) is the key concept of the salutogenic model, which involves comprehensibility (the stressors driven by an individual's internal and external life environments are structured, predictable, and meaningful), manageability (the individual has access to the necessary resources to address the challenges presented by these stressors), and meaningfulness (these challenges require effort to overcome). A strong SOC supports individuals in perceiving life as structured, predictable, and meaningful in dealing with stress and maintaining health.

Antonovsky proposed that there is a need to understand what he termed as Generalised Resistance Resources (GRRs), with a focus on the experiencing of discomfort that is unrelated to diagnosis and disease (Vinje et al., 2017). He gave a clear explanation and definition of GRRs as 'any characteristic of the person, the group, or the environment that can facilitate effective tension management' (Antonovsky, 1979, p. 99). According to Antonovsky (1979), GRRs are resources that help individuals perceive lives as structured, predictable, and manageable to effectively deal with stressors. GRRs are categorised into three resources: '(1) adaptability on the physiological, biochemical, psychological, cultural, and social levels; (2) profound ties to concrete, immediate others; and (3) commitment of and institutionalised ties between the individual and the total community' (Antonovsky, 1979, p. 100). Such resources may include the following elements: (1) material resources, such as money and food, (2) knowledge and intelligence—knowing the real world and acquiring skills, (3) ego identity—a sense of inner self that is integrated but

flexible, (4) coping strategies, (5) social support, (6) commitment and cohesion with one's cultural roots, (7) cultural stability, (8) ritualistic activities, (9) religion and philosophy (e.g., stable set of answers to life's perplexities), (10) preventive health orientation, (11) genetic and constitutional GRRs, and (12) individuals' state of mind (Horsburgh and Ferguson, 2012, p. 182; Idan et al., 2022, p. 93).

Life experiences and health behaviours are other factors contributing to salutogenesis. Salutogenesis is also facilitated by promoting overall health and wellbeing through engaging in positive health behaviours, including maintaining a regular exercise routine, a healthy diet, and the avoidance of dangerous habits such as smoking and excessive alcohol use.

The traditional medical view of homeostasis as the basic human condition—homeostasis being defined as a self-regulating process by which an organism can maintain internal stability while adjusting to changing external conditions (*cf* Billman, 2020)—was challenged in Antonovsky's theory, where he introduces the fundamental philosophical view of 'the human organism as prototypically being in the state of heterostatic disequilibrium as the heart of the salutogenic orientation' (Antonovsky, 1987, p. 130). In Antonovsky's book *Health, Stress and Coping* (Antonovsky, 1979), he suggested that disease, illness, and entropy (decline into disorder) are common occurrences rather than being the exception when it comes to otherwise self-regulated homeostatic processes that are occasionally disturbed, leading to pathology (Vinje et al., 2017). In this book, he emphasised the importance of specific resistance resources (SRRs), as he found them both numerous and frequently beneficial in specific circumstances of tension:

> *'They (SRRs) are many and are often useful in particular situations of tension. A certain drug, telephone lifelines of suicide-prevention agencies or an understanding look in the eyes of an audience to whom one is lecturing can be of great help in coping with particular stressors. But these are all too often matters of chance or luck, as well as being helpful only in particular situations.'* (Antonovsky, 1979, p. 99).

2.2 Research design and participants

The current research drew on Antonovsky's theoretical framework of GRRs (Generalised Resistance Resources) and SRRs (Specific Resistance Resources) to make sense of flautists' reported experiences of their health and wellbeing related to practice, rehearsal and performance. A basic qualitative approach was used for data gathering (Merriam and Tisdell, 2015). All the fieldwork was undertaken during or immediately after the Covid-19 pandemic. Consequently, the participating flautists were deliberately selected using professional networks as being able to participate remotely, as well as on the basis of the combined characteristics of their personal backgrounds and experience. The eight participants were all of a similar performance demographic, in that each had played the flute at an advanced level for some considerable time (on average 42 years).

Following an initial pilot study, the research involved two main phases of data collection. Phase 1 was a specially designed pre-interview questionnaire that drew on appropriate literature and also sought an initial commentary from a specialist medical consultant in performance-related injury and who is also a flautist. Phase 2 was built on the pre-interview questionnaire responses and was designed as individual semi-structured interviews, undertaken via Zoom.

The pre-interview questionnaire was designed to collect demographic and background information. It was completed by a diverse group of flautists, aged above 18 and with varying levels of experience, ranging from music students and amateur enthusiasts to professional flautists and experienced flute teachers. Participants included both male and female flautists from various geographical locations and cultural backgrounds. The first section of the pre-interview questionnaire collected demographic information, such as age, gender, level of education, and occupation, as well as details about their flute training and experience, including years of flute playing. The second section investigated any physical or mental health issues participants perceived to be related to flute playing. The final section inquired about the flautists' stress levels before, during, and after the COVID-19 pandemic.

Using questionnaires as a preliminary data collection tool can significantly improve contextual understanding by collecting background information and tailoring interview questions to address specific aspects of the participants' experiences. Patton (2002) emphasises that understanding participants' backgrounds allows for more effective and targeted interview questions. In addition, integrating data through questionnaires can enrich results by providing a structured understanding of the participants' context (Creswell and Plano Clark, 2018).

The interview participants were selected based on their completion of the pre-interview questionnaire and their willingness to subsequently engage in a more in-depth interview. The aim of the interviews was to explore the lived experience of being a flautist (whether as a student, performer, teacher, or a combination of these roles) with health-related problems arising from flute playing, as well as their flute-playing history. The in-depth interviews were designed as 'conversations with a purpose' (Burgess, 1988) and were loosely structured around the participants' reported difficulties. The interview also included an opportunity for participants to create a 'River of Flute-playing Experience' (*cf* Burnard, 2000; Denicolo and Pope, 1990; Taylor, 2011)—see examples from Helen and Jane (Figures 1, 2; names anonymised). Odena and Welch (2009) indicate that the aim of the River of Experience was to allow the participants to reflect on what had happened and what they experienced. This technique facilitated the structuring of an in-depth narrative that included salient features of the participant's flute-playing history and was designed to generate opportunities for detailed reflection and discussion. Participants were asked to think back on their life experiences, write down their experiences and challenges at significant points of the river on paper, and subsequently discuss these with the researcher. The 'River of Flute-playing Experience' sheet also provided an opportunity for participants to reflect on their past musical lives (*cf* Kelly, 1955), which, for some participants, included the dual roles of being both a performer and a current flute teacher.

Interviews were fully transcribed and were analysed using specialist software NVivo (March 2018, version 12, Lumivero, *cf* Odena, 2007). Learning to play an instrument can be seen as a personal process that involves psychological, physiological, social, cultural, and aesthetic components. The themes for the interviews were related to the concepts of general and specific resistance resources (GRRs and SRRs), as well as physical, psychological and social challenges, and favoured coping strategies.

For example, in Figure 1, Helen's River of Flute-playing Experience, she reported suffering from a dry mouth during her university studies. During the interview, she explained how she dealt

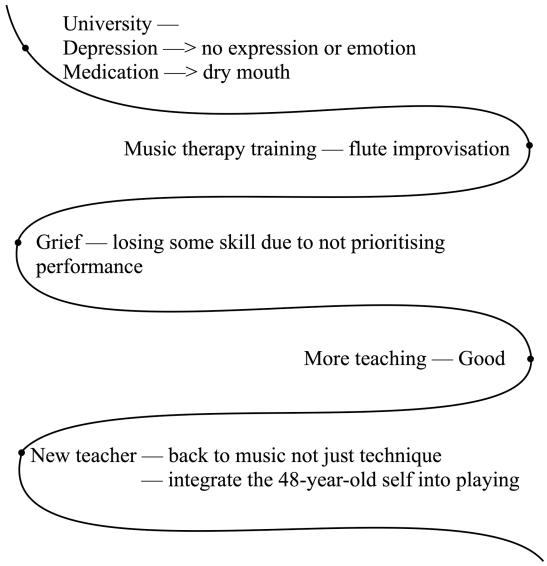

FIGURE 1
Participant Helen's River of Flute-playing Experience.

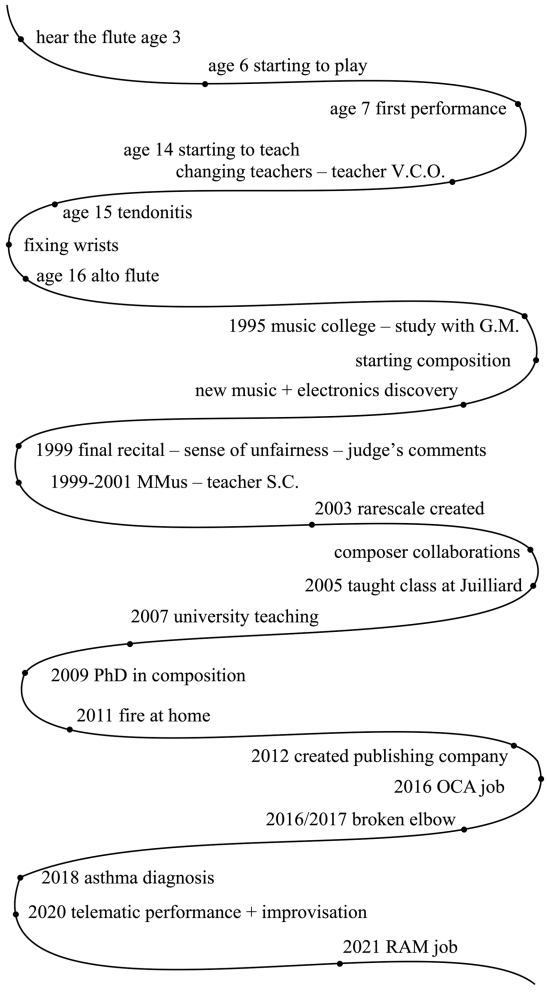

FIGURE 2
Participant Jane's River of Flute-playing Experience.

with this problem by seeking support from her teacher. In this instance, the teacher could be seen as providing information that could serve as specific resistance resources (SRRs).

> *'I just had to always have a bottle of water next to me. And, in fact, my doctor wrote to the head of my music department and said that I would need to take sips of water while I was playing.' (Participant Helen).*

The primary framework guiding the analysis was Antonovsky's theory of salutogenesis, which emphasises factors that support health and wellbeing rather than those causing disease. This theory was applied to understand the factors contributing to flautists' health and wellbeing, with a focus on enhancing their sense of coherence—a core component of Antonovsky's theory, which includes comprehensibility, manageability, and meaningfulness. By organising the themes according to Antonovsky's components, the research provided a more nuanced understanding of how various factors contribute to flautists' health and wellbeing.

Throughout the analysis process, themes not directly related to Antonovsky's theory were also identified and explored. This involved inductively coding the data to capture themes that naturally emerged from the participants' experiences and integrating them into the interpretation. This iterative process of moving between inductive and deductive approaches ensured openness to all possible insights. The approach aligns with the qualitative research philosophy of being data-driven and responsive to the complexity of human experiences, ensuring that the findings are both theory-informed and grounded in actual data.

2.3 Research ethics

As the study involves human participants, prior to the commencement of data collection, a formal ethics application was reviewed and approved by University College London, reference Z6364106202010122, dated 30th October 2020. No children or young people identified as vulnerable were selected for this study. Potential participants were sent an information letter and confirmed their willingness to participate by email. A consent form was also provided, which made it clear that participation was voluntary. Permission to video-record the interview over Zoom was requested. Participants were also informed of their right to withdraw at any point, for any or no reason, in line with the British Educational Research Association (BERA) guidelines (2018). In addition, a contact email address for the researcher was also given so that participants could make contact, have any questions answered and report any concerns about the research process. Overall, all potential participants were informed of the focus and content of the study and signed a consent form prior to participation. To ensure that participants cannot be identified, they are given pseudonyms, which is the most prevalent method of anonymisation discussed in the literature (Clark, 2006; Saunders et al., 2015).

3 Results

In the application of Antonovsky's theory, the following findings emerged:

3.1 Theme 1: General and specific resistance resources

Music could be seen as offering a General Resistance Resource for the participants since they felt that they could express themselves through playing the flute.

> *'So, if you play and have a certain level of technique but are also a 48-year-old woman with life history, that brings a different kind of maturity, I think, to my expression in my flute playing, which is a bit different; although, when I was at university, I was technically probably a lot better. I wasn't a person who could express myself, whereas now I am a bit more.' (Participant Helen, teacher and therapist).*

> *'Flute is, by and large, for me, a huge, positive mental health influence. One is it allows me these peak self-actualisation experiences when you are doing something really beautiful, which is a great antidote to ordinary stress and depression and feelings of loss and grief and sadness when you can do that. It's the only thing that assuages such negative feelings. So that's a huge plus.' (Participant Albert).*

Positive relationships with students and working collaboratively with other flautists or flute teachers serve as examples of social interaction, and according to the Salutogenic Model of Health (SMH), such social support is crucial for promoting wellbeing.

> *'The other thing that happened was with [another professional flautist], and I decided to start these e-flute things. So, we did an e-flute festival first of all. And because everyone was at home, it was really successful. It was, you know, quite a big thing, [an] international thing. And when loads of international artists [were] there, and that was really a positive experience. I mean, I really enjoyed that.' (Participant Chloe).*

> *'Now, as a teacher, you know, I try to get a feel of what the person I'm teaching is like, what they are learning…and have a really positive relationship with them. Because I think that's just I know as a therapist that it's within a positive, broader relationship that change can happen in my patients, and of course, learning the flute is about change, and that's more likely to happen if I've got that really positive relationship with my students.' (Participant Helen).*

> *'It's all about having a relationship with somebody, and ideally working collaboratively with that person. So, as a result of my understanding of that as a teacher, I think my primary way of working is to have a positive relationship with my people. And working collaboratively with them towards whatever goals we set together.' (Participant Helen).*

Participant Helen's narratives indicate that she places a strong focus on the significance of building positive relationships with her students, which enhances their sense of being encouraged and motivated. Moreover, this approach enables her to identify and address any performance-related concerns at an earlier stage.

> *'I suppose in the last two years, I started having flute lessons for myself again. And that's been a positive and a different phase of me kind of trying to integrate the skill I do have with the person I am now.' (Participant Helen).*

> *'And so my career then developed into people started inviting me to play flute conventions. And so it developed into more of, kind of soloist. I started bringing lots of, because of my own kind of wellbeing journey. I felt like I'm in a really good position to help other people in their wellbeing.' (Participant George, flautist, flute teacher and Feldenkrais method practitioner).*

Teachers could be viewed under the category of Specific Resistance Resources, as they provided specific support during the musical journey, such as the example reported above of Helen always having a bottle of water to compensate for her experience of a dry mouth.

> *'I did not trust my own judgment of how good I was or what my skill was. I really could not trust my own judgment, but I think it's given me a clear idea of where my playing sets in terms of standard, because I'm getting feedback from somebody who I trust. I know [my new teacher] is always going to be nice. She's not going to say anything really horrible, but she would not tell me something was great if it wasn't, either. I have trusted her opinion for so long.' (Participant Helen).*

Helen continues pursuing flute lessons and additional certificates, demonstrating her dedication to improving her skills for professional development and personal growth.

3.2 Theme 2: Physical challenges and adaptations

Flautists' performance-related health challenges were explored. Physical and psychological health challenges included discomfort, like swelling and pain in the left forefinger, tinnitus, stress, chronic pain and chronic fatigue. These were examples of the challenges reported by the participants.

> *'Tendinitis was a big deal when I was a teenager. So, it was a long time ago. And it came about because I had a teacher who did not understand posture properly… He wasn't a terrible teacher, but he had a quite old-fashioned view of posture. I was studying with him from the ages of seven to about thirteen–fourteen, and it caused a lot of damage physically. So, I used to have pains all the way up both arms, to the extent that I could not play… Firstly, I [needed to have] the right support in order to fix it. So, by that time, I had changed to a new teacher. So, I was changing my posture, and that helped. I went to an osteopath who really helped me to understand what my body was doing, how things worked, and how things were connected. And what he explained to me was that all of these problems [that] were raised there came from the top of my back.' (Participant Jane).*

> *'It was just the swelling in my finger, which meant I could not bend it at all, and a swollen joint.' (Participant Helen).*

> *'There was certainly a phase when I was a teenager, and I was playing in a lot of sort of youth groups, … when I would hyperventilate when I was playing, because I think the combination of anxiety making your breathing a bit erratic, with the fact that you are imposing erratic breathing because you are trying to play the flute which caused me to hyperventilate. And then that was really embarrassing, because I might have to leave the rehearsal because I needed to cover it, and everyone would see me. And then, being a teenager, expecting that to happen, almost made it happen. I made it worse because I was worried about being embarrassed at the anxiety showing.' (Participant Helen).*

> *'Shoulder feels a bit odd…[because of] putting too much pressure on the keys… I'm pretty much aware of those… People have physical issues by holding the flute wrong, or they just do it for too long a time.' (Participant Ruth).*

> *'It was in between my shoulder blades under my left shoulder… it was the chronic pain, was really, really that. It would just get very, very uncomfortable, kind of neck and shoulders… my neck and shoulders were just so tense… Every time I go on a holiday, I would have a massage to try and fix it.' (Participant George).*

> *'I've got quite small hands and not much extension. And I was advised to play an open-hole flute, so I got an open-hole flute. And I learned to play the open-hole flute for quite a number of decades, and then suddenly about, I do not know, trying to think what age I was, I suppose, in my 50s, I mean, I'd been playing a long, long, long time, I suddenly got a problem with my right-hand thumb. And it was a sort of tendonitis, and I had an injection, and I had to put it in a splint. And then my wrist got locked, and I had to do so much exercise to get it all moving again.' (Participant Olivia).*

3.3 Theme 3: Perceived psychological impact and emotional resilience

Amidst the experienced adversities, participants learned from challenges, found new ways to thrive despite the limitations imposed by the COVID-19 pandemic, and exhibited remarkable resilience. Their personal growth and enhanced ability to navigate challenges fostered a sense of adaptability to change.

> *'My shoulders were very tense, and I did a lesson [Feldenkrais lesson] where my arm came comfortably on the floor… I just immediately knew how this was my pathway towards myself, really… It [Feldenkrais] teaches you strategies to be more resilient. So, you become better able to regulate yourself during times of stress or anxiety. You suddenly have tools that you can use, and you have the awareness of some people's problems playing… Feldenkrais teaches you to be more sensitive to the earlier points of going [awareness of the beginnings of discomfort]. This could get a bit uncomfortable, or I need a rest right now.' (Participant George).*

Participant George reflects on a method of somatic education, the Feldenkrais method, that provided tools for resilience. It helped him become more aware of his body and its signals, allowing him to better manage stress and anxiety. His increased awareness and ability to regulate contributed significantly to his psychological resilience.

> *'PANDEMIC [sic]—extra challenge! Back to the loop of not touching the instrument and practice. I ended up practising piano more at home—a digital piano with headphones. Playing the flute at home alone wasn't much fun, and I had to deal with noise issues—all the family members were at home, and everyone was working from home. I also lost lots of opportunities to explore the flute-playing scene in London.' (Participant Ruth).*

Participant Ruth's experience underscores the necessity of adaptability and persistence in order to maintain her musical practice during the pandemic. The limitations and challenges, such as noise issues and lost opportunities, had a negative psychological impact on her, as playing the flute at home alone was not much fun.

> *'In 2011, there was a fire in my house, and all my instruments were destroyed. My entire house was destroyed. So, it wasn't a physical thing, but it was definitely a mental thing in that I had to deal with everything being lost… It was also just before I was going to submit my PhD. And I lost my entire PhD. And I had to start it again from scratch. I mean, literally, it was three months before submission… And at the point where I submitted it. I did not even have the instruments. I had to do it without any instruments in the end. Because they were destroyed. That was a challenge. But that was kind of interesting because I think resilience is important… I feel like every time something was problematic in my life, it gave me a new way forward. That was a very tough time. But it gave me an opportunity to again change everything if I wanted to change everything. So, I moved somewhere else. I got new instruments. I think it was very healthy in terms of my relationship with the flute. Because when the fire happened, I was just like, well, I'm not even a musician anymore. I have not got any instruments. How can I be a flute player if I do not have a flute? And I had to [be a flautist]… There are things the way I look at it is, there are things that we have control over, and they are the things that you can use in a positive way to question and learn. And then there are things that happen to us, like my house fire. It was an arson attack. Somebody did it. I had no control over that. There was nothing I could have done. So, I had to accept it, and I had to find a way of learning from it. And so that's resilience.' (Participant Jane).*

Participant Jane's account of losing everything in her house fire, including her PhD work and instruments, highlights profound emotional resilience. After facing such a devastating loss, she managed to rebuild her life and develop a more positive connection with her music. Her story highlights how resilience involves accepting uncontrollable events and using those circumstances as opportunities for personal growth and change.

> *'Although these kinds of physical problems are seen as a negative, I think, actually for me, every time I've had some form of adversity, it's been one of the most positive things that could have happened once I got through it. So, you know that experience, what happened was I managed to get back into, you know, great physical health. I changed all my posture when*

> *I was playing, and it removed all of the problems.' (Participant Jane).*

Participant Jane regards physical adversity as a catalyst for positive change. She changed her flute-playing posture to overcome the physical challenges, which ultimately eliminated all the problems and improved her physical health. This experience exemplifies her resilience and ability to transform negative experiences into opportunities for personal development and progress.

> *'It wasn't much of a challenge, but in society, we do not really connect with other human beings in a very meaningful or deep way. We, you know, might have relationships and partners, but [to experience] touch itself, we lack that experience. And when I started doing the training, suddenly being touched in a gentle and kind way by so many people, and was just so new for me… So, there's something about accepting that connection. You know, because sometimes we are protective and that to do something about kind of accepting that, and also being able to connect with other people.' (Participant George).*

Participant George also reflects on the importance of human connection. His Feldenkrais method training helped him connect with others. This illustrates how he found a way to build meaningful relationships, which in turn improves emotional resilience and fosters a strong sense of community.

> *'Because I'm not very good at technology. And now I've got a good setup here, I bought sort of proper equipment. But to start with [COVID-19 pandemic], I was using a small laptop, and I found it so tiring. But once I got used to it, and I got better equipment, it was alright.' (Participant Olivia).*

Participant Olivia's effort and eventual adjustment to technology during the pandemic demonstrates her resilience. At the beginning of the pandemic, her lack of technological skills and inadequate equipment were exhausting. However, she overcame these obstacles by acquiring better equipment and becoming accustomed to its use, which enabled her to adapt to the new conditions.

Participants' quotes reflect their psychological resilience and adaptability in the face of adversity. From leveraging somatic education for stress regulation to overcoming significant personal losses, these narratives highlight how individuals can find strength and growth through challenging experiences.

3.4 Theme 4: Coping mechanisms and strategies—sense of community and support

Perceptions of stressors are personal and based on the situation (Antonovsky, 1979). Resources on a personal level are about understanding the lived experience of flautists' challenges, utilising coping strategies, and maintaining motivation.

> *'I think there's dealing with it when you are not feeling anxious, to try and reduce the overall level of anxiety and stress in life. And my advice would be practising things such as mindfulness and breathing, mindful breathing exercises. So, I would recommend specific exercises like square breathing, where you, you know, inhale for four, hold for four, exhale for four, hold for four. I know that, um, I sometimes get pupils or people who are stressed to touch their, feel their pulse in their neck, and then, if you breathe in, say, for four, and then breathe out for seven. What happens is, you can actually feel that as we exhale, our pulse slows down, and then it speeds up again. And once you could actually feel that, then you can understand the value in exhaling for a longer time to just reduce the overall levels of stress.' (Participant Helen).*

As depicted in Figure 3, participant Helen faced mental health issues, including chronic stress, depression, and anxiety. She used strategies to help reduce her overall stress levels, such as practising mindfulness, yoga, and mindful breathing exercises. The breathing techniques slow and deepen her breath to control hyperventilation.

> *'For making sure that I'm staying well and things like that, I mean, I'm not really into this, but I'm trying to do it so that I do not play without stopping for more than probably half an hour, maximum, before I put the flute down. You know, I would not want to just keep playing, but partly that's because I'm starting to feel some pain as well. That's the sign I need to do some stretching.' (Participant Chloe).*

Participant Chloe manages physical discomfort and prevents injury by recognising and responding to her body's signals. She avoids prolonged flute playing by taking breaks to prevent pain and uses any emerging discomfort as a cue to stretch.

> *'I found things like basic breathing exercises [to be] very good for anxiety. I do a little bit of yoga now. I had not really incorporated exercise into my routine very much as a young person… Stress and anxiety are, you know, [managed through] some physical exercise, looking after your body, and thinking about when you are an adult, and you have more control over your diet, and paying attention to what makes you feel good and feel balanced and healthy. So yeah, all of these lifestyle kind of elements, I think, have come into my thinking now about dealing with anxiety and stress.' (Participant Sophie).*

Participant Sophie shared her experience of incorporating breathing exercises and yoga into her routine for managing anxiety. She highlights the importance of physical exercise, a healthy diet, and lifestyle changes in achieving balance and health.

> *'I decided during the pandemic to help people and make myself useful. So, I did, I did a lot of video recordings, practising live on Facebook. I did a lot of practice myself… I was being there for everyone else, but nobody was there for me, really. So, it came to a point. So, I was teaching, and I found teaching younger students on Zoom really stressful—parents guessing what time the lesson is… And I really went through a period of very, very, really intense anxiety. Actually, it just triggered a huge amount in me, and I went back to my old therapist and started working with him because everything was just too much, and it was, that was on top of the worry and stress about the pandemic itself. And the positive that came out with that is I learned a lot about how I deal with stress and anxiety. And I learned how to best manage*

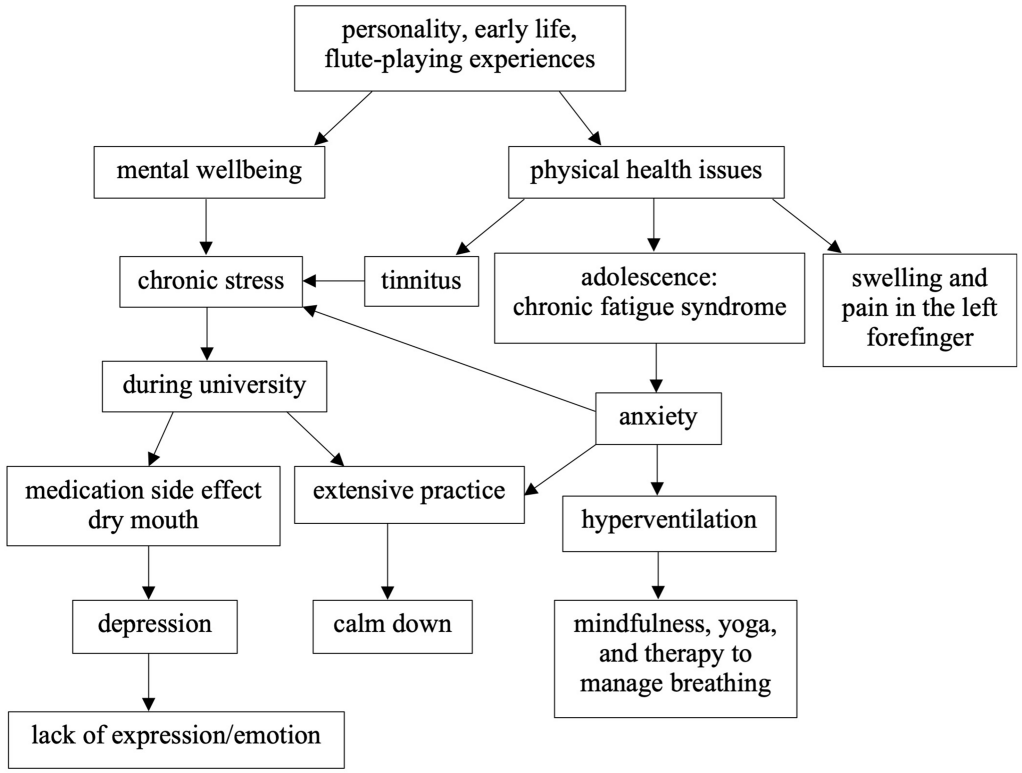

FIGURE 3
A model of Helen's flute-wellbeing.

> *it so that there's been a huge positive impact from it, actually. But it was difficult. And when I came out of the pandemic, I got more teaching in the school that I taught, and I changed where I teach my Feldenkrais lessons from a huge positive impact was teaching Feldenkrais online classes. I had loads of people coming to my classes and did loads of workshops. So, overall, the pandemic helped me to learn a lot about myself, and I've grown.' (Participant George).*

During the pandemic, participant George supported others by conducting online sessions, but this led to his own stress and anxiety. He sought help from his therapist and learned to manage these issues. Although he experienced challenges, he found a positive impact through teaching Feldenkrais lessons online, including enhanced self-awareness and personal growth.

Resources on a relational and social level are about understanding the importance of social support, such as from other flautists and flute teachers and through the experience of flute performance, as well as the development of positive relationships between themselves (as teachers) and their students through the teaching and learning process. Flute teachers can have a strong sense of coherence due to strong social relationships and support. These participating flautists reported leveraging online platforms for peer support. A connection with fellow musicians and opportunities for collaboration were reported to foster a sense of community and shared experience.

> *'At that time [of the fire] there was a lot of support from the community. They did a lot of fundraising to help me buy a flute, and this kind of thing.' (Participant Jane).*

> *'Sometimes because music is the way we express, I think sometimes that is where the stresses can come out as well, and maybe we hold physical tension. So, I mean, in terms of that, I know lots of people who have had issues in different kinds of ways, some of them physical, some of them mental, some of them performance anxiety. I mean, I've taught students with performance anxiety that's so severe that they cannot even approach a performance without crying. And I feel like there's a way of overcoming all of those things, [this is] a lot of my work with the performance students. We have an online performance class once a month. And when they first come, some of them are really nervous. A lot of my job is to help them understand that it's okay, and it's normal. And that nervousness and excitement are similar things.' (Participant Jane).*

> *'Meeting lots of other people who are interested in the flute, even the ensemble playing, not so much the playing, but just being around other people, and having good social networks and connections, and making new friends. Those are all things that are extremely important for mental health.' (Participant Albert).*

> *'Having done that PhD, and having thought more about the way that we set up the rules, I suppose, of flute playing, or of music making for students, and have thought more about the social relations between a teacher and a student and the environment that we sort of set up, and this idea of power… which was something I had not really thought about when I was teaching before.' (Participant Sophie).*

> *'I reflect back on myself as a student, wanting to model or wanting to use my teachers as models for my playing and for the kind of musician I would want to be. And I think for a young person who works one-to-one with a teacher. It's a very powerful position to be in, you know, when you are that teacher, because you are a sort of a gatekeeper to opportunities. And if that student is serious about making music part of their life, then you have quite a heavy responsibility as an educator.' (Participant Sophie).*

> *'At the beginning of the pandemic, I decided to make myself useful, so I created Flute Online… We have people from all over the world, and they join me, and they practise along with me… So, I decided during the pandemic to help people and make myself useful.' (Participant George).*

Participants discuss a variety of strategies to manage physical and mental health, including taking breaks, incorporating physical exercise, yoga and breathing techniques, and seeking help from a therapist. Their experiences reflect journeys towards personal growth and adaptation to challenges, especially during the pandemic.

4 Discussion

Hours of daily training are required for expert musical performances, yet the physical and mental load and fatigue of playing have been recognised as risk factors for performance-related pain and injury. There are other causes of fatigue, not directly arising from the affected muscles, such as 'the general physical aspects of your body (insufficient sleep, failing to adopt a balanced diet, a sedentary lifestyle, and the existence of concurrent disease)' (Llobet et al., 2007, p. 3), and also mental fatigue (related to stress, mental overload, anxiety, perfectionism, constraint, choking under pressure or interference from other activities; e.g., Ascenso et al., 2018; Llobet et al., 2007). In conclusion, fatigue is multi-faceted and can accumulate and increase the risk of performance-related injury or illness. High-performing musicians are seen as motor athletes (Dick et al., 2013; Mazzon et al., 2023). A majority of student and professional musicians have been reported to suffer from one or more performance-related health issues (e.g., pain, overuse syndrome, tendonitis) over the course of their music journeys (McCrary and Altenmüller, 2020).

Although Antonovsky's theory provided a useful lens for understanding the data, another significant aspect discovered beyond the specific scope of salutogenesis was the ergonomics and instrument design, particularly the weight and design of the flute. For instance, participant Olivia plays the open-hole flute. Over several decades, the challenges of holding the open-hole flute led to physical problems, specifically tendonitis in her right-hand thumb. This condition prevented her from keeping her thumb in a natural position, making it difficult to cover the holes.

In addition, flautists' performance-related health problems concerning physical injuries can be typically depicted as overuse syndromes, such as tendinitis and tenosynovitis,[1] and which—in mental health terms—can be described as neurological impairments (e.g., Guptill, 2011; Jankovic and Ashoori, 2008). Participant Jane also experienced tendonitis when she was at a young age, as shown in Figure 2. The impact of physical and mental health problems can result in discomfort, illness, and injury in professional flautists, which can inhibit artistic development. Approaches to healthy practising can also be derived from experienced music teachers' recommendations, as well as from encountering the biographies of historical musicians. For example, in Clara Wieck-Schumann's opinion, as a child instrument learner, she was not encouraged to practise more than three hours per day in order to avoid physical and mental exhaustion (reported by Papageorgi and Kopiez, 2012). Altenmüller and Kopiez (2010) propose the significant importance of having general physical endurance, as well as regular physical exercises of the hands, such as finger stretching—based on the view of a piano teacher, Friedrich Wieck (Wieck, 2005). Therefore, the acquisition, development and application of reflective powers are required in instrumental teaching and learning. Instrumental teachers need to develop constantly through their ongoing experience and reflection to support students who have questions.

The 48-year-old flautist Helen has held roles as a flute teacher and music therapist throughout her career. Figure 3 shows the results from the interview and her River of Flute-playing Experience, illustrating that Helen has suffered from tinnitus, chronic stress, chronic fatigue syndrome, and swelling and pain in her left forefinger. These challenges have impacted her professional and personal life. She copes with these issues by focusing on her own routine of practice, yoga, mindfulness, therapy, and specific techniques. She seeks medical advice and therapy when needed.

Helen suffered from chronic fatigue when she was a teenager. The fatigue was not caused by flute playing and is considered a pre-existing condition. However, playing the flute can worsen it and cause her anxiety. She faced challenges, including hyperventilation triggered by anxiety, which made her embarrassed during rehearsals. To manage her breathing, she practised breathing exercises described in Theme 4.

Helen experienced significant depression during her time at university. The medication she took caused dry mouth, and her depression severely impacted her flute performance. She also reflected that she played the piccolo a lot at university, which led to slight hearing damage. Furthermore, her tinnitus became permanent a few years ago, which increased her stress levels. To reduce anxiety and improve her overall wellbeing, she adopted various strategies such as extensive practice to calm down and integrating yoga and mindfulness into her life.

These ongoing challenges have an impact on her stress levels and flute-playing abilities, highlighting the necessity of adapting to the challenges. She uses specific techniques to manage her chronic fatigue and stress, improve her physical health, and promote mental wellbeing. While these performance-related issues are significant challenges for Helen, she also fosters resilience and adaptability throughout her journey.

Furthermore, Helen places a strong emphasis on building positive relationships with her students, which enhances their sense of encouragement and motivation. This approach also enables her to identify and address any performance-related issues at an earlier stage. Additionally, she continues to take flute lessons and pursue additional certificates, demonstrating her

1 Tendinitis and tenosynovitis: Tendinitis is inflammation of a tendon, often developing after degeneration (tendinopathy). Tenosynovitis is tendinitis with inflammation of the tendon sheath lining. Symptoms usually include pain with motion and tenderness with palpation.

commitment to improving her skills for both professional development and personal growth, which shows her not to be held back by her health issues.

In summary, Helen copes with long-term performance-related health and wellbeing issues while adapting to the effects of her health conditions on her flute playing. Her experiences exemplify her extraordinary resilience and adaptability when confronted with health challenges. Her dedication to flute teaching and passion for music, along with her ability to build positive relationships that promote wellbeing, make her a dedicated flute teacher.

As depicted in Figure 4, the flute-wellbeing model of 46-year-old participant Jane, based on her interview and the River of Flute-playing Experience data, outlines the contributing factors to understanding performance-related health and wellbeing issues.

Jane's first positive experience with the flute occurred when her parents took her to a concert at the age of three, and she expressed her desire to play the flute on stage. She began playing the flute at six. The concept of 'challenge' is drawn from Jane's interview, in which she believes that challenge has kept her playing the flute for so long, as it pushes her to continuously improve. She stated, 'There's always something else to learn, always something else to explore, always another piece of music to discover, another musical culture to discover… I'm doing more and more improvisation-based work. I've always done a lot of collaborations, and those collaborations kind of spark ideas off each other.' For Jane, challenge serves as a resource, helping her practise, improvise, collaborate, and find inspiration.

When Jane was a teenager, she had tendonitis due to hypermobility and postural issues. This issue arose because she had a flute teacher who did not understand posture properly. Jane began learning the flute at the age of seven. Her first flute teacher was brilliant, but then, when she was seven, she changed teacher and started studying with someone else who did his best but had a quite old-fashioned view of posture. Jane studied with him from the age of seven until around fourteen, which caused significant physical damage. However, she later adjusted her posture, which helped alleviate her problems. She also consulted an osteopath who helped her understand what her body was doing, how things worked, and how things were connected. Changing her posture when she was playing removed all her issues.

Jane also experienced wrist problems due to improper playing posture and hand positions, as instructed by a flute teacher who insisted on a rigid posture that caused her wrists to bend in ways they should not have.

Interestingly, when Jane started playing the alto flute at the age of sixteen, she did not experience any physical problems, possibly due to her body size and the different physical demands of the instrument. This could also be linked to her early learning experience with the flute, which required a big stretch for her small hands.

Jane faced unfairness because of the low marks received on her flute performance at the end of her undergraduate degree. The sense of unfairness led her to switch from flute performance to composition. This experience significantly impacted her, as she nearly gave up the flute. This turning point reshaped her perspective on things, and now, when she assesses others, she makes sure everything is fair, as it may impact one's future.

The fire at Jane's house was a traumatic event, destroying all her instruments and composition, and profoundly affecting her mentally. This occurred three months before her PhD submission, resulting in the loss of her entire PhD work. She had to start her PhD again from scratch and complete her composition without any instruments. She noted that this experience required her to develop strong resilience by accepting the loss and finding ways to learn from it. To cope with post-traumatic stress, Jane focused on small positive things, which gradually became bigger sources of positivity. She believes that accepting and learning from things beyond her control is a form of resilience.

In addition, Jane broke her elbow a few years ago and had to stop playing for a while. She sought help from a physiotherapist who told her that she would never get full use of her arm again. She questioned about this. When she started playing the flute again, she had to learn again, coming back to playing a little bit at a time, questioning everything she did. She would think, 'Do you really need to have your hand in that position? And what if you do this?' She used this period as an opportunity to question and revisit everything she was doing when she was playing before. During her rest and

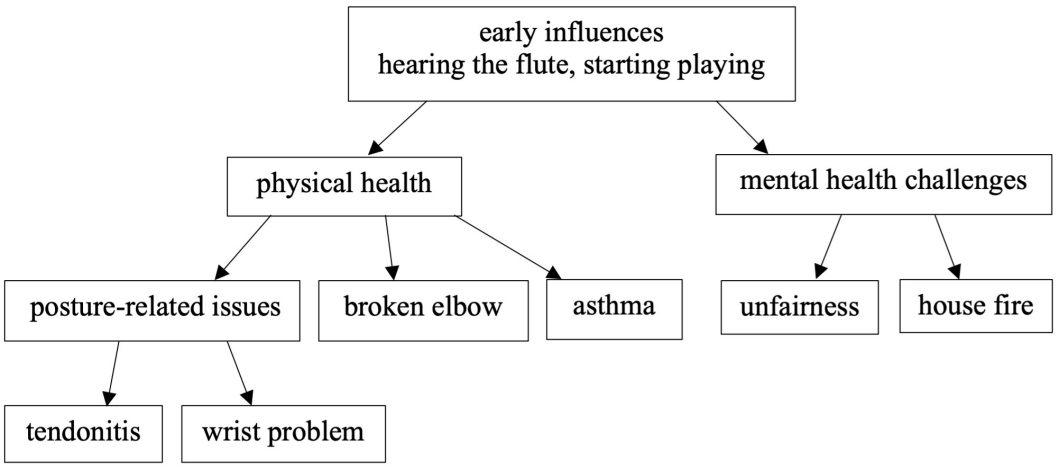

FIGURE 4
A model of Jane's flute-wellbeing.

rehabilitation, she used a timer in her practice sessions to measure time, assess her condition, and decide whether to keep playing for another five minutes. Despite her ongoing right arm issues, this approach became an effective coping strategy for her. The trauma she experienced ultimately contributed to her personal growth, which she now views as an opportunity to reflect, question, and improve.

Jane reported experiencing breathing problems throughout her life and was diagnosed with asthma in 2018. She learned two distinct breathing techniques from her flute teachers, which influenced her to develop her own approach. Her method emphasises breathing naturally while controlling the speed of the movements, without the need to tense a lot of muscles unnecessarily.

Jane never had any formal training in health education but attended a few online body mapping sessions, which she finds useful. She realised that as we grow, our bodies change, and the way we play the flute has to change. This is something she has embedded into her teaching.

Overall, the outcome was that Jane managed to get back into great physical health. Jane reflects, 'Although physical problems are seen as negative, actually for me, every time I've had some form of adversity, it has been one of the most positive things that could have happened once I got through it… So my approach was, I mean, it was difficult at the time, but I got through it, and I learned a lot in the process.' Both physical and mental health issues are significant challenges for Jane. She developed strategies to manage her physical health by learning proper posture and building resilience by viewing these experiences as learning opportunities. Jane demonstrates resilience and adaptability by recovering from physical issues and rebuilding her life after a traumatic house fire. Her approach to living with these challenges is her capacity to uncover favourable results from adverse events. She demonstrates her remarkable ability to turn adversity into resources and opportunities for personal growth. Jane's story highlights the significance of managing physical health, mental resilience, adaptability, and supportive social relationships in personal growth and professional development.

In common with other professional musicians, flautists can experience health and wellbeing challenges, resulting in physical and mental difficulties. They need resources that promote health throughout their lifespan. Each instrument places specific demands on the performer, and for flautists, the physical stance requires a particularly stressful posture. Helen and Jane exemplify how early experiences, continuous challenges, proper training, resilience, adaptability, and social support contribute to managing performance-related health and wellbeing issues. In addition, participants who are flute teachers expressed a desire for greater access to health education to enhance their knowledge of how best to promote students' health during lessons.

5 Conclusion

Flautists encounter health-related challenges associated with their practice and performances. The questionnaire and interview data suggest that they each require an understanding of likely performance-related health challenges and supportive resources to assist them in managing these challenges and enhancing their overall health. Importantly, during the interviews, participants were eager to disseminate their insights into their own health education and to integrate these personal lessons into their own music pedagogy. The study highlights the importance for flute teachers in having practical knowledge of injury prevention in order for such knowledge to be a key component of their own teaching.

The participants' experiences provide valuable insights for other flautists facing similar challenges. Although participants' stories were diverse, certain common themes emerged, shedding light on how they manage and live with these issues. The study emphasises the importance of managing health and the value of supportive social connections. Participants cope with health challenges by integrating passion, resilience, and adaptability into their lives, finding ways to grow and continue to thrive in their flute-playing journey. In conclusion, the study underscores the need for comprehensive health education and support resources for flautists. It highlights the significance of resilience and adaptability in fostering health, wellbeing, and success in the pursuit of their musical careers. These findings highlight the potential for other music educators to benefit from the insights and experiences of these flautists, hopefully leading to more informed and holistic music instruction that prioritises health and wellbeing.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University College London, reference Z6364106202010122. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JW: Writing – original draft, Data curation, Investigation, Methodology, Conceptualization. GW: Methodology, Supervision, Writing – review & editing, Conceptualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Early harmonies, enduring echoes—how early life experiences and personality traits shape music performance anxiety

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Music performance anxiety (MPA) is a deeply personal and often debilitating experience, causing talented musicians to dread the very stages upon which they showcase their art. An increasing number of studies have addressed this anxiety phenomenon, however, definitions vary and the underlying causes remain unclear. According to the DSM-5, MPA is categorized as a specific subtype of social anxiety disorder, with a shared understanding that its development is shaped by predisposing vulnerabilities as well as external stressors and circumstances. This mini-review provides an overview of relevant literature on the multi-dimensional causes of MPA, with a particular focus on early life experiences and personality traits. It aims to address three key challenges in the field by emphasizing the importance of an enhanced investigation of formative life events, recognizing the (potentially) mediating effects of personalities, and highlighting the necessity to explore protective factors. Investigating early life experiences and personality traits in the context of MPA can deepen our understanding of its origin and development, offering valuable perspectives to tailor interventions, prevent the escalation of anxiety, and foster supportive environments conducive to the well-being and professional growth of musicians.

KEYWORDS

music performance anxiety, musicians' mental health, parental behavior, attachment style, music teacher's role, Five-Factor Model, perfectionism, sensory processing sensitivity

1 Introduction

What roles do early life experiences and personality traits play in the development of music performance anxiety (MPA), a multi-faceted and widespread phenomenon commonly experienced by musicians of all skill levels, from hobbyists to professionals (Spahn et al., 2011)? Kenny's conceptualization of MPA builds on Barlow's theoretical framework, which posits that three types of vulnerabilities contribute to anxiety development: a generalized biological (hereditary) vulnerability, a generalized psychological vulnerability, and a specific psychological vulnerability (Barlow, 2000, 2002; Kenny, 2011). According to this model,

a musician's inherent traits and formative experiences shape their susceptibility to MPA. A growing body of literature (Fernholz et al., 2019; Kirsner et al., 2023; Papageorgi, 2022) underscores that a comprehensive understanding of MPA requires closer attention to these formative years and traits, while acknowledging their complex interactions. Examining personality traits and early life experiences within this framework helps identify individual vulnerabilities and potential maladaptive coping mechanisms, which lay the groundwork for preventive measures and effective anxiety management interventions. This review aims to provide a structured and critical overview of recent research, highlighting three key areas that demand attention for advancements in the field: the imperative for enhanced exploration of formative life events, understanding the (potentially) mediating effects of personalities, and the necessity to recognize protective factors.

Several researchers have already explored variables contributing to MPA, spanning from genetic factors to performing circumstances and experiences. In particular gender (Hildebrandt et al., 2012; Kenny et al., 2004, 2014; Khalsa et al., 2009; Papageorgi, 2022; Tardif et al., 2023), age (Dempsey and Comeau, 2019; Fehm and Schmidt, 2006; Fishbein et al., 1988; Kenny et al., 2014; Middlestadt, 1990; Osborne et al., 2005; Papageorgi, 2022; Patston and Osborne, 2016; Steptoe and Fidler, 1987), performance setting (Boucher and Ryan, 2011; Papageorgi, 2022; Ryan and Andrews, 2009), instrument type, musical genre (Nusseck et al., 2015; Perdomo-Guevara, 2014), and performance experience (Fehm and Schmidt, 2006; Kenny, 2011; Papageorgi et al., 2013). Beyond the genetic and conceptual factors mentioned above, the depth of personal experiences and individual traits play a crucial role in shaping the onstage experience of musicians. Individual personality traits and early life experiences have been found to influence an individual's perception and management of psychological distress, such as anxiety (Kotov et al., 2010; Lähdepuro et al., 2019). Some musicians may therefore be inherently more prone to MPA, while others demonstrate greater resilience. Studies have highlighted the role of early life experiences in shaping personality development (Csathó and Birkás, 2018; Kitamura and Fujihara, 2003) and their interconnection with psychosocial factors such as self-esteem, self-efficacy, and social support (Bandura, 1997; Pérez-Fuentes et al., 2019). For instance, a study conducted by Kitamura et al. (1999) showed that individuals who perceive stronger social support tend to display higher levels of extraversion and lower levels of neuroticism. Other findings indicated that extraversion, agreeableness, conscientiousness, and openness to experience were positively associated with self-esteem, whereas neuroticism was found to be a significant negative predictor (Amirazodi and Amirazodi, 2011). Social support, self-esteem, and self-efficacy have also been found to play pivotal roles in shaping musicians' beliefs about their ability to cope with anxiety and on how to perform well (Chan, 2011; Dempsey and Comeau, 2019; Papageorgi, 2022; Schneider and Chesky, 2011). How early life experiences and personality traits affect MPA's emergence will be discussed in the following sections.

2 Early life experiences

Studies suggest that children exposed to early adverse experiences are more prone to developing anxiety or other mental illnesses (Bick and Nelson, 2016). Therefore, acknowledging the heightened vulnerability during these stages is essential when addressing MPA. Early life experiences can mold core beliefs, influencing self-esteem, self-efficacy, and the overall perspective on performance (Givertz and Segrin, 2014; Kirsner et al., 2023; McPherson et al., 2012; Zarza-Alzugaray et al., 2018). Furthermore, the occurrence of MPA in very young musicians (Boucher and Ryan, 2011) underscores the need to address coping strategies as early as possible, which, correspondingly, relies on the support provided by their environment (Fehm and Schmidt, 2006). Factors explored in the context of early life experiences and MPA include parental behavior, attachment style, the influence of music teachers, and early exposure to music performance. For an overview, see **Supplementary Table 1**.

2.1 Parental behavior

During childhood, parental behavior can exert substantial influence on children's musical development. McPherson (2008) presents a model that clarifies how parental goals influence various child outcomes, including musical competence and the development of a musical identity. Parents, for instance, who show interest and value their children's musical activities through supportive words or actions, strengthen the parent-child relationship, provide encouragement and motivation during difficult times, and enhance feelings of competence (McPherson and Davidson, 2002). Moreover, parents often take the lead in initiating young musicians' careers and are actively involved in their offspring's musical advancement (Corrigall and Schellenberg, 2015; Upitis et al., 2016). Ryan et al. (2023) noted that young piano students with musically educated parents exhibited higher levels of MPA, suggesting a potential influence of the parents' expectations and their critical understanding of musical performance. In the course of researching MPA various parenting styles were examined. Notably, perceiving parents as critical, abusive, over-controlling, or overprotective emerged as potential risk factors for experiencing heightened MPA (Aubry and Küssner, 2023; Dobos et al., 2019; Kirsner et al., 2023; Papageorgi, 2022; Wiedemann et al., 2020). A study by Kirsner et al. (2023) explored MPA in the context of early childhood experiences and dysfunctional cognitive schemas. The authors found that when musicians perceived their primary caregivers as failing to meet fundamental emotional needs, it could lead to the development of dysfunctional cognitive schemas, which were subsequently identified as significant predictors of MPA. The fundamental aspect of these schemas, as defined by Young et al. (2003), was characterized as *Impaired Autonomy and Performance*. Individuals with this schema may struggle with a persistent sense of incompetence, fear of failure, or a heightened sensitivity to perceived shortcomings, impacting self-esteem, decision-making, and overall performance.

2.2 Early attachment

Attachment style, which refers to an individual's patterns of emotional bonding and connection developed in early childhood through interactions with caregivers, has been linked to MPA

(Kenny, 2011). These early attachment patterns shape one's approach to intimacy and relationships throughout life (Bowlby, 1969; Karavasilis et al., 2003). However, there are only a limited number of publications exploring this area in relation to MPA (Kenny and Holmes, 2015; Kenny and Holmes, 2018; Wiedemann et al., 2020). Wiedemann et al.'s (2020) findings suggest that musicians characterized by dismissive or secure attachment styles exhibit lower anxiety levels compared to those with preoccupied or anxious attachment styles. Individuals exhibiting a dismissive or secure attachment style may possess a greater sense of confidence, self-assurance, and emotional security, leading to a reduced susceptibility to performance anxiety. In contrast, individuals displaying a preoccupied or anxious attachment style may experience heightened performance anxiety due to increased self-doubt, concerns about external evaluation, or a lack of confidence in their abilities. A published case report further demonstrated the relationship between insecure attachment and the occurrence of MPA. A young musician's unresolved early attachment ruptures contributed to vocal difficulties and heightened anxiety during musical performances (Kenny and Holmes, 2015).

2.3 The role of music teachers

The importance of the music teacher's role in the context of MPA has been underscored in various studies. Music teachers serve as influential guides during key stages of musical education. They shape students' perceptions, self-efficacy, and coping mechanisms, thereby influencing their pupils' vulnerability to experiencing and ability to manage MPA (MacAfee and Comeau, 2023; Gill et al., 2022). However, it seems that music teachers do not always adequately address MPA during performance preparation. Fehm and Schmidt (2006) identified the significant influence of teachers on anxiety in music students aged 15–19, which was linked to their expertise and the perceived judgments they made. The students further conveyed a desire for more support in managing performance-related anxiety, emphasizing the importance of candid discussions about experienced distress and highlighting the necessity to provide more practical techniques such as relaxation or performance skills. Ryan et al. (2021) found comparable outcomes revealing that although a considerable number of piano students experienced nervousness during lessons, less than half mentioned that their teachers tackled concerns related to performance preparation, memorization strategies or MPA management. Moreover, they noted that students who experience negative emotions after lessons often link it to a sense of having disappointed their teacher. Ryan and Andrews (2009) investigated choral singers from seven choirs, stating that the conductors' attitude and behavior during rehearsals emerged as a crucial factor influencing the singers' experiences of performance anxiety.

2.4 Early exposure to music performance

Although the literature presents differing views on how performance experience influences MPA (Fehm and Schmidt, 2006; Kenny, 2011; Papageorgi et al., 2013; Sârbescu and Dorgo, 2014), a recent study highlighted that the onset age of musical training exert a favorable impact on MPA. According to Zarza-Alzugaray et al. (2018) musicians who commence their musical training at or before the age of seven typically report lower levels of performance-related anxiety compared to those who initiate training later in life. Cultivating familiarity and comfort with musical elements, instruments, and performance environments may reduce anxiety and facilitates individuals' navigation through such events. Early skill development might enhance confidence and competence in performance, potentially reducing anxiety arising from the fear of making mistakes or facing negative judgment. However, in addition to the onset age of musical training, the nature of the experience appears to be crucial. Kenny and Holmes (2018) revealed in their qualitative research that humiliating sensitizing experiences during adolescence, such as memory lapses associated with feelings of shame, are linked to heightened MPA. Similarly, Osborne and Kenny (2008) discovered that music students who reported having a negative performance experience scored notably higher on MPA.

3 Personality traits

Musicians' personality traits have been studied with regard to musical preferences (Rentfrow and McDonald, 2009), training and involvement (Corrigall and Schellenberg, 2015), genius (McCrae and Greenberg, 2014), and musical sophistication (Greenberg et al., 2015). Personality is further linked to the experience of flow during musical activities and performances (Antonini Philippe et al., 2022; Biasutti, 2017; Cohen and Bodner, 2019; Forbes, 2021). Whereas individuals displaying higher levels of Openness, Emotional Stability, Extraversion, and Conscientiousness are more inclined to encounter the psychological state of flow (Butkoviæ et al., 2015; Gözmen and Aşçı, 2016; Tan et al., 2021), suffering from MPA decreases the probability of experiencing flow (Cohen and Bodner, 2019, 2021). Flow is thus fundamental for musicians dealing with MPA, as it enhances performance quality and reduces anxiety-related symptoms, contributing to a more fulfilling and enjoyable musical experience (Spahn et al., 2021). While studies on trait anxiety have offered significant insights into MPA (Osborne and Kenny, 2008; Niering et al., 2023; Thomas and Nettelbeck, 2014), the following sections will concentrate on personality traits that reveal more specific influences on this phenomenon. While trait anxiety helps explain general predispositions to anxiety, it does not capture the distinct ways in which individuals experience and respond to performance-related stress. In contrast, the Five-Factor Model, perfectionism, and sensory processing sensitivity (SPS) might directly shape MPA through specific mechanisms. For example, openness to experience may help performers reframe anxiety as a source of motivation and growth; perfectionism may heighten anxiety by enforcing unattainable performance standards; and SPS might amplify stress through an increased sensitivity to environmental stimuli, such as audience feedback or performance settings. By concentrating on these personality dimensions, we can uncover distinct subtypes of MPA, identify critical stress triggers for different individuals, and provide tailored strategies that address the unique interplay of personality and performance-related stress (see overview in **Supplementary Table 2**).

3.1 Five-Factor Model

The Five-Factor Model, commonly referred to as the Big Five personality traits, is a widely accepted framework in psychology, encompassing Openness (the inclination to embrace new ideas and experiences), Conscientiousness (organized and goal-directed behavior), Extraversion (sociability and assertiveness), Agreeableness (cooperativeness and empathy), and Neuroticism (emotional instability and lack of resilience) (Digman, 1990; Goldberg, 1993). A study on the Five-Factor Model and performance anxiety revealed that Neuroticism and Conscientiousness predicted performance anxiety positively, while Extraversion predicted performance anxiety negatively. Openness correlated negatively with performance anxiety but lacked predictive value, and Agreeableness showed no correlation (Özdemir and Dalkıran, 2017). Although research on the Five-Factor Model is limited in the context of MPA, one of its components—Neuroticism—features widely in the literature about MPA. Neuroticism reflects the extent to which an individual experiences negative emotions and emotional instability. It correlates positively with various mental health issues and appears to negatively predict life quality and longevity (Lahey, 2009). It is therefore not surprising that musicians' with neurotic tendencies seem to be in general more susceptible to MPA (Hodapp et al., 2009; Rae and McCambridge, 2004; Sadler and Miller, 2010; Smith and Rickard, 2004; Spahn et al., 2024; Steptoe and Fidler, 1987). Neurotic traits may intensify emotional responses to MPA stressors, contributing to persistent rumination on potential mistakes, heightening the fear of failure, and increasing concerns about perceived judgment and criticism. This, in turn, further fuels the cycle of anxiety in the intricate realm of music performance.

3.2 Perfectionism

Perfectionism is a personality trait characterized by a persistent striving for flawlessness, an elevated tendency for self-criticism, and the establishment of unrealistically high standards (Flett and Hewitt, 2002). In a competitive environment such as the music industry, the fear of making mistakes and the constant pursuit of excellence motivates musicians to strive for perfection. Studies have shown that perfectionism appears to already be common among young musicians (Patston and Osborne, 2016; Stoeber and Eismann, 2007) and findings reveal positive correlations between MPA and perfectionism (Diaz, 2018; Dobos et al., 2019; Kenny et al., 2004; Kobori et al., 2011; Langendörfer et al., 2006; McNeil et al., 2022; Mor et al., 1995; Papageorgi, 2022; Sarıkaya and Kurtaslan, 2018; Sinden, 1999). Patston and Osborne (2016) highlight a more pronounced developmental trajectory for females compared to males and demonstrate that while developmental pathways are similar for both genders in late childhood, they appear to diverge during early adolescent. Moreover, as musicians gain experience, levels of both MPA and perfectionism tend to ascend. Notably, MPA research underscores the need to differentiate between positive and negative aspects of perfectionism. Stoeber and Eismann (2007) demonstrated that responding negatively to imperfection correlated positively with performance anxiety, while the pursuit for perfection aligned with musical effort and accomplishment. These findings were supported by Butkoviæ et al. (2022) who identified a positive correlation solely between maladaptive perfectionism and MPA, without any observed link to adaptive perfectionism. Dobos et al. (2019) found positive associations with only four out of six perfectionism subscales, including Parental Criticism and Doubts about Actions. Patston and Osborne (2016) further emphasized a particularly significant positive relationship between MPA and the subscale Concern over Mistakes, emphasizing the diverse nature of perfectionism.

3.3 Sensory processing sensitivity

Sensory processing sensitivity (SPS) is a personality trait characterized by a heightened awareness and responsiveness to sensory stimuli. Individuals experiencing high SPS process information on a much deeper level, experience intensified emotional reactions, and may find themselves more easily overwhelmed by intense sensory input. It is assumed that highly sensitive people are inclined to choose creative professions (Aron, 1997), suggesting that this trait might be especially prevalent among musicians. Highlighting this assumption, Bridges and Schendan (2019) illustrate how individuals with heightened sensitivity tend to demonstrate elevated levels of creativity. This occurrence arises from a combination of diverse traits and biological processes that influence the development of neurotransmitter systems, sensitivity mechanisms (especially reduced inhibition), and brain networks responsible for automatic attention and orientation. While SPS has been studied in connection with various aspects of psychological functioning (Aron et al., 2005; Liss et al., 2005, 2008), its association with MPA has been relatively unexplored. However, a recent study examined the relationship between MPA, parenting style and SPS in a diverse sample of 342 musicians, indicating that SPS could be a potential risk factor for experiencing heightened MPA (Aubry and Küssner, 2023).

4 Challenges for future research

To advance our knowledge of the impact of early life experiences and personality traits on MPA, we propose to focus on three key areas: examining formative life events, investigating how personality traits (potentially) mediate MPA, and identifying protective factors. Addressing these areas will enhance our ability to identify risk factors and enable us to develop more effective interventions. These points are explored further in the subsequent sections.

4.1 Enhanced investigation of formative life events

Research on the impact of early life experiences on MPA is still limited, and there is a pressing need for a deeper exploration of how formative life events and cultural/environmental influences shape the development of MPA. For instance, the absence of research examining the connection between trauma and MPA is particularly striking, given that trauma's

effects have been explored in connection to various aspects of musical practice, including creative expression, performance, memory, and concentration (Swart, 2014; Swart et al., 2010). Trauma has also been linked to anxiety disorders (Heim and Nemeroff, 2001; Kuo et al., 2011; Lochner et al., 2010; Śpila et al., 2008), but its specific impact on performance anxiety remains unexplored. Understanding this mechanism could lead to more targeted, trauma-sensitive interventions that address the unique challenges musicians face when performing under intense fear. Moreover, examining other formative experiences—such as negative peer interactions, social standing, experiences of loss, social isolation and early physical health issues—will broaden our understanding of MPA's complexity.

4.2 Understanding personality's (potentially) mediating effect

It is crucial to recognize that the trajectory of personality traits is not uniform, with personality and early life experiences being deeply intertwined (Srivastava et al., 2003). This relationship underscores the individual variability in how musicians experience and cope with MPA, highlighting the need to address the holistic development of musicians when exploring MPA in the context of their careers. While the specific connection between early life experiences and personality in relation to MPA has been limitedly explored, findings in other domains suggest that these effects are relevant. For instance, Liu et al. (2021) found that childhood psychological maltreatment is linked to increased neuroticism and reduced coping behavior, contributing to higher levels of social anxiety. Thus, musicians with a history of childhood distress may be more vulnerable to MPA due to the development of anxiety-prone personality traits. Moreover, traits such as perfectionism and sensory processing sensitivity may act as mediators between early life experiences and MPA. For example, musicians who grew up in hypercritical or unsupportive environments may develop perfectionistic tendencies, characterized by an intense fear of failure and a drive for flawless performance, which heightens their susceptibility to MPA. Similarly, individuals with high SPS, tend to react more intensely to all kinds of environmental stimuli. This heightened responsiveness can increase the likelihood of developing anxiety, as they are more affected by stressors such as performance pressure or audience reactions (vulnerability-stress model, Zubin and Spring, 1977). Further empirical studies are essential to shed light on the mediating roles of perfectionism and SPS in the development of MPA.

4.3 The exploration of protective factors

Finally, it seems important to not only address how early life experiences can have adverse effects on MPA but also to emphasize factors that can yield positive effects. Currently there are no studies investigating for instance parenting styles that may mitigate the development of MPA. Nevertheless, research in other areas of psychological functioning has indicated that an authoritative parenting approach serves as a preventive measure against anxiety in children. Authoritative parents are responsive to their children's needs while maintaining clear expectations (Erozkan, 2012; Manoochehri and Mofidi, 2014; Panetta et al., 2014; Pinquart, 2017; Timpano et al., 2015; Wei and Kendall, 2014; Wolfradt et al., 2003; Yaffe, 2018; Yazdani and Daryei, 2016). It would be interesting to find out if this holds true in the context of MPA. Providing a guided, structured and at the same time supportive environment may encourage independence and self-expression contributing positively to a child's confidence in its musical pursuit. The same applies to the behavior and the role of music teachers. Indeed, several recent studies have focused on strategies that teachers impart to help their students better cope with performance stressors (MacAfee and Comeau, 2023; Huang and Yu, 2022). However, some teachers stated feeling ill-prepared to support pupils in this regard and expressed a need for additional training to effectively address MPA during music lessons (Moura and Serra, 2021; Sieger, 2017). Further research should explore how primary caregivers and teachers can enhance musicians' overall enjoyment of performances.

5 Conclusion

Considering MPA to be multifaceted, early life experiences and personality appear to influence musicians' responses to performance stress. However, limited research exists on how specific formative experiences (e.g., trauma, negative peer interactions, cultural influences) contribute to MPA's development. Similarly, the mediating roles of personality traits like perfectionism or SPS remain underexplored, particularly their interplay with early life experiences in creating vulnerability or fostering resilience to MPA. Addressing these gaps is crucial for identifying how foundational experiences and personality traits predispose individuals to MPA or buffer against it. Such knowledge would clarify risk factors and support the development of targeted, evidence-based interventions, especially for musicians with unique vulnerabilities. By uncovering the nuanced interplay between early life experiences and personality traits, we can refine our understanding of MPA, predict susceptibility more accurately, and tailor interventions that empower musicians to navigate performance anxiety with greater confidence and resilience, ultimately supporting their well-being and artistic expression.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1360011/full#supplementary-material

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Wellbeing for young elite musicians: development of a health protocol from a student perspective

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Musicians' vulnerability to psychological and physical problems provides a compelling argument to include health and wellbeing training in music education. This study forms part of a larger project to design an evidence-based wellbeing protocol for young elite musicians at a pre-professional music training institute. Recommendations from the health, education, performance science, behavior change, and occupational and public health literature provided theoretical and practical foundations for the project. The aim of this study was to identify barriers to wellbeing and strengths of an existing health protocol, and provide recommendations for change from the student perspective. Four in-person focus groups were held on the same day, attended by 68% (n = 45) of the student cohort. Semi-structured discussions were recorded, transcribed and analyzed thematically. Barriers to wellbeing and recommendations for change were collated from the data and distributed to the student body to be rated in priority order. Participants appreciated the existing program for its holistic approach delivered by a range of skilled practitioners. Barriers to wellbeing included constraints in finances, leave allowances and time, pressure from interpersonal challenges and unhealthy norms in the music performance culture. Recommendations for change included updating the financial policy; having more flexible leave conditions to allow higher earnings and better access to performance opportunities; having reliably scheduled time off; collaborative planning with staff around playing rosters; more activities for musician enhancement and social bonding; exercise opportunities in-house; addressing pervasive cultural norms around practice and breaks; education regarding respectful and professional conduct; an effective complaints procedure, and more practical wellbeing sessions.

KEYWORDS

health promotion, performance-related problems, music student, musician, conservatoire, tertiary music, wellbeing, qualitative

Introduction

Musicians in pursuit of excellence must develop exceptional psychological and physical skills in environments that often present significant challenges to mental and physical health. Mental health studies have reported over 75% of professional musicians and around 70% of tertiary music students have at some time experienced anxiety or depression (Gross and Musgrave, 2016; Koops and Kuebel, 2019). A systematic review of prevalence and risk factors for musculoskeletal pain in musicians reported lifetime prevalence ranging between 46 and 90%, and point prevalence ranging between 9 and 60% depending on study methodology (Rodríguez-Gude et al., 2022). Symptoms arising from playing an instrument or singing can

appear as early as childhood, with higher prevalence estimates reported in musicians with more playing experience (Ackermann et al., 2012; Cruder et al., 2020; Ranelli et al., 2015). The extent of playing-related problems and investigation into contributing risk factors has received considerable attention, with music and health experts recommending multifaceted approaches to musicians' health promotion and education (Araújo and Spahn, 2022; Chesky et al., 2006; Ginsborg et al., 2012; Matei and Phillips, 2023). The expansion of work in this area has raised awareness of playing-related problems and led to interdisciplinary health initiatives tailored for musicians, including Healthy Conservatoires UK, the NASM requirements for music schools in the US, and specialist musicians' clinics in Germany (Healthy Conservatoires, 2018; NASM 2019-2020, n.d.; Rosset et al., 2022; Zalpour et al., 2021). However, studies on health programs with musicians have delivered mixed results (Rotter et al., 2020; Stanhope et al., 2020), and there is no gold standard approach to preventing playing-related problems. The success of public health and occupational health initiatives in improving population health and wellbeing and reducing workplace injury suggests that these and allied disciplines may offer perspectives or processes that could be useful for improving the health status of musicians. This article presents a discussion of multidisciplinary frameworks and interventions that informed development of a health protocol design for young elite musicians, and enlarges on the stakeholder engagement phase of the protocol development to present student perspectives on wellbeing and recommendations to help them to thrive.

The problem

Musicians experience more psychological and physical problems than the general population (Loveday et al., 2022; Vaag et al., 2016), while also delivering higher scores in positive psychology and emotional regulation (Ascenso et al., 2018; Athalia and Kilis, 2020). In a pre-COVID study with over 2,000 UK professional musicians, 71% reported anxiety or panic attacks, and 69% reported depression resulting from precarity of employment opportunities and tenure, income uncertainty, and challenges related to damaging industry cultural norms and working conditions (Gross and Musgrave, 2016). In terms of physical health, up to 90% of professional and 89% of tertiary musicians report physical symptoms related to music performance (Ackermann et al., 2012; Ioannou et al., 2018; Steinmetz et al., 2015). These statistics represent unacceptably poor levels of occupational health among musicians that are accompanied by substantial personal and social costs.

Ideally, healthy performance principles would be integral to music education from the outset and underpin a professional musician's work (Rosset et al., 2022). As the primary contact and source of advice for students experiencing music-related health issues, music teachers are concerned about students experiencing music-related health issues (Norton, 2016). However, other than in countries such as Austria, Germany or Switzerland where music physiology training for music teachers is well-established, teachers' knowledge of wellbeing and playing-related problems may be guided more by personal experiences of symptoms and symptom management rather than on a working knowledge of the complex factors that contribute to playing-related problems (Norton, 2016). Consideration of wellbeing and playing-related problems is not generally included in elementary music instruction, at least partly due to teachers' limited knowledge of playing-related problems and due also to the focus being on acquiring music skills and on performance rather than the musician's condition.

Higher education offers a structured environment where students' playing health can be influenced positively while they are still in an active learning context (Rosset et al., 2022). Student wellbeing programs are more common in universities and conservatoires now than they were in the past, but many music faculties are yet to include wellbeing initiatives that cater for the specific needs of musicians (Wijsman and Ackermann, 2019). Where they are present, health initiatives offered by tertiary music faculties typically comprise information and advice, optional involvement with wellness activities, symptom treatment through student services, and perhaps musicians' health as an elective rather than a core subject. With few exceptions, musicians' health education programs provide information but do not actively facilitate behavior change, even though information on its own is not sufficient to change behavior and does not necessarily improve health status (Kelly and Barker, 2016; Michie et al., 2011; Rosset et al., 2022). Additional influences on music students' health are the conservatoire environment itself, and that music students appear to exercise low responsibility for self-care (Araújo et al., 2017; Perkins et al., 2017).

While the higher education setting is well-placed to improve musicians' health in the long term, the overarching work environment is likely to exert a stronger influence on health and health behavior than individual knowledge or skills (Oakman et al., 2018; Weale et al., 2022). Psychosocial as well as biomechanical hazards at an organizational level have a higher impact on psychological and physical health than education or protective equipment for individuals in the work environment (NIOSH, 2016; Oakman et al., 2018). However, it is unclear whether this is known or how much it is acted upon in professional or educational music settings, where for the most part health initiatives are implemented only at the musician level rather than also working with organizational structures and expectations. Our research questions for designing a wellbeing protocol for young elite musicians were:

1 What are the structures, processes and content that influence musicians' wellbeing?
2 What needs to be done to reduce musicians' health problems?

A review of the interdisciplinary literature was the first stage in answering these two questions.

Wellbeing definition

The need to thrive and not just survive is expressed in the World Health Organisation's (WHO) definition of health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 2020, p.1), and health also as "a resource for everyday life, not the objective of living. Health is a positive concept emphasizing social and personal resources, as well as physical capacities" (WHO, 1986, p. iii). The WHO's biopsychosocial concept of wellbeing encompasses the spectrum of health promotion, problem prevention, early intervention, and treatment of psychological and physical conditions in a given socio-cultural context. Therefore, the terms "health" and "wellbeing" are used interchangeably in this article.

In keeping with the WHO's definition of wellbeing, the Healthy Conservatoires (2020) Fit to Perform eight-factor framework captures the multidimensional nature of performer wellbeing (Figure 1). A healthy university is one that: "aspires to create a learning environment and organizational culture that enhances the health, wellbeing and sustainability of its community and enables people to achieve their full potential" (Dooris et al., 2010, p. i). Music performance demands high physical and emotional engagement with appropriate levels of fitness to meet those demands. It is not enough to be injury-free; musicians need to have the resilience to perform at their best under considerable pressure (Araújo et al., 2017).

A unifying aspect of the WHO and Healthy Conservatoires' wellbeing models is that wellness is multidimensional. Wellbeing research represents psychological health as positive emotion combined with the practice of self-care, making meaning, and having a sense of personal agency within the social environment (Keyes, 2009; Ryff and Singer, 2008). Keyes' (2009) assessment of mental health ranging from robust mental health (flourishing), through to poor mental health (languishing), provides a useful tool for mapping change in response to wellbeing initiatives. Self-Determination Theory specifies three core psychological needs that determine wellness: *competence* (the desire to feel effective); *relatedness* (the need to feel connected to others), and *autonomy* (sense of choice or personal control). Growth and psychological wellbeing result when these core needs are fulfilled; conversely, psychological illbeing arises when these needs are not met (Evans, 2015).

Interdisciplinary perspectives

In view of the ongoing prevalence of playing-related problems despite several decades of research into musicians' health, we expanded on emerging directions in performance science (Araújo et al., 2017; Gross and Musgrave, 2016; Perkins et al., 2017), to source perspectives from disciplines that have invested significant resources over time in reducing costs associated with injury and ill-health, including public and occupational health. In keeping with the recognition that health literacy requires behavior change as well as education (Kelly and Barker, 2016; Nutbeam, 2019), additional perspectives were sought from the behavior change and health promotion literature. This shifts the focus of musicians' health, usually centered on biomedical constructs, to recognizing contextual and choice elements in addressing the problem of playing-related problems.

FIGURE 1
Healthy conservatoires wellbeing framework. Reproduced from https://healthyconservatoires.org/framework/. Used with permission.

Behavior change

Behavior change involves working with behavioral determinants to bring about constructive change (Michie et al., 2008). There is a growing realization that if health outcomes are to improve in the music environment, education must move beyond providing information to changing behavior (Ajzen et al., 2011; Araújo and Spahn, 2022; Matei and Ginsborg, 2022). Ajzen et al.'s (2011) Theory of Planned Behavior proposes that behavior arises from a complex mixture of attitudes, subjective norms and perceptions of behavioral control which are affected by context but not reliably by information, while Araújo and Spahn (2022) concluded that as well as appropriate information, healthy behaviors in musicians require healthy musician-centered settings that foster healthy decision-making and practices. Matei and Ginsborg (2022) reported positive engagement with health and increased adoption of healthy behaviors in some participants following a 5-month health module. However, other participants identified a number of barriers to engaging practically with the course material, some of which were that they felt the program did not apply specifically to their situation, or was not sufficiently practical or solution-focused, or was partially redundant.

According to Michie et al. (2011), behavior change is characterized by three main drivers: Capability, Opportunity and Motivation. The COM-B model of behavior change elaborates on these drivers to provide a framework to achieve positive changes in individual health behavior within a psychosocial environment applicable across individual, institutional, and legislative domains (Figure 2). Resistance to change at one level can affect factors lower in the hierarchy, effectively locking in a chain of systemic attitudes or behaviors, positively or negatively. The COM-B model moves beyond the customary focus on knowledge and behaviors of individual musicians to include the institutional and social layers that actively influence behavior. Musicians' health has previously been considered through the lens of the COM-B model (Norton, 2020) and used to effect changes in health behavior as part of the Music Impact study (Matei and Ginsborg, 2022).

Occupational and public health

A review of international guidelines for workplace mental health scored Canada's *Psychological Health and Safety in the Workplace* (CSA Group and BNQ, 2013/2018) highest of all reviewed guidelines for well-researched, rigorous design that included comprehensive guidance and implementation tools at every level of an integrated approach to mental health (Memish et al., 2017). Canada's guidelines specify three "strategic pillars" for psychological health and safety: prevention of harm, promotion of health, and resolution of incidents or concerns. These strategic pillars parallel levels 3, 4 and 5 of the WHO's 10 essential public health operations: health protection, health promotion, and disease prevention/ management, including early detection of illness (WHO, 2021).

Working conditions including policies, practices, programs and the work environment have been identified in the hierarchy of control as the most influential factors in workers' health (Figure 3) (NIOSH, 2016). When institutions actively create safe work environments through policy and practical strategies in the work environment, they are operating at the highest possible level of health and safety. Although positive change needs to be shown to happen at the individual level, targeting individual behaviors has the least traction in the health and safety hierarchy.

Recent performance science research parallels recommendations in occupational health to understand not just ill health, but wellness

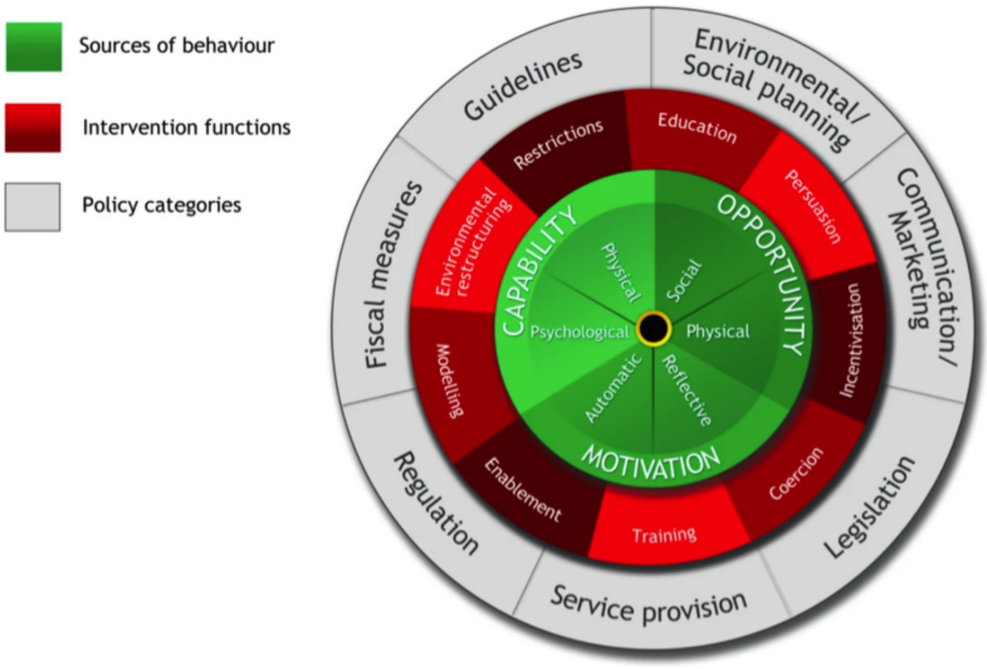

FIGURE 2
COM-B: The Behaviour Change Wheel. Reproduced from Michie et al. (2011, p. 7). Used with permission.

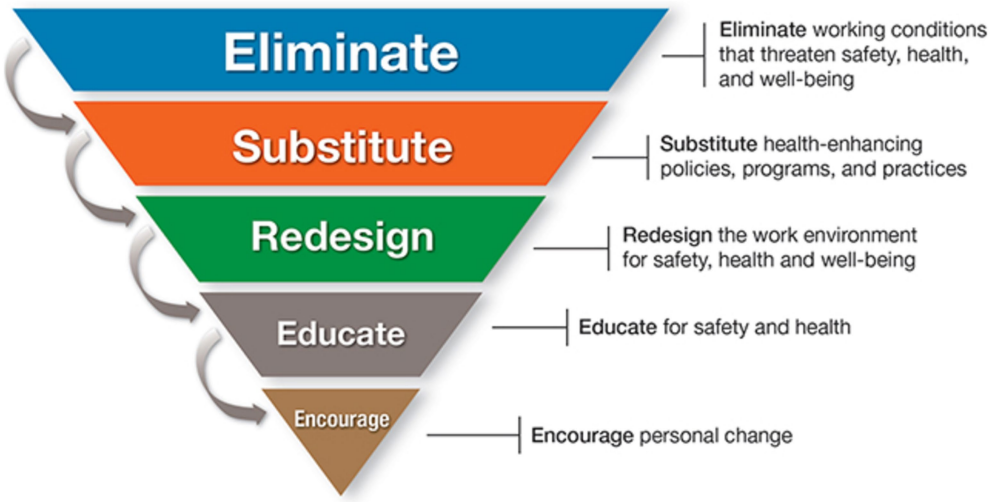

FIGURE 3
Hierarchy of Controls Applied to NIOSH (National Institute for Occupational Safety and Health) *Total Worker Health* ®. Reproduced from NIOSH (2016).

in the work context, and to attend to the institutional and social culture within which musicians work (Araújo and Spahn, 2022; NIOSH, 2016; Oakman et al., 2018; Perkins et al., 2017). It is the role of institutions to advocate for and support healthy cultures and healthy work practices based on contextual risks.

A key factor in Canada's approach to workplace psychological health is active participation of stakeholders in identifying health and safety issues and engaging in all aspects of program development, implementation and evaluation. Worker consultation enables clearer identification of barriers to health and improves the effectiveness and sustainability of health initiatives (NIOSH, 2016). The NIOSH guidelines stress that an organization's health protocol is unlikely to achieve significant success unless gaps in psychological safety are assessed and needs are addressed before embarking on active health promotion (CSA Group and BNQ, 2013/2018). A combined top-down and bottom-up approach is held to be more effective than the top-down approach usually taken. Wellbeing initiatives must be designed and tested in context if they are to be effective (Weale et al., 2022). Stakeholder consultation and program review are especially critical in view of the point that there is no one-size-fits-all approach to wellbeing.

Evidence-based interventions are considered to be the gold standard for health initiatives. However, even where evidence of intervention effectiveness exists, an acknowledged gap separates research evidence and its translation into practice (Gentry et al., 2020; Verhagen et al., 2014). Linear models of health policy, where scientific findings are directly applied to real-life contexts, can fall short of meeting complex "real-world" situations (Gentry et al., 2020). Although numbers derived from linear research methods provide a valuable picture of the extent of playing-related problems and any changes to that picture in response to intervention, they do not capture the complexities that drive health behavior, including the dynamic psychosocial environment that influences minute-to-minute behavior choices. Epidemiologists recommend bridging the research-practice gap by including representative stakeholders in reviewing evidence, devising effective practices or products for their population, and ensuring the success of these practices by evaluation and adjustment (Verhagen et al., 2014). Verhagen et al. (2014) recommend evaluating the impact of any intervention on the population at both individual and organizational levels.

Health education and health promotion

Education aims to provide access to knowledge and skills, training in practices and traditions, to equip students with tools to be life-long learners and to responsibly exercise their full potential (Biesta, 2020). There has been a shift in education over the last two decades from traditional top-down approaches focused on inputs to more active student engagement in the learning process (Biesta, 2020). Contemporary educational theory argues that higher education should be transformative, not merely involve transmission of information and skill acquisition (Paul and Quiggin, 2020). In line with educational theory, health education needs to move beyond learning about healthy behaviors and aim to change beliefs, attitudes, and the choices people make (Nutbeam, 2019).

Health literacy as a goal of health promotion is seen as building skills and abilities across the lifespan to adopt healthy behaviors in the face of complex changing circumstances. Context is important to the exercise of health literacy; people with high levels of health literacy can make unhealthy decisions under the pressure of environmental influences that make it difficult to choose in favor of one's own wellbeing (Kelly and Barker, 2016). The teaching of personal skills and strategies must be supported by attention to the social, economic and cultural environment (Nutbeam, 2019). The shift away from the top-down model in educational theory echoes the shift from early concepts of health education centered on personal risk exposure and lifestyle choices to the WHO's adoption of a health promotion paradigm that includes five strategies: "build healthy public policy, create supportive environments for health, strengthen community

actions, develop personal skills and reorient health services." (Nutbeam, 2019, p. 706).

Health protocol design

Consultation and engagement

The success of a workplace health protocol depends on stakeholder engagement at every stage from the design phase onward (NIOSH, 2016). Competing interests between stakeholders including health professionals, administrators, researchers, workers and workers' families can prevent effective realization of evidence-based health policy (Cherniack and Lahiri, 2010). Additional obstacles to effecting positive changes in workplace health include health practitioners or others offering advice on the basis of cultural values or beliefs rather than on evidence, and service provision based on health care interests rather than appropriately fitting workers' needs (Cherniack and Lahiri, 2010). A further complication can arise for musicians trying to recover from injury who receive conflicting advice from health practitioners. Musicians already having difficulty accessing appropriate treatment, trying to make sense of the array of options on offer, and trying to balance injury and a playing schedule can be confused by having to navigate contradictory advice from different professionals (Price and Watson, 2011). This highlights the need for a cohesive team approach, for an understanding of best practice among support professionals, and for a central objective serving musicians' performance goals. The whole-system settings-based approach espoused by Healthy Conservatoires Network UK reflects this principle (Araújo et al., 2017).

Ongoing program evaluation and adjustment

The success of health promotion in occupational settings hinges on continuous evaluation and adjustment (CSA Group and BNQ, 2013/2018). However, few ongoing programs have been assessed for their impact on reducing playing-related pain, with none known to the authors undergoing regular ongoing evaluation.

A scoping review of health education programs for music students and teachers suggested health education with injury prevention strategies reduced playing-related pain and music performance anxiety (Evans et al., 2024). However, as scoping reviews are designed to capture key concepts rather than evaluate the quality of the evidence, the reliability of results from the included studies is unclear. Systematic reviews of intervention studies with musicians have reported inconsistent results with respect to improving participants' health (Rotter et al., 2020; Stanhope et al., 2020). One systematic review of 20 intervention studies indicated that incorporating strength training in preventative programs might reduce musculoskeletal complaints among musicians in the short term (Laseur et al., 2023). Matei and Ginsborg (2022) found that a health education course increased knowledge and self-efficacy among first-year music students but did not significantly improve health behaviors or reduce PRMD frequency and severity. Similarly, Rosset et al. (2022) reported increased knowledge and skills from a compulsory health education program with first year students, but no significant changes in health attitudes, pain, impairments, general health, mental health, or performance anxiety. A 2-year review of a musician-specific preventative health curriculum given to first year university students by Zander and colleagues (Zander et al., 2010) found that psychological health and performance skills stabilized, with no reduction in physical symptoms. Some evaluated programs show improvements; however, study quality varies, and long-term evidence is lacking (Laseur et al., 2023). To address limitations, these studies recommend understanding the needs of music students as essential for developing effective courses and support measures from the onset of education. Consulting best-practice literature and employing iterative processes with rigorous investigations, including pilot studies and a range of validated measures, is crucial. Methodological improvements such as larger sample sizes, stratification by instrument sub-group to enhance targeted interventions and assist in meta-analyses, and longer follow-up periods are recommended. Interventions at both the institutional and individual levels should be evaluated for their timing, duration, and impact on disease processes (Verhagen et al., 2014).

Interdisciplinary recommendations to achieve a successful health protocol are summarized in Table 1.

Study context

The brief for the overall project was to design and implement a benchmark wellbeing protocol for a pre-professional training institute that is sustainable, reduces occupational, psychological, and physical problems, and enhances musicians' overall wellbeing.

We designed a 7-step theoretically-driven process based on recommendations from the occupational and public health literature, and from wellbeing and behavior change theories (Figure 4). The first step was to conduct the literature review as described above to provide an evidence base for best practice in implementing a health protocol for musicians. The second step was to conduct a quantitative online health and wellbeing survey to map students' psychological and physical health status. For the third and fourth steps of the project reported here, we conducted focus groups with student participants to gain a contextualized understanding of the survey results, and from the focus group results we synthesized barriers to wellbeing and recommendations for change to guide improvements to the institute's existing wellbeing protocol. The online survey and focus groups were designed to provide baseline data to assess wellbeing protocol effectiveness and inform responsive change. Step 5 was to observe work practices *in situ* to identify any unconscious agendas or work practices that might not have been mentioned during the focus groups, but that may be affecting wellbeing. Step 6 was to implement a revised program based on student health data and recommendations for change, and best practice from the literature. Step 7 is recommended as a repeating ongoing exercise to ensure continuing relevance and effectiveness of the wellbeing protocol.

Aim

The aim of this study, which includes the third and fourth steps of the overall project, was to identify strengths in the existing wellbeing supports at a pre-professional training institute for elite classical musicians from the student perspective, and synthesize student views on barriers to wellness and recommendations for improvements to the existing health protocol.

TABLE 1 Interdisciplinary recommendations for implementing a successful health protocol.

	Recommendation	Source
1	Use appropriate theoretical frameworks through all stages of research, planning, intervention and evaluation of wellbeing initiatives.	Willis et al. (2019)
2	Implement multi-tiered strategies across organizational culture and governance as well as individual interventions.	CSA Group and BNQ (2013/2018), Lowe (2004), Matei and Ginsborg (2022), Michie et al. (2011), Nutbeam (2019), Oakman et al. (2018), Perkins et al. (2017), and Sorenson et al. (2013)
3	Research work instead of focusing on problems as the main source of information.	Rae et al. (2020)
4	Identify systemic, contextual, personal, physical and psychosocial risk factors and the relationships between them using quantitative and qualitative research methods.	Macdonald and Oakman (2015), and Sorenson et al. (2013)
5	Consult stakeholders throughout the health initiative, including researching, planning, implementation, ongoing program evaluation and adjustment.	CSA Group and BNQ (2013/2018), Lowe (2004), Sorenson et al. (2013), and Verhagen et al. (2014)
6	Address attitudes and processes within the institution that do not align with wellbeing goals.	CSA Group and BNQ (2013/2018), Matei and Ginsborg (2022), Nutbeam (2019), and Perkins et al. (2017)
7	Change behavior rather than just improve health knowledge	Kelly and Barker (2016), Matei and Ginsborg (2022), and Michie et al. (2011)
8	Address risk factors at highest level of control hierarchy.	Oakman et al. (2018)
9	Consider the legislative and social environment in which the institution is situated.	Kelly and Barker (2016), Michie et al. (2011), and Nutbeam (2019)
10	Ensure health initiatives are appropriate and relevant to the context.	Lowe (2004) and Nutbeam (2019)
11	Everyone being responsible for workplace health; managers assume health advocacy roles.	CSA Group and BNQ (2013/2018), Lowe (2004), and Sorenson et al. (2013)
12	Evaluate whether clearly defined wellbeing goals are being met and adjust program accordingly on an ongoing basis.	CSA Group and BNQ (2013/2018), Lowe (2004), Matei et al. (2018), Nutbeam (2019), Sorenson et al. (2013), and Verhagen et al. (2014)

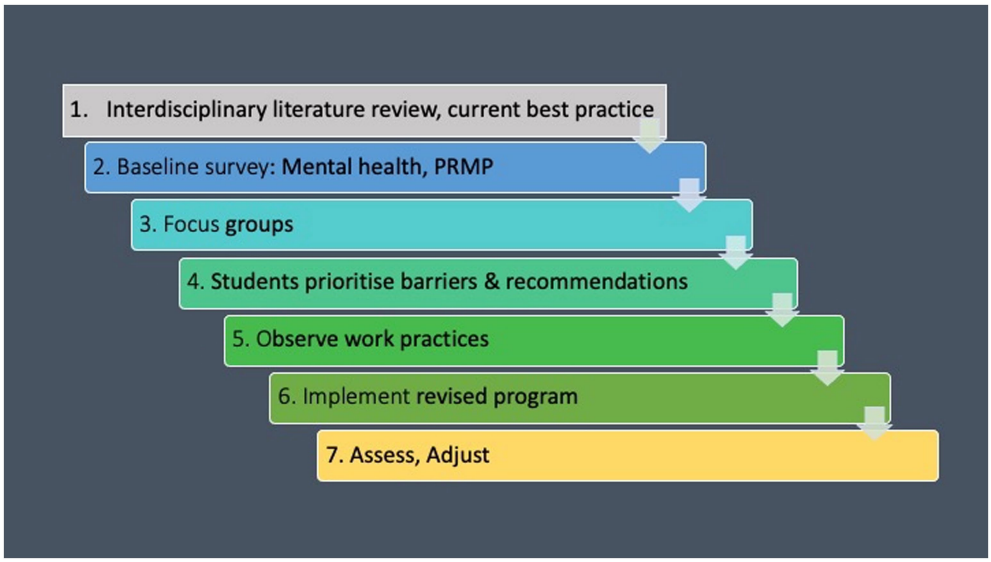

FIGURE 4
Protocol design 7-step process.

Materials and methods

A qualitative approach using a social constructivist framework was used for this study. The social constructivist framework rests on the principle that knowledge is not a fixed entity, but constructed from the meaning individuals give to their experiences within their social environment, which are subjectively interpreted within cultural, social and psychological contexts (Pilarska, 2021). The constructivist

framework, used in previous education and conservatoire research (Jin et al., 2020; Perkins et al., 2017) recognizes that our backgrounds and experience as musicians' health researchers, psychological and physical health care professionals and health and performance educators, form our understanding of wellbeing and health behavior. At the same time, constructivism allows the potential for unforeseen and contrasting attitudes and experiences to be introduced by study participants.

In keeping with recommendations from the literature and the complexity of factors that influence wellbeing, we sought the experiences and views of participants as service recipients and key stakeholders in the wellbeing program. All students were advised about the study by the institute's manager of people and culture at the start of the academic year. The second author (MO) emailed every student with information about the study and an invitation to participate. Participants returned signed consent forms by email.

The study was conducted in two stages. Stage 1 involved running the focus groups and conducting a thematic analysis. Stage 2 involved students ranking the importance of themes as barriers and recommendations.

Stage 1: Focus groups

According to Kristiansen and Grønkjær (2018, p.1), "interactions between focus group participants can reveal and highlight the participants' perceptions, attitudes, thinking, and framework of understanding, as well as identifying group norms, subcultural, and cultural values." As the music culture and the formal learning environment are both cultural entities that influence individual and group experiences, focus groups were used as an appropriate forum to capture participants' attitudes and responses, with group discussions guided by a semi-structured questionnaire (Supplementary material 1).

Focus groups were scheduled at a time when most students were on campus. To accommodate the number of participants while limiting group size, four focus groups were run on the same afternoon in November 2022, two consecutive groups by each author. Each group ran for between 45 min and an hour. Focus group discussions were recorded with the consent of all participants and transcribed for thematic analysis. The identities of students who attended focus groups remained confidential, known only to the authors and the other members of their focus group.

Thematic analysis using inductive and deductive processes enabled participant responses and attitudes to wellbeing and the wellbeing program, to be distilled and synthesized in the form of acknowledged barriers to wellbeing and recommendations for change for the institute's use (Braun and Clarke, 2006). Initial coding included gerunds reflecting participants' actions, and descriptive words and phrases. The final themes resulted from a reflexive process of returning to the transcripts and audio recordings, grouping the codes, and identifying recurring patterns through the narratives (Braun and Clarke, 2013). The thematic analysis provided a structure that moved beyond a summary of student responses to highlighting systemic issues that related back to wellbeing and behavior change theories. In addition to this, specific recommendations for change offered by participants were highlighted in the transcripts and included in the final lists distributed to the students for ranking.

Stage 2: Ranking of barriers to wellbeing and recommendations for change

Hard copy lists of possible barriers to wellbeing (Supplementary material 2) and recommendations for change (Supplementary material 3) derived from focus group discussions were distributed to students by researchers at a lunchtime gathering in April 2023. Using a participatory method (Vaughn and Jacquez, 2020), students were invited to rank their five most important items on each list in order from 1 to 5. The sheets were completed and returned to the authors at the time by students who chose to do so. The ranked lists were then analyzed to establish which items carried the most weight, and a report with recommendations from the analysis was submitted to the institute's administration.

Results

Participants

Forty-five musicians (response rate 68%) at a prestigious pre-professional music training institute participated in one of four focus groups. Each of the four focus groups included 9–14 participants. The average age of participants was 23 years (SD = 2.09). Twice as many males as females participated in the focus groups, which reflected the proportion enrolled across the program. Further details on age and gender have been withheld to protect the identity of participants.

Entry to the institute is gained through a two-stage audition process. All students play orchestral instruments. Students attend for between 1 and 3 years of individual and ensemble classical music tuition and performance programs which aim to prepare them for life as professional musicians. Applicants must be no older than 28 when they enrol, and most students who enter the institute have completed year 12 of secondary school. Each student is provided with a limited stipend through philanthropic funding, and sources the balance of living expenses through family support or external employment.

Pre-intervention wellbeing supports

Health supports have been part of musician training at the institute for all year levels from the early 2000's, instigated by members of the managerial team and teaching staff. Advice was sought from performing arts medicine organizations and health care professionals with expertise in musicians' health to inform program content and delivery. The institute has developed relationships with trusted external experts who visit to deliver the health components of the program. The program varies somewhat from year to year, but for a little over a decade has included compulsory lectures, workshops, and the opportunity to have individual assessments by a musicians' audiologist and a physiotherapist. Three free psychology

TABLE 2 Elements of the wellbeing program participants identified as being helpful.

1	The priority placed on wellbeing, with provision of a range of different services and information to meet different needs
2	Health education, resources and services provided by people who are highly skilled in their fields
3	Musicians' health research presented in an accessible and practical way
4	Learning and performance opportunities that develop skills in how to monitor thinking and attitudes and connect one's mindset with playing outcomes
5	Physiotherapy expertise in musicians' health and performance
6	Audiology advice and care
7	Free counselling sessions with choice of psychologists
8	Dietician
9	Having a clear go-to person for any difficulties they were experiencing
10	Group and individual social events including Baroque dancing, staff concerts, and gatherings around food building a sense of community and morale amidst what is otherwise a very demanding life
11	Having a voice in the affairs of the institute through the Musicians' Committee

sessions are available for students, as are subsidised custom-made earplugs.

The program provides health and wellbeing education, information on policies around appropriate behavior, and crisis support contacts. Support persons among the institute's professional staff are clearly nominated for students to approach if experiencing health and wellbeing issues.

The wellbeing program team includes teachers, senior management and administrative faculty, and performing arts health professionals who are experienced in consulting, research and teaching in a high-performance context. External professionals include a physiotherapist, audiologist and psychologists. Topic areas covered in the program include musculoskeletal health, psychological health, body/mind techniques, social/spiritual/environmental matters, and career skills. Social events were scheduled to enhance student wellbeing and facilitate group cohesion. Supplementary material 4 shows specific issues covered under each wellbeing topic area.

Wellbeing sessions have to fit around a packed performance schedule and the availability of external consultants, so they are often spaced at irregular intervals as time and health experts' schedules permit. This hinders information being presented in a cohesive, scaffolded manner that systematically reinforces and builds on prior learning. This study was the first instance of the wellbeing program being assessed for efficacy.

Strengths of the existing wellbeing protocol

Participants had a prior understanding that health was both physical and psychological. They understood that being fit to play, sufficient rest, healthy diet, social connection and injury prevention are all part of wellbeing. They spoke about wellbeing as individually experienced, and about the challenge of finding balance in the intense environment of the institute. They noted that when wellbeing suffers, playing is adversely affected.

Participants expressed appreciation for the supportive culture of the institute, the opportunities it created for them as musicians, its commitment to their wellbeing, and for the initiatives offered to support their playing longevity. They felt well-informed about what they should be doing in terms of self-care. Most had not experienced the holistic attitude to performance wellbeing cultivated by the institute prior to entering the program. Elements of the existing wellbeing offerings that participants found helpful are summarized in Table 2.

Barriers to wellness and recommendations for change

Barriers to wellness and recommendations for change divided into four main themes, all of which related to the institute's organizational systems:

1 Finances
2 Leave
3 Time
4 Pressure

Further issues participants raised concerned program structure and content, health and fitness, and their social lives. See Supplementary material 2 for the complete list of barriers to wellness and Supplementary material 3 for the complete list of recommendations for change.

Finances

Financial difficulties were experienced as a major stressor. The limited stipend combined with a cap on allowable earnings created pressure to work to earn enough to live on, while simultaneously restricting participants to an income below the amount needed to pay basic living expenses. The conflict between limited opportunities to cover living expenses and practice and playing commitments placed affordable adequate nutrition, time to exercise, rest, and maintaining social connections largely out of reach.

> *You cannot just be using the institute's financial assistance. That's not going to be enough, so you need to be making work some other*

> *way, and so if that works, what you are doing happens to also be coming at the same time as a really busy program, and those can be some exhausting weeks.*
>
> *Group D Speaker 5*

> *...and then I spend it all on the food because I'm too knackered to cook... so you are spending the money, it takes energy to work, and then you get the money and you are spending the money on food, literally to live and survive. And that's exactly, like, I'm not thriving. I'm surviving at that at that point, and then I cannot go home to see my family over summer. I have to stay here and work to pay off my rent, and then I'll probably not have much time for practicing because I'm working, and then I'll probably feel like I have not improved all summer at the end of it, and then again, I'll be surviving and not thriving.*
>
> *Group B Speaker 10*

Participants were left with insufficient funds to pay for health care when needed, either for maintaining wellness (gym membership, exercise classes, massage) or for therapeutic support not covered by the institute's subsidy. The tension between needing and wanting to practice and struggling to make ends meet was described as exhausting and one of the main threats to psychological and physical health. Recommendations to address financial barriers are listed in Table 3.

Leave

Participants described having insufficient time off to have a healthy private and social life alongside the institute's schedule. They spoke of the difficulty of having leave approved even when the schedule was quiet, making it hard to organize paid work, including opportunities for external orchestral work with a potential impact on future employment.

> *I think there could be more allowance with leave requests... I've just heard of lots of people getting denied leave which the instances seem like they should have definitely been approved for leave and then they end up having to do this concert that they barely played in, or they could have easily been replaced for and it definitely seems like that's a big stressor for a lot of people. Especially when the leave is to do something like a professional gig where what we are here to do is prepare for those, you know, to be professional.*
>
> *Group B Speaker 3*

While sometimes students were given several days off at a time, at other times the rehearsal and performance schedule meant they might be required for 2 or 3 weeks straight without a break. Travel to distant venues reduced potential time off. Participants experienced snowballing fatigue because of having to play catchup during scheduled breaks. Scheduling without the opportunity for a reasonable break was seen as unsustainable, incompatible with self-care, and a source of distress.

> *In semester 1 my friend did not have a single Saturday off. That was 13 Saturdays in a row and there were going to be 4 weeks where she did not have a Saturday or a Sunday off. I think that is due to the nature of the instrument she plays, in that that instrument family plays with the strings and the winds and brass in everything. But I just think if you want us to be well, do not make someone work 13 Saturdays in a row.*
>
> *Group D Speaker 11*

> *And fatigue really snowballs as well. Like being busy for one period and then something else comes up, and something else keeps coming up... All of a sudden we had an empty week, we can rest there, all of a sudden, [it's] just as busy as the last one.*
>
> *Group C Speaker 3*

Participants recommendations for addressing the "Leave" barrier are listed in Table 4.

Time

While they felt well-informed about general mental and physical self-care, participants said that lack of time restricted their resources and opportunities for effective self-care. Examples offered

TABLE 3 Student recommendations for change addressing "Finance" barrier.

1	Increase the stipend to match the rising cost of living
2	Either remove or significantly raise the cap on independent earnings
3	Review playing schedule to enable openings for paid work
4	Determine a health budget for each student that can be used according to need, for example funds currently assigned for counselling could be used for physiotherapy instead
5	Set up a small gym where students can put into practice physiotherapy recommendations for playing fitness
6	Morning yoga classes on site

TABLE 4 Student recommendations for change addressing "Leave" barrier.

1	Structure timetable for at least 1 day off a week. If there have been rehearsals/ concerts over the weekend, then schedule Monday or Tuesday off
2	Consider approving leave if there is no or minimal playing requirement at the institute at that time
3	Never schedule institute activities on a public holiday

TABLE 5 Student recommendations for change addressing "Time" barrier.

1	Structure the timetable for at least 1 day off each week
2	Increase stipend to reduce the need for outside earnings
3	Teachers plan rosters in dialogue with students; perhaps a section meeting at the beginning of semester where the teacher explains the roster and invites input
4	Possible exchanges between students on the playing roster
5	Encourage class attendance as a performance opportunity in front of peers
6	More regular social events along the lines of Baroque dancing, staff concerts, gatherings around food and playing sport

included insufficient time to engage in regular exercise, buy and prepare healthy food, get adequate sleep or rest, visit health care practitioners, or see family and friends. They experienced this situation as unsustainable, with some participants showing signs of distress during the discussion.

> *I would say the no days off... because from a physical health point of view it's unsustainable. But also from a mental and social perspective just actually having time to see your family and see friends and actually be able to socially engage, because by the time you are finished with your studies, then you go and work your part time job because your financial assistance is not enough to live off, there is not many hours left in the day.*
>
> *Group A Speaker 4*

> *What I would say is I think that by this point we are all very educated on what, in an ideal world, we would need to do. We're all aware of how to eat properly, how much exercise, and what sort of exercise we need to do. We're well aware of the treatment options that are available should we get injured, etc. But as we said, if you just do not have the time to do it and get everything done, you are not going to do it.*
>
> *Group A Speaker 2*

> *I think most of us can be aware that we are working too hard or doing something's not good for our well-being, but there's still that class tomorrow that you have to practice for and you are going to pick your instrument over your physical and mental health every time... I think you can sometimes feel like you are kind of fighting the schedule or something to find time for yourself. Say if you have got a busy week and you barely have any time to think, let alone check in with yourself. Which is not necessarily a problem for a short amount of time, but if it grows and grows and 1 week turns into a couple months, then it can become a serious issue.*
>
> *Group B Speaker 3*

Time pressures were also seen as causing people to miss performance classes, which impacted a sense of cohesion among the student cohort. Although the institute scheduled some social activities, participants spoke of insufficient time spent together to bond as a whole group, with a tendency for instrument groups to remain siloed.

> *What I felt I've missed is organized social activities... In a way I feel like there can be activities designed to sort of get people talking to people they might not normally. I feel like there's a very big divide between the strings and everyone else.*
>
> *Group C Speaker 4*

Participant recommendations to address time constraints are listed in Table 5.

Pressure

Participants experienced pressure from multiple sources: having insufficient downtime; successive unrelenting deadlines; pressure from wanting to keep up with peers, pressure from one's own self-expectations that result in unhealthy behaviors; lack of control over one's own time and financial status; difficulty of scheduling timely lessons with peripatetic staffing, and students being responsible for staying within the lesson budget.

> *I think within music... there's a degree of unspoken competition between the players. This is not a spoken thing, but you definitely do not want to be the worst [musician] there. And so a lot of motivation, especially for me, is just trying to keep up. And I think that's a limiter because in regards to especially mental health... It just kind of weighs on my mind. I think that's a bit of a limiter because even though it's such a positive environment, such a great place to study, and everybody here is really positive and a great influence - it's just still the industry itself is competitive I think. Or maybe I'm just a competitive person, but - it's just hard to kind of mitigate that in one's mind.*
>
> *Group B Speaker 1*

> *For me whenever I practice, there's some sort of degree of almost cognitive dissonance or something if I feel in my mind that I have not done enough for today... I always set this goal of 3 h a day and I have a lot of commitments outside of music that it's almost impossible sometimes to put that in the day within reason. And so if I even go to the degree of doing 2 h and 40 min, it weighs on my mind for the rest of the day, and oh I need to do 20 min or I have not done my work. And I might have done, I might have maxed out my work, I might have done lots of really great work on something and I was like, I know it's plenty of work done for today, but it just does not sit right in my mind.*
>
> *Group A Speaker 6*

Some participants raised the uncertainty of career prospects and their futures generally, and a few experienced pressure from unprofessional behavior onsite, including bullying.

> *I struggle with the uncertainty of not knowing where you might get work in the future, what country it might be in, how far out of your comfort zone you'll have to go. To perhaps find the smallest amount of work. Yeah. Struggle with that and the future being so unknown.*
>
> *Group A Speaker 8*

Participant recommendations to address issues around pressure are listed in Table 6.

Program structure and content

Further comments regarding the structure and content of the wellbeing program included:

- Some activities and presentations were insufficiently targeted to musicians. Participants noted that lectures or activities needed to show a practical application to music performance and to them as musicians to be seen as relevant.
- Practical and hands-on classes were more readily integrated than lectures, while large amounts of information and presentations not systematically structured or connected could be repetitive or disjointed, and difficult to integrate and put into practice.
- Wellbeing sessions scheduled for the morning or on days that were already heavily scheduled increased the pressure burden, creating resentment rather than achieving their purpose of supporting wellbeing or relieving stress and symptoms. The sense of resentment particularly applied to sessions that were over 45 min in length which started to encroach on practice time.

Student recommendations to improve the wellbeing program structure and content are listed in Table 7.

Prioritized barriers and recommendations

Forty-nine students (response rate 74%) ranked their top five points on each of the two documents *Barriers to Wellbeing* and *Recommendations for Change* (Supplementary materials 2, 3) in order of importance from 1 to 5. Table 8 shows the five barriers to wellbeing nominated most frequently, with the percentage of students who

TABLE 6 Student recommendations for change addressing "Pressure" barrier.

1	Schedule fewer than 9 h of performance classes in a week
2	Use performance classes to lead into a social opportunity
3	Schedule performance classes in the afternoon for more reliable attendance
4	Education sessions on emotional intelligence, ethical behavior, professionalism, and culture/behavior expected at the institute
5	Skills training in responding to inappropriate behavior in others, including bullying
6	Training in self-reflection and self-awareness (this already happens in various contexts across the faculty in relation to performance)
7	Manage student wellbeing on an individual level, similar to elite sport

TABLE 7 Student recommendations for change addressing "Program Structure and Content" barrier.

1	More sessions like those scheduled with high-level musicians during lockdown, where those musicians spoke about their journeys and careers
2	More experiential/ hands-on classes
3	Create a framework for wellbeing information so it is organized, accessible, relevant, avoids unnecessary repetition, and can readily be put into practice
4	Have wellbeing practitioners attend more than once to develop information that has been offered previously
5	Do not schedule wellbeing sessions in project weeks
6	Schedule wellbeing sessions at the end of the day with the possibility of everyone gathering afterwards for food/ drink

TABLE 8 Barriers to wellbeing ranked by participants in the top 5.

Barrier category	Specific problem	% of students who placed problem in top 5
Financial	Stipend insufficient to cover basic expenses	72%
Leave	The difficulty of having leave approved to engage in outside work, including opportunities for orchestral work	60%
Time	Conflict between playing demands and time for mental/ physical/ social self-care	56%
Financial	Low cap on allowable earnings	44%
Time	Unsustainable weekly playing schedule when there are no days off	38%

TABLE 9 Recommendations for wellbeing ranked by participants in the top 5.

Recommendation category	Specific recommendation	% of students who placed recommendation in top 5
Financial	Update policy around stipend (e.g., allow higher earnings from outside work/ abolish earnings cap)	46%
Leave	Consider approving leave if there is no or minimal playing requirement at the institute over the time requested	44%
Leave	Modify playing schedule to ensure at least 1 day off each week	36%
Health and fitness	Set up a small gym where students can put into practice physiotherapy recommendations for playing fitness	36%
Social	Regular "Circuit-breaker activities" for social bonding and musician enhancement, e.g., staff concerts, Baroque dancing, pizza afternoons	30%

placed each one in the top five. Table 9 shows the five recommendations for change nominated most frequently, with the percentage of students who placed each one in the top five.

Discussion

This study identified systemic practices around finances, time, leave, and pressure as main themes affecting student wellness at an elite pre-professional music training institute. The focus group discussions from which these themes were drawn centered around cultural and institutional attitudes and policies, which reflected the multilayered frameworks that formed the theoretical background for this study (Healthy Conservatoires, 2020; Michie et al., 2011; NIOSH, 2016; WHO, 1986). In contrast to the more usual situation of wellbeing initiatives in music faculties either being optional or not offered at all (Wijsman and Ackermann, 2019), an unusual feature of this institute is that all students are expected to engage with its comprehensive wellbeing program. A similar study conducted elsewhere may have yielded results that focused on the need for wellbeing offerings to be made available, but as these were already in place, this study moves to the foreground the crucial role of institutional policies and cultural mores in musicians' health.

Previous studies have discussed the need to address the conservatoire culture and its structures and processes (Araújo and Spahn, 2022; Araújo et al., 2017; Matei and Ginsborg, 2022; Perkins et al., 2017), however, this is the first study to our knowledge to formulate a design process for a musicians' health protocol using recommendations from occupational and public health as well as behavior change perspectives. Where efforts in improving the health status of musicians have historically been focused on conveying knowledge and skills, with more attention over the past 5 years given to behavior change (Matei and Ginsborg, 2022; Norton, 2020), this study shifts that focus to addressing organizational systems and attitudes as a priority as emphasized in occupational health (NIOSH, 2016).

The institute

The institute where this study was conducted is committed to equipping its students for successful music performance careers. This has included dedicating significant resources to student health and wellbeing. Philanthropic funding and the administration's attention to wellbeing means that it is arguably better-resourced than most music faculties and able to provide a content-rich wellbeing program, including many of the aspects proposed in Matei and Phillips (2023) (see also Rosset et al., 2022). At the time of the study, the institute's wellness protocol addressed all eight domains of the Healthy Conservatoires UK Fit to Perform framework (Healthy Conservatoires, 2020), in contrast to the widespread lack of health knowledge and skills available at most tertiary music faculties (Wijsman and Ackermann, 2019).

While participants expressed appreciation and gratitude for the wellbeing program and for the opportunity to study at the institute itself, they noted the dislocation between what they had learned and been advised to do, and the absence of time, opportunity and energy to do it due to financial and time constraints and practice and performance demands. This dislocation between stated policy and achievable practicality has been previously signposted by Matei and Ginsborg (2022) and Araújo and Spahn (2022). The situation where participants felt they were not thriving but struggling to survive (Keyes, 2009) illustrates the application of NIOSH (2016) hierarchy of control and Michie et al.'s (2011) COM-B model, suggesting barriers to health at the level of organizational policy and culture can make it difficult if not impossible for individuals to practice effective health literacy.

Music students have been reported as exercising low responsibility for their own health (Araújo et al., 2017), however, perhaps part of the reason they do not exercise adequate self-care is because of the logistic and cultural environments in which they operate. The established approach of directing health interventions toward the behavior of individual musicians without addressing the overarching policies and the cultural environment could be an explanation of why the prevalence of playing-related problems has remained persistently high. However, it remains to be seen whether the health of musicians improves in healthier music study and work environments. It seems easier to place full responsibility for exercising health literacy on musicians by providing them with information and strategies, than to face the formidable challenges of institutional and cultural change. However, the interdisciplinary literature suggests that unless those needed changes are addressed, strategies aimed at increasing the knowledge and skills of individuals are unlikely to bring about sustained improvements in wellbeing (Kelly and Barker, 2016; Lowe, 2004; NIOSH, 2016; Nutbeam, 2019; Weale et al., 2022).

Barriers to wellbeing and recommendations for change

Among the four main themes of finances, leave, time and pressure derived from the focus group data, barriers most often prioritized in the student ranking fell into the finances, time and leave themes, whereas the most frequently prioritized recommendations for change included fitness and exercise and social connection. This flags the importance of returning to stakeholders for consideration of issues that may initially have been nominated by a minority in one format, as these issues may come to the fore when presented back in another format.

Three of the four main themes: finances, time and leave, were all discussed by participants in terms of instability and insufficiency. Conflict between financial and time constraints and practice and performance demands compromised participants' self-care even though they were well-informed and possessed a good understanding of wellbeing. Participants did not regard the problems as unsolvable, putting forward clear recommendations to allow more flexibility in the schedule (See Tables 3–5 and Supplementary material 3 for the full list of recommendations). However, the strain around finances leading to problems with mental health echoed Gross and Musgrave's (2016) findings that the leading cause of mental health difficulties in professional musicians in the UK was financial and vocational precarity.

A willingness to negotiate flexible solutions was more prominent in focus group discussions than were requests for more services or less work, reflecting participants' interest in constructive engagement with problem-solving when it came to barriers to wellness, and their desire for more autonomy. For example, when discussing factors contributing to pressure, participants spoke of sometimes being required for 2 or 3 weeks' performing without a day off, during which time other aspects of life banked up. When days off did arrive, participants used them to try to catch up on earnings and other commitments, causing snowballing fatigue. To help counteract these unsustainable conditions, participants requested more input into rehearsal and performance scheduling, introducing the possibility of being able to swap with someone else if logistics allowed it. The request for active participation in scheduling is consistent with the appreciation participants had for everything the institute had to offer while increasing their autonomy within it. Autonomy is named as one of three core psychological aspects of wellness in Self-Determination Theory (Evans, 2015).

One way of analyzing focus group discussion data is noting how long the group spends on a topic or how many people speak on it. However, that has the potential to underplay the importance of topics that might be more difficult to bring into a group discussion. This includes issues that came under the theme of internal pressures. Isolation from family and friends, and limited opportunities to socialize with fellow students due to packed schedules compromised relatedness, which is one of Self-Determination Theory's three essential components for wellbeing (Evans, 2015). While many participants were happy with the support structures the institute provided, several had experienced repeated difficulties with feeling unheard and felt they were regarded as the problem, instead of the problem being the one they were trying to bring forward. Similarly, there was some discussion around unprofessional behavior and bullying that gave rise to recommendations for training in ethics and emotional intelligence. Though the voices were few on these matters, there was intense silence through these parts of the discussion, which raises the question of how many others felt the same but were reticent to speak about it. Bullying and micro aggression can potentially play into the perfectionism prevalent in this population and undermine a sense of competence, which is another component of wellbeing.

Several participant barriers and recommendations were similar to those put forward in Matei and Ginsborg's (2022) analysis of a 5-month wellbeing course with UK conservatoire students, for example, participants felt that lack of specificity to their situation and too much overlap in the material was a waste of their time; they wanted more sessions with high-level musicians telling their stories and offering guidance, and they wanted more "hands-on" practical sessions that applied directly to playing their instrument. In addition, participants in this study reflected that health protocol content would be easier to absorb if it was more structured and the topics progressed logically.

This study supports public and occupational health statements that even in the presence of a comprehensive, well-resourced wellbeing program, playing-related problems arise in the context of personal, institutional, and social practices and attitudes that can influence health behavior more strongly than health literacy (Nutbeam, 2019), and that psychosocial as well as other health determinants need to be addressed at the organizational level (CSA Group and BNQ 2013/2018; Michie et al., 2011; Oakman et al., 2018). The inclusion of cultural and organizational factors in participants' perception of factors contributing to playing-related problems shows the utility of the multiple levels in the COM-B behavior model when considering prevention and management of playing-related problems, and illustrates the congruence between the COM-B model and occupational and public health frameworks for use in the tertiary music context.

Author recommendations for revised health protocol

At the time the overall project ended at the end of Step 4 of the 7-step process, and subject to potential adjustments in response to further data collected in Steps 5–7, the working plan was to apply the following principles, design and content delivery to the existing protocol:

Principles

1 Engaging curricula and learning experiences.
2 Supportive social, physical and digital information exchange environments.
3 Community awareness and actions involving all levels of the organization.
4 Development of students' mental health knowledge and self-regulatory skills.
5 Access to effective services.
6 Ongoing evaluation at institutional and individual levels, with responsive policy and program adjustment.

Design

Provision of early detection and intervention for mental and physical health symptoms progressing through the following four levels with levels 1 and 2 addressed in the education program:

1 Preventative or 'foundational' components;
2 Indicated (at-risk) prevention components;
3 Early intervention;
4 Access to musician-specific health care.

Education program content delivery

Modularized: Modules to cover each element of the Healthy Conservatoires 8-factor wellbeing framework (Figure 1).

Scaffolded: To clarify content structure across the year-long program, each module begins with an introductory session, for example for a mental health module, Emotional WB 1.0 Introduction, which expands and develops in complexity in subsequent modules, for example Emotional WB 2.0 Mindfulness; 2.1 Mindfulness for Optimal Performance; Emotional WB 3.0. Performance anxiety; 3.1 Arousal regulation; 3.2 Self-talk; 3.3 Performance routines; Emotional WB 4.0 Mood management etc.

Scheduled: One module delivered in at least one session per week during term time.

Measured: Students complete validated outcome measures of mental and physical health and wellbeing on commencement of the program and after each term to track progress, flag areas of risk and those needing remediation.

Applied: Students complete short learning summaries at the end of each session and set wellbeing action points for how they intend to apply that learning over the coming week into their practice sessions, rehearsals, performances, and/or their lives outside of music. Instrumental teaching faculty are aware of the worksheets and ask students to review their intentions for healthy playing at the start of each lesson and rehearsal session.

Future directions

It would be useful for future research to expand its focus from wellbeing strategies for individuals, to consider systemic influences at organizational and cultural levels as suggested by the interdisciplinary literature and by the results of this study. The music industry has a long history with established traditions and priorities that can make it challenging to integrate wellbeing as a key factor in music performance. However, traditions and priorities can be examined and tested over time to establish which must be constructively managed and which can be modified or discarded to achieve enhanced wellbeing as well as improved performance.

To move in the direction of cultural change, this study supports the use of multidimensional theoretical frameworks for designing and testing health initiatives for musicians, for example the Healthy Conservatoires Wellbeing Framework (2020) the COM-B behavior change model (Michie et al., 2011), and occupational and public health principles (CSA Group and BNQ, 2013/2018; Nutbeam, 2019; WHO, 1986).

Strengths and limitations

The strengths of this study were that it was theoretically grounded across an array of disciplines; the two researchers are qualified in several music, health and education-related areas between them and thus brought a broad range of views and expertise to the project; participation rate in the focus groups was high; and unusually, the study was conducted with a multidisciplinary health protocol already in place at the institute. Synthesizing focus group results and returning them to students for rating in order of importance elicited a good response rate and provided triangulation of results, helping to offset researcher bias. Additional rigor was added to the study by the researchers working together in real time throughout project planning and data analysis, reflecting on assumptions we had made from our professional backgrounds, and contrasting study results with those we had expected.

Limitations of this study include that it is based on a single institution so the results are not necessarily generalizable, and the study was conducted by researchers with experience as healthcare practitioners and educators, but with no experience of working as professional musicians or music administrators. In addition, asking participants to prioritize their top five barriers to wellbeing and recommendations for change had the unintended effect of screening out potentially equally important barriers and recommendations suggested by a minority. These should be held over for reconsideration during future program reviews.

Conclusion

Barriers to wellbeing in the context of elite pre-professional music training, and proposed recommendations for change to improve student wellbeing related mostly to institutional policy and culture. Psychosocial, organizational and cultural factors contribute to psychological and physical playing-related problems, and need to be addressed using a structured, integrated approach, with risk control implemented at the highest possible organizational level. Successful health promotion programs need to be theoretically sound and contextually appropriate; operate across every level of the institution; possess the committed support of managers and teachers; involve ongoing collaboration with all stakeholder representatives; build healthy environments; strengthen community action around wellbeing; improve individual health literacy, and prove to be effective in achieving specified wellness outcomes. Evaluation of the effect of wellbeing programs on the health of musicians and program adjustment in response to continual feedback and changing conditions is key to success.

Data availability statement

The datasets presented in this article are not readily available because ethics approval for this project does not permit sharing the collected data. Enquiries regarding the datasets should be directed to mosborne@unimelb.edu.au.

Ethics statement

The study involving humans was approved by The University of Melbourne Human Ethics Committee. The study was conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. MO: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2025.1401511/full#supplementary-material

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Unconscious overtone manipulation and transmission in flute performance: insights into musical expression and perception

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This study aims to elucidate the overtone structure of the flute, examine the impact of acoustic parameter alterations on timbre perception, and foster a shared vocabulary among players and listeners. Employing principal component analysis (PCA) and listening experiments, the investigation delves into the ways in which players subconsciously adjust timbre and the manner in which these adjustments are perceived by listeners. The analysis concentrated on overtone components up to the fifth overtone ($5f_0$) utilizing flute long-tones. PCA revealed that the first principal component (PC1) predominantly captured variations in the overall strength of overtones, whereas PC2 and PC3 were indicative of a balance around specific overtones. Furthermore, the coordinates of PC1, PC2 and PC3 for sounds deliberately produced with varying timbres were found to diverge. This finding indicates that the flute's timbre is influenced by both the overall loudness and the balance of overtones, and that players modify the overtone structure for expressive purposes. A listening experiment involving 28 participants ascertained that listeners were capable of distinguishing between different timbres, revealing significant differences in the percentage of coincident judgment based on the player and the musical register. Notably, professional players were more adept at conveying the intended timbre to the listener, and the middle register was identified as having the greatest potential for expressive variation.

KEYWORDS

flute timbre, overtone structure, principal component analysis (PCA), listening experiments, musical expression, auditory perception

1 Introduction

Music encompasses a myriad of values predominantly resting on subjective evaluations and verbal expressions rooted in impressions. The complexity of impressions received from musical performances intertwines with multifarious factors, rendering it challenging for listeners to precisely articulate why they perceive a performance as "good" or otherwise.

In classical music, a field in which the first author specializes, a unique structure exists where various players perform the same musical piece repeatedly, eliciting preferences from the audience based on slight differences attributable to the performers' individuality from the same score. Such distinctions enable the audience to categorize performances according to preference or the lack thereof. Moreover, variations in the performances of the same musician across different pieces or even the same piece at different ages are recognized as distinct, reflecting the nuanced nature of musical performance.

Nevertheless, the specific differences between these performances often remain elusive, with assessments of sound or performance improvement largely subjective to the listener. Neither the listener nor the performer can definitively identify which changes in acoustic parameters contribute to these perceived differences.

Recent efforts have been made to estimate proficiency in instrumental performance (Nonogaki et al., 2011; Okemoto and Miura, 2020), suggesting that performances of the same musical piece by players of similar proficiency can still be distinct in content and evaluation. Prior studies have modeled the flute's instrument structure (Coltman, 1968; Ando, 1969; Terrien et al., 2013; Fletcher and and Rossing, 2012), including measurements of lip shape and the distance from the lips to the apex (de la Cuadra et al., 2008), and explored the relationship between exhalation and sound production (Lefebvre and Scavone, 2012). Controlling multiple performance parameters facilitates the transmission of emotion through music, allowing the performer to deviate from the composer's indications by employing elements not specified in the score, such as timbre (Juslin, 2000). Contrastingly, for instruments such as the clarinet and oboe, experiments have been conducted to discern and distinguish timbres (Saldanha and Corso, 1964).

In a previous study by the authors, a distinction was made between the long-tones practiced by wind instrument players as a fundamental exercise and the notes employed in actual musical performances. This work emphasized differences in overtone structure through the Mahalanobis distance (Hiraiwa and Miura, 2023), focusing on musical phrases requiring minimal dramatic changes and similar nuances. Five partials were identified from the first overtone (f_0) to the fifth ($5f_0$), with quantification on the compositional balance of these overtones. Utilizing a Vector Autoregression Model, it was demonstrated that players unconsciously adjust the balance of overtones to maintain consistent musical expression by referencing their previous performances of a piece (Hiraiwa and Miura, 2023). This unconscious control over the transition of overtone balance is hypothesized to ensure smooth and convincing musical performances.

Vocalists and wind instrumentalists, unable to hear their sound from the listener's perspective throughout their careers, continuously compare their sound with third-party impressions to enhance their technique. Through intersubjective matching, they can only conjecture how their sound might be perceived in an auditorium.

Players have individual methods for improving their performance; nonetheless, such enhancements are subjectively aligned with their ideals. For instance, a player seeking a warmer sound might experiment with various techniques to achieve this effect, relying on empirical understanding rather than direct manipulation of specific overtones.

This research aims to visualize the sound structure of the flute and the transitions of acoustic parameters during performance, ultimately developing parameters that reflect musical quality and establish a common language for listeners and players. Specifically, it will examine changes in the flute's timbre made unconsciously by the player as part of their musical expression and how these changes are perceived by listeners through listening experiments. This study is not about the perception of timbre and its linguistic transmission, rather the generation of common understanding in the perception of timbre. While certain studies have investigated sounds deemed "good" by skilled flutists and the impact of listener proficiency (Kasahara et al., 2018; Yorita and Clements, 2015), judgments of relative sound quality among players with considerable experience often remain subjective. In this study, timbre, which is essential in musical expression, was analyzed in terms of the type of changes in the balance of overtones responsible for the tonal differences that players currently rely on in their subjective expressions (von Bismarck, 1974a,b; Saitis and Weinzierl, 2019). Furthermore, it investigates whether listeners can discern the changes in timbre as the player intends them to be, in response to a performance in which the player has changed the timbre.

The potential for players to recognize their performance improvements through visual information and numerical values, transcending the limitations of verbal expressions such as "better" or "improved", presents a significant advancement. It enables a tangible representation of performance differences accessible to the performers themselves.

2 Materials and methods

The study is structured into two main sections:

1. The first section employs principal component analysis (PCA) (Hotelling, 1933; Hastie et al., 2001) to dissect the timbre changes in flute music, illustrating that these changes are primarily due to variations in the balance of overtones. This analysis aims to ascertain which elements of the overtone series are predominantly affected by shifts in their balance.
2. The second section delves into understanding how listeners perceive the timbre changes identified in the first section through listening experiments. It examines the impact of the player's musical expression on timbre and which overtone elements are significantly influenced by changes in the balance of overtones. Furthermore, it explores whether the timbre changes controlled unconsciously by the player are perceived by listeners as the player intended, based on the results of the PCA analysis.

2.1 Sound source

In this study, we analyzed the flute's tonal characteristics by recording long-tones and tones at the same pitch but with varied timbres within the instrument's playable range. We focused on the difference in the number of components for each harmonic, ranging from the fundamental frequency (f_0) to five times the fundamental frequency ($5f_0$). This range was chosen as the parameter group for conducting PCA (Pearson, 1901). The methodology for calculating specific parameter values is detailed below.

All sound recordings were captured at a sampling frequency of 48,000 Hz with a 16-bit depth. From these recordings, 16,384 points were extracted for analysis. A fast Fourier transform (FFT) was applied using a Hanning window, and the power spectrum was calculated, setting the energy of f_0 at 0 dB.

The decision to limit our focus to the $5f_0$ overtone is based on the flute's extensive playable sound range, which allows for stable and reliable partial observations up to $5f_0$. This approach is consistent with similar studies on instruments with comparable structures to the flute, such as recorders, where observations up to the $5f_0$ have been employed to investigate changes in timbre (Haverkamp, 2023).

For the purpose of this analysis, flute performances were recorded by three flutists, including the first author. Table 1 provides details regarding each player and the instruments utilized in the study.

A total of 37 notes, spanning the flute's playable range from C4 to C7, were analyzed. This range encompasses three registers: the low register from C4 to B4, the middle register from C5 to B5, and the high register from C6 to C7. The recording of all tones was conducted in stereo using two microphones: an ambient microphone (RODE NT2-A), positioned 238 cm from the flute, and a proximity microphone. These recordings were subsequently monoised at a ratio of 1:1 for the purpose of analysis. The observed difference in loudness between the proximity and ambient recordings is approximately 8.14 dB. The recording was conducted in a lesson room at the Kunitachi College of Music, with an RT60 of 0.0273 s.

2.2 Respondents

In total, 28 respondents (22 women and 6 men) completed the survey. The participants primarily comprised university and postgraduate students who speak Japanese, with ages ranging from 18 to 48 years and an average age of 25.75 years. The survey aimed to collect a sample from individuals who listen to music daily, thereby being regularly exposed to and contemplative of the differences in instrumental timbre. Responses were primarily solicited from our universities and their affiliates. Of these respondents, 26 are either currently enrolled in or have graduated from music colleges, with 14 of them specializing in flute.

2.3 Stimuli and procedure

2.3.1 Long-tone

To elucidate the fundamental overtone structure of the flute's performance sound and compare it with sounds where the timbre has been altered, with the objective of enabling players to sustain a "good sound" to the greatest extent possible during long-tone playing, recordings were made of long-tones played by three individuals. Three beats at a tempo of ♩ = 60 were recorded for each note from C4 to C7.

Each peak power spectral was averaged separately to analyse the harmonic structure of the long tones. Specifically, the average values of f_0 to $5f_0$ were used in the analysis. To explore variations in timbre, five patterns of long-tones, lasting 1 s for each note, were generated by altering the starting second of the excerpt in five predetermined locations within the specified range. To remove the effects of tonguing, five sample patterns were obtained by using tones within 0.5–2.5 s of the three seconds, which involved shifting the starting time by 0.25 s and cutting out 1 s samples.

TABLE 1 Details of each flutist and the instrument.

Player	Details of instruments	Flute experiences	Details of player
X	Altus 1807AL REH	33 years	Associate professor at a music college and former professional orchestra player
Y	Altus A14K(S)II REH	19 years	Student of music college in Doctor course
Z	Altus 1807AL REH	13 years	Master's degree at a music college

2.3.2 Performance sound with different timbre

While long-tones are foundational to instrumental performance, musicians often employ tones diverging from the "good tones" associated with long-tones to enhance musical expression. Given the infinite variety of tonal patterns that can emerge from the piece's content and the performer's interpretation, this study introduced sound nuances encapsulated by two sets of opposing tones: "quiet (p)/intense (f)" and "cold/warm". The objective was to execute the combination patterns of sounds detailed in Table 2. Participants X, Y and Z attempted to embody the timbre characteristics to the extent feasible according to their personal interpretation. They permitted themselves unlimited re-recordings until achieving satisfaction with the sound quality of their performances, focusing on the notes A4, A5, and A6.

2.3.3 Listening experiments with tones of changing timbre

As previously mentioned in Section 2.3.2, two recordings of each of the four timbre patterns were made. However, listening experiments for quiet and intense timbres were conducted separately due to the significant difference in sound pressure levels between the two. In the listening experiment focusing on the differentiation between (cold, p) and (warm, p) in quiet tones, two recordings of (cold, p) and two of (warm, p) at the same pitch and performed by the same player were randomly rearranged. Listeners were subsequently asked to make a choice in a two-alternative forced choice format (Bogacz et al., 2006), deciding whether the four sounds were relatively "(more or less) cold" or "(more or less) warm". In this case, specifying two sounds as "cold" and two as "warm" was unnecessary; participants instead assessed all sounds, aiming to classify them as "warm" to the greatest extent possible.

TABLE 2 Patterns of timbre changing.

	Cold	Warm
Quiet (p)	(i)	(ii)
Intense (f)	(iii)	(iv)

Listening for i) (c,p) and ii) (w,p)				
①	A4_X(i)_1	A4_X(i)_2	A4_X(ii)_1	A4_X(ii)_2
②	A4_Y(i)_1	A4_Y(i)_2	A4_Y(ii)_1	A4_Y(ii)_2
③	A4_Z(i)_1	A4_Z(i)_2	A4_Z(ii)_1	A4_Z(ii)_2
④	A5_X(i)_1	A5_X(i)_2	A5_X(ii)_1	A5_X(ii)_2
⑤	A5_Y(i)_1	A5_Y(i)_2	A5_Y(ii)_1	A5_Y(ii)_2
⑥	A5_Z(i)_1	A5_Z(i)_2	A5_Z(ii)_1	A5_Z(ii)_2
⑦	A6_X(i)_1	A6_X(i)_2	A6_X(ii)_1	A6_X(ii)_2
⑧	A6_Y(i)_1	A6_Y(i)_2	A6_Y(ii)_1	A6_Y(ii)_2
⑨	A6_Z(i)_1	A6_Z(i)_2	A6_Z(ii)_1	A6_Z(ii)_2

Listening for iii) (c,f) and iv) (w,f)				
①	A4_X(iii)_1	A4_X(iii)_2	A4_X(iv)_1	A4_X(iv)_2
②	A4_Y(iii)_1	A4_Y(iii)_2	A4_Y(iv)_1	A4_Y(iv)_2
③	A4_Z(iii)_1	A4_Z(iii)_2	A4_Z(iv)_1	A4_Z(iv)_2
④	A5_X(iii)_1	A5_X(iii)_2	A5_X(iv)_1	A5_X(iv)_2
⑤	A5_Y(iii)_1	A5_Y(iii)_2	A5_Y(iv)_1	A5_Y(iv)_2
⑥	A5_Z(iii)_1	A5_Z(iii)_2	A5_Z(iv)_1	A5_Z(iv)_2
⑦	A6_X(iii)_1	A6_X(iii)_2	A6_X(iv)_1	A6_X(iv)_2
⑧	A6_Y(iii)_1	A6_Y(iii)_2	A6_Y(iv)_1	A6_Y(iv)_2
⑨	A6_Z(iii)_1	A6_Z(iii)_2	A6_Z(iv)_1	A6_Z(iv)_2

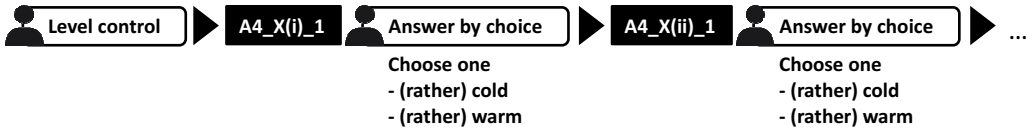


FIGURE 1
Flowchart of the experiment.

TABLE 3 Parameters of PCA.

Name	Details
D_{1-2}	Difference between F0 and 2F0 (F0–2F0)
D_{1-3}	F0–3F0
D_{1-4}	F0–4F0
D_{1-5}	F0–5F0
D_{2-3}	2F0–3F0
D_{2-4}	2F0–4F0
D_{2-5}	2F0–5F0
D_{3-4}	3F0–4F0
D_{3-5}	3F0–5F0
D_{4-5}	4F0–5F0

This procedure was replicated for all players and pitches. Figure 1 presents the labels of all sounds used in the listening experiment and provides an example of the experimental flow. Each listener was tasked with evaluating 72 sounds.

Notational example: Two cuts of A4 (cold, p) tone played by X is A4_X(i)_1, A4_X(i)_2, A4 (warm, p) tone played by X is A4_X(ii)_1, A4_X(ii)_2,... etc.

2.4 Ethical note

This study received approval from the Ethical Committee of Kunitachi College of Music, Faculty of Music Research, under approval number 2339 on 13 December 2023. Conducted in alignment with the Declaration of Helsinki, all participants provided informed consent for their participation in the study and for the processing of their personal data.

2.5 Statistical analysis

PCA was conducted on the overtone components ranging from $2f_0$ to $5f_0$, with the exclusion of the fundamental frequency (f_0) and the parameters used to calculate the difference in the number of components across the overtones. The 10 parameters employed in this analysis are detailed in Table 3.

Binomial and chi-square tests are used to analyse the results of the listening experiment.

3 Results

3.1 Long-tone and performance sounds with different timbres

The distribution of the harmonic components $2f_0$, $3f_0$, $4f_0$, and $5f_0$ for the five long-tones is presented in Figure 2.

The results of PCA performed on five patterns of long tone data for each of the three players, utilizing the parameters specified in Table 3, are presented in Table 4. This table shows all Standard Deviations (equal to the square root of Eigenvalues) up to the fifth principal component, contribution rates, and eigenvectors for each variable. Figure 3 depicts a loading plot with the first principal component (PC1) and the second principal component (PC2). In addition, a plot of PC1 and PC2 for each long tone, separately for players X, Y and Z, is shown in Figure 4. Although there was variation according to pitch, a tendency for the range to increase as PC1 progressed in the positive direction was observed for all players. Furthermore, as indicated in Table 4, the cumulative contribution rate of the third principal component (PC3) reached 0.85.

From Table 4, Figure 4, the first principal component (PC1) primarily reflects the magnitude of each harmonic's distance from the fundamental frequency (f_0), specifically from $2f_0$ to $5f_0$. This suggests that PC1 correlates significantly with the strength of $2f_0$, $3f_0$, $4f_0$ and $5f_0$, with an increase in PC1 associated with a rise

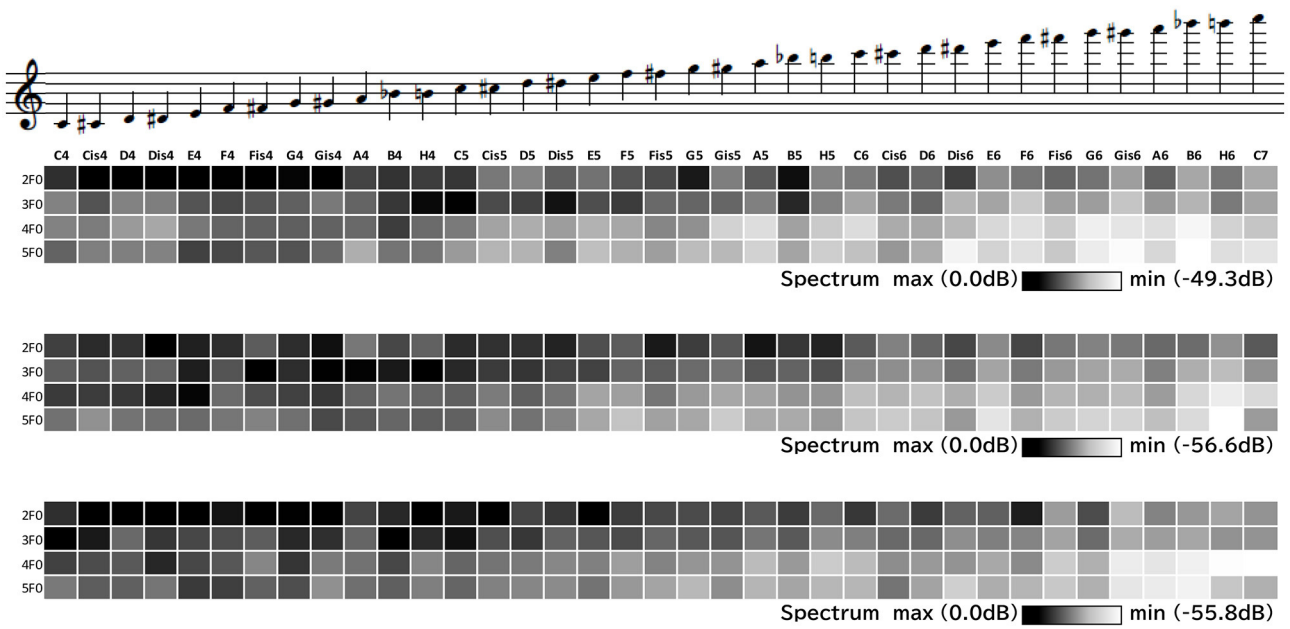


FIGURE 2
$2f_0$-$5f_0$ component amount in long-tones (X, Y, Z from the top).

in the fundamental frequency across lower to higher frequencies. Consequently, all overtone components exhibit augmentation as the fundamental frequency escalates from lower to higher registers.

Conversely, the second principal component (PC2) emerges as crucial, with positive loadings on 2-3, 2-4 and 2-5, and negative loadings on 3-4 and 3-5. This indicates that if the balance among 2-3-4, 2-3-5, 2-4 and 2-5 is deemed essential, PC2 may play a role in the amalgamation of overtones cantered around $2f_0$. Alternatively, by examining the positive and negative loadings, the reversed signs for 2-3 vs. 3-4 and 2-3 vs. 3-5 suggest a reliance on the strength of $3f_0$, aligning with the perfect fifth relative to f_0. Thus, PC2 is implicated in modulating the overtone balance, contrasting with PC1⁄s influence on the overall overtone intensity.

Moreover, the third principal component (PC3) features significant 3-5 and 4-5 elements, indicating a focus on the balance of $5f_0$, which aligns with the major third relative to f_0.

For the analysis, two segments (3s each) matching the successfully performed long-tones were prepared for each pattern, and the overtone structure was analyzed similarly to ascertain PC1, PC2 and PC3, which were subsequently juxtaposed with the long-tones of identical pitch. Figure 5 supplements this with an additional plot of the four timbre patterns, distinguishing long-tone plots in a subdued shade as shown in Figure 4.

Alterations in timbre resulted in scattered instances where the sound substantially diverged from the PCA coordinates of a long-tone of the same pitch. This deviation among the PCA coordinates across the four patterns highlights the performer's subconscious modulation of the overtone balance to facilitate a wider expressive range. This phenomenon was similarly observed across the PC1-PC3 and PC2-PC3 axes.

TABLE 4 Summary of each principal component and principal component loadings.

	PC1	PC2	PC3	PC4	PC5
Standard deviation	2.03	1.58	1.38	1.21	0.00
Proportion of variance	0.41	0.25	0.19	0.14	0.00
Cumulative proportion	0.41	0.66	0.85	1.00	1.00
D_{1-2}	0.37	−0.25	0.00	−0.42	−0.20
D_{1-3}	0.39	0.23	−0.08	−0.39	0.34
D_{1-4}	0.48	−0.04	−0.12	−0.06	−0.08
D_{1-5}	0.45	0.03	0.24	−0.17	−0.09
D_{2-3}	0.04	0.63	−0.10	0.03	0.30
D_{2-4}	0.32	0.27	−0.21	0.47	0.22
D_{2-5}	0.20	0.40	0.39	0.31	−0.62
D_{3-4}	0.28	−0.39	−0.10	0.44	−0.07
D_{3-5}	0.17	−0.30	0.52	0.30	0.55
D_{4-5}	−0.14	0.13	0.66	−0.19	0.09

In this study, each player recorded four patterns, with two takes (cuts) for each pattern, across the notes A4 to A6. To assess the similarity and differences in timbre among these recordings, three specific comparisons were made for each cut:

1. Comparison with the other cut recorded as the same tone (to assess consistency within the same timbre).
2. Comparison with a cut that shares the same "quiet/intense" attribute but differs in "cold/warm" attribute (to examine the impact of changing one aspect of timbre while keeping the other constant).

	PC1	PC2	PC3	PC4	PC5
$D_{1\text{-}2}$	0.37	-0.25	0.00	-0.42	-0.20
$D_{1\text{-}3}$	0.39	0.23	-0.08	-0.39	0.34
$D_{1\text{-}4}$	0.48	-0.04	-0.12	-0.06	-0.08
$D_{1\text{-}5}$	0.45	0.03	0.24	-0.17	-0.09
$D_{2\text{-}3}$	0.04	0.63	-0.10	0.03	0.30
$D_{2\text{-}4}$	0.32	0.27	-0.21	0.47	0.22
$D_{2\text{-}5}$	0.20	0.40	0.39	0.31	-0.62
$D_{3\text{-}4}$	0.28	-0.39	-0.10	0.44	-0.07
$D_{3\text{-}5}$	0.17	-0.30	0.52	0.30	0.55
$D_{4\text{-}5}$	-0.14	0.13	0.66	-0.19	0.09

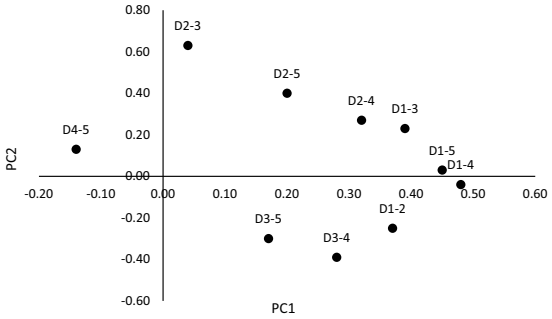


FIGURE 3
Loading plot of PC1 vs. PC2.

3. Comparison with another cut recorded with the same timbre as in point 2 (to validate consistency within the changed timbre).

Notably, the exact differences in how the listener perceives the change in timbre include those attributable to instrumental differences.

The study utilized the Euclidean distance in the 3D space defined by the first three principal components (PC1, PC2 and PC3) to quantify the differences between these cuts. This approach led to the observation of a significant difference in the average distances between sounds of the same timbre compared with those of different timbres, with a statistical significance ($p < 0.01$).

Table 5 in the study likely presented the detailed correspondence between each tone and the mean distances for each category, although this table was not displayed here. The results of the Friedman test, which compared the mean distances across the three groups mentioned above, confirmed the significance of the differences between these means. The findings indicate that the distance between cuts of the same tone was markedly shorter than between cuts of different tones, suggesting that both the overall magnitude of the overtones and their balance play a crucial role in timbre perception.

This significant finding highlights that players are capable of altering timbre by manipulating the overtone structure in response to the specific imagery or descriptive language used (e.g., "quiet/intense" and "cold/warm"). It reflects the nuanced control musicians have over their instrument's sound production, allowing them to adjust their playing technique to convey different emotional and sonic characteristics intentionally.

3.2 Results of listening experiments

The aggregated outcomes for all 28 responses are shown in Figure 6. A response is deemed correct if the listener identifies a cold tone played by the player as "(rather) cold". This criterion equally applies to warm tones. The results of the responses facilitate the rejection of the null hypothesis via a binomial test ($p < 0.01$).

Furthermore, a chi-square test was conducted to examine the number of correct and incorrect responses. The analysis revealed a significant difference in the percentage of correct responses between the player and register ($p < 0.01$). Conversely, the relevance of the respondent's specialization in flute to the accuracy of responses was found to be statistically insignificant ($p = 0.821$).

4 Discussion

4.1 Principal component analysis

The observation that the first principal component (PC1) encapsulates the overall increase or decrease in the overtone components and demonstrates a level of cohesion by the register in which the flute can be played aligns logically with the structural design of the flute. Specifically, it appears plausible that the overtone structure is categorized by register to a certain extent, given that the flute's playable registers are organized such that the fingering patterns loop with each octave increase.

Despite the evident indication that PC2 and PC3 are associated with the balance around $2f_0$, $3f_0$ and $5f_0$, the flute, being an instrument capable of producing very high notes, presents challenges in discerning overtones by ear during performance. Unlike the piano, where resonant strings are visible, it becomes complex for a player to intentionally emphasize the $3f_0$ overtone, which aligns with the perfect fifth degree, with the objective of enhancing its volume. Nevertheless, in practice, players do manipulate these overtones to convey musical expressions. The PCA illustrates that the coordinates not only diverge significantly between sounds of different timbres but also between long tones of the identical pitch.

4.2 Listening experiments

The percentage of correct answers per player was the highest for Player X, who was distinguished as the sole professional among the three participants in this session. The variance in instrumental proficiency reveals a key insight: higher skill levels correlate with an enhanced capacity to modulate the instrument. To enable listeners to accurately perceive changes in timbre, not only should the instrument produce a quality sound but also demonstrate a broad spectrum of tonal variation. Hence, it

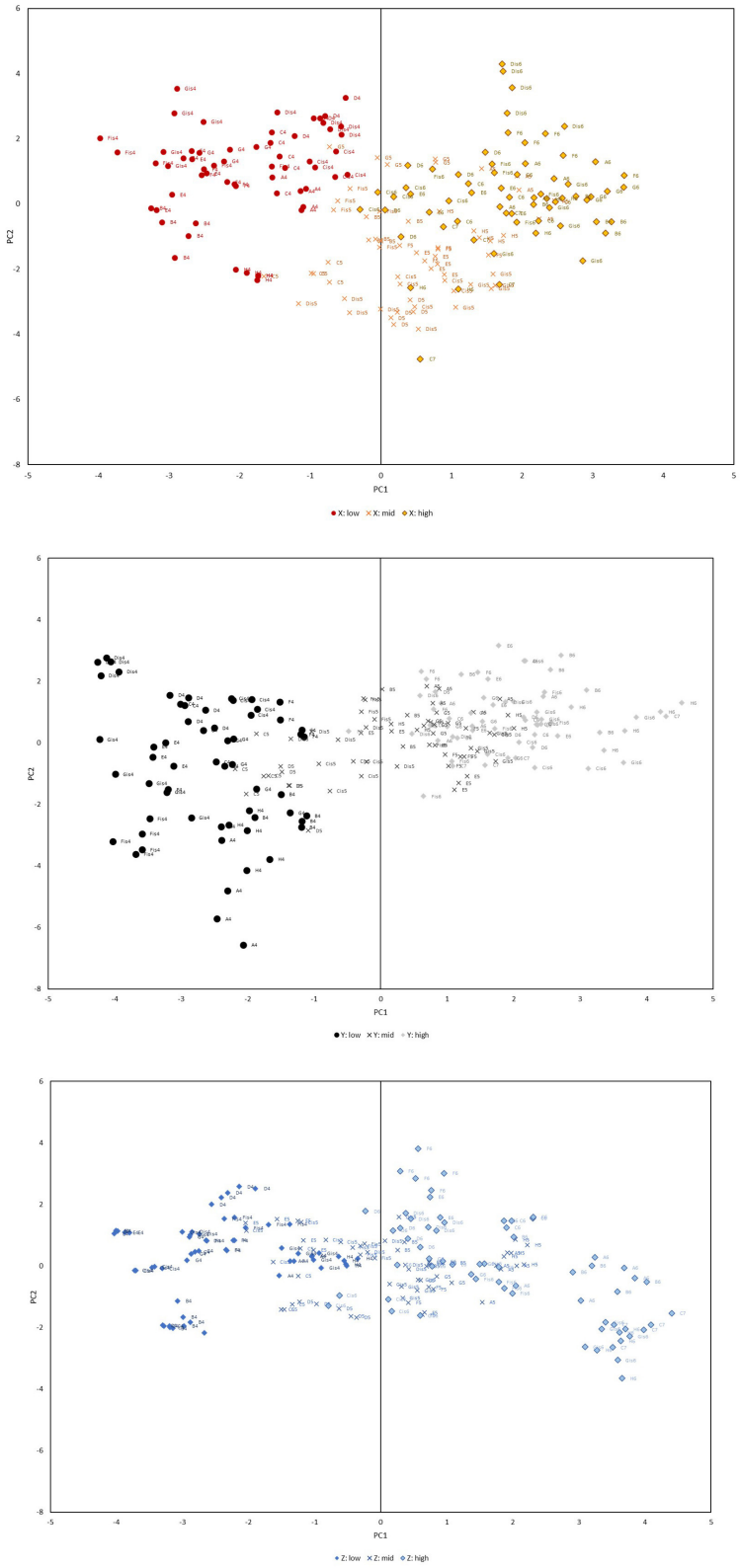


FIGURE 4
Long-tone distribution of the three players.

logically follows that more adept players are better equipped to convey a timbre that aligns more closely with their intentions to the listener.

Regarding the percentage of correct responses per register, the highest accuracy was observed in the middle A (A5), which insightfully mirrors the structural characteristics of the flute. Unlike

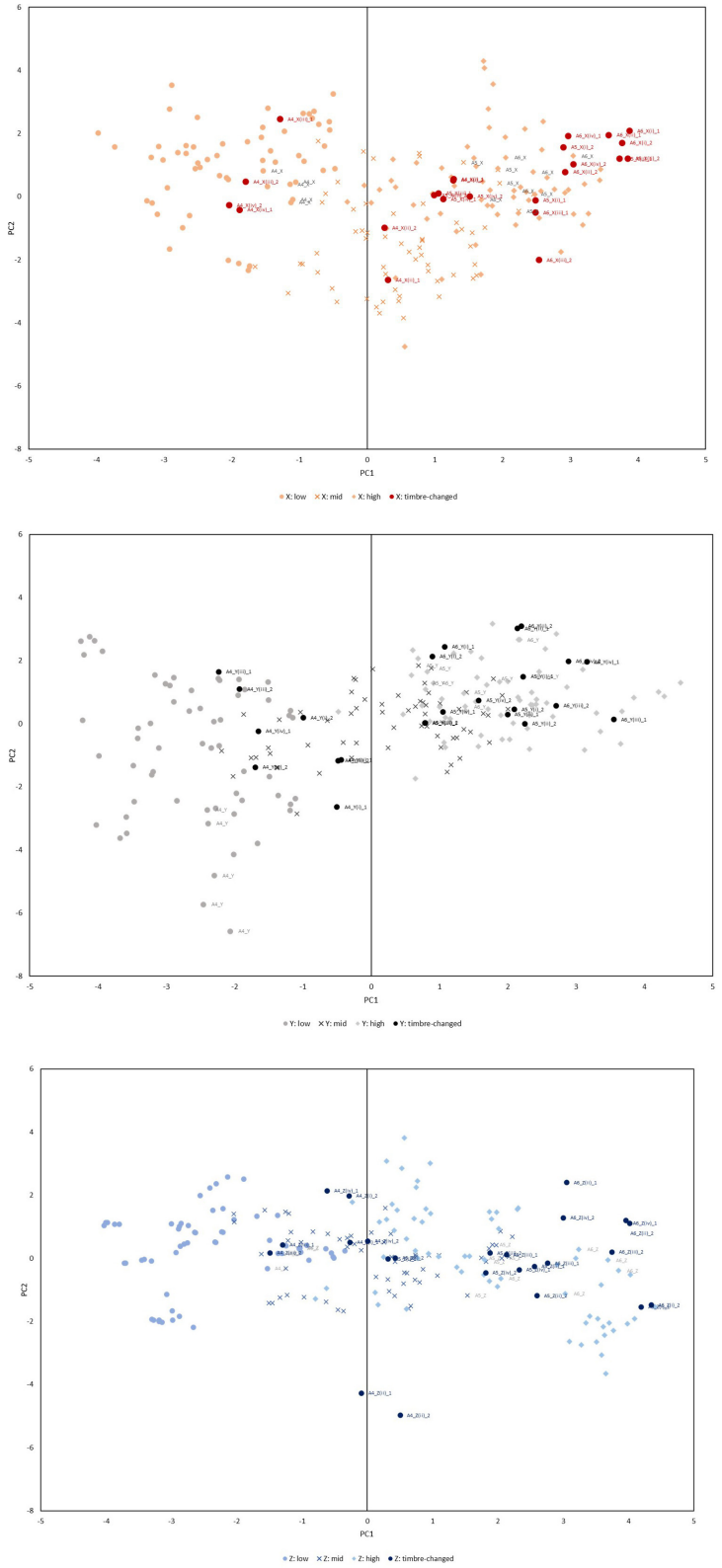


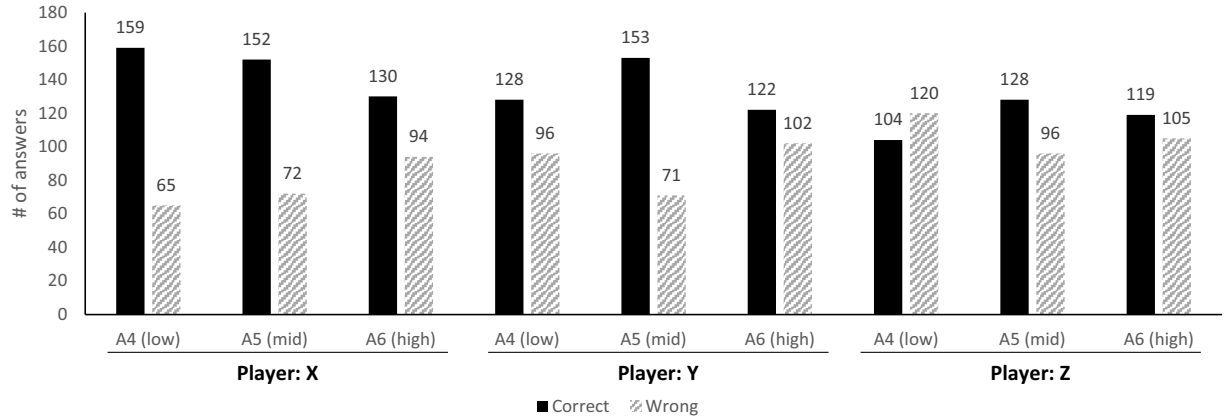
FIGURE 5
Mapping of the distribution of timbre-changed A4, A5, and A6.

other woodwind instruments, the flute lacks an octave key, relying instead on the manipulation of breath speed and pressure to control its tonal range. Typically, lower notes require a slower breath, whereas higher notes demand a swifter breath. Consequently, an excessive increase in breath speed when playing lower notes inadvertently shifts the note into the middle register, similar to

TABLE 5 Correspondence between each tone and the mean distances in each category.

Base tone	(1)	(2)	(3)	Distance from base tone		
				(1)	(2)	(3)
A4_X(i)_1	A4_X(i)_2	A4_X(ii)_1	A4_X(ii)_2	0.064	0.781	3.221
A4_X(i)_2	A4_X(i)_1	A4_X(ii)_1	A4_X(ii)_2	0.064	0.718	3.153
A4_X(ii)_1	A4_X(ii)_2	A4_X(i)_1	A4_X(i)_2	1.659	3.002	4.411
A4_X(ii)_2	A4_X(ii)_1	A4_X(i)_1	A4_X(i)_2	1.659	3.725	3.033
A4_Y(i)_1	A4_Y(i)_2	A4_Y(ii)_1	A4_Y(ii)_2	3.975	5.784	4.427
A4_Y(i)_2	A4_Y(i)_1	A4_Y(ii)_1	A4_Y(ii)_2	3.975	3.868	4.449
⋮	⋮	⋮	⋮	⋮	⋮	⋮
A6_Z(iv)_2	A6_Z(iv)_1	A6_Z(iii)_1	A6_Z(iii)_2	0.966	2.687	2.844
Average				1.024	3.064	3.41

	X			Y			Z		
	A4 (low)	A5 (mid)	A6 (high)	A4 (low)	A5 (mid)	A6 (high)	A4 (low)	A5 (mid)	A6 (high)
Correct	159	152	130	128	153	122	104	128	119
Wrong	65	72	94	96	71	102	120	96	105
% of correct answers	0.710	0.679	0.580	0.571	0.683	0.545	0.464	0.571	0.531



	A4 (low)	A5 (mid)	A6 (high)
Correct	391	433	371
Wrong	281	239	301
% of correct answers	0.58	0.64	0.55

	X	Y	Z
Correct	441	403	351
Wrong	231	269	321
% of correct	0.66	0.60	0.52

FIGURE 6
Results of responses to the listening experiment.

how an undue decrease in breath speed when playing higher notes causes the note to drop into the middle register.

Thus, the flute most readily accommodates a diverse range of performance modifications within the middle register, achieving optimal sound quality. This finding concurs with the results of this experiment. It should be noted that it is premature to conclude that more skilled players are better at blowing tones. The sample of performers needs to be further increased. In addition, it cannot necessarily be asserted that the percentage of correct responses increases with increasing proficiency, as the analysis did not include

the sounds played by novice players. Alternatively, more extreme expressions are possible for beginners. However, it is also true that these are the types of tones that are rarely used when actually performing in public.

5 Conclusion

In this study, PCA was conducted on long-tones and altered performance sounds, focusing on overtones and the variation in component numbers among these overtones as parameters. The overtone structure of the flute is partially dependent on pitch; however, by modifying the overtone structure at a consistent pitch, a variety of expressions can be imparted to the flute. The PCA utilized PC1, PC2 and PC3 to calculate the distances between performance sounds of identical timbres and those of differing timbres, revealing that the distances between sounds of the same timbre are notably shorter.

The outcomes of the listening experiment indicated that listeners could effectively distinguish between "cold" and "warm" tones. It was also observed that the rate of correct responses varied significantly based on the player and the tonal range. Professional players demonstrated a higher proficiency in communicating the intended tone to the listeners. Additionally, listeners most accurately discerned differences in expression within the middle register, which is where flute players typically find it most comfortable to play.

These findings imply that the timbre of the flute is shaped by the overall loudness and the balance of overtones, with players adjusting the overtone structure for expressive intentions. Such manipulations of overtones are conducted unconsciously by the player, who alters the timbre based on auditory judgment. When changing timbre, players do not consciously aim to produce a different overtone structure; rather, they inadvertently select sounds with a distinct overtone structure. The deviation from the overtone structure of long tones also indicates that the absence of a singularly "correct" or "ideal" overtone structure, suggesting that diverse overtone structures facilitates a spectrum of musical expressions.

Accurately conveying the intended timbre to the listener requires a high level of performance skill in reproducing the suitable overtone structure, influenced, to a certain degree, by the instrument's characteristics.

Future research should address three primary concerns:

1. To ascertain how proficiency with the instrument affects the production of different tones, an analysis involving the recorded performance sounds of both professional players and novices who have recently begun playing the instrument is necessary.
2. Additional factors indirectly related to timbre but potentially influencing the listener's perception, such as breath noise inherent to the flute's structure and vibrato, must be considered.
3. Enabling players to verify the overtone structure of the concerned tone upon alteration could facilitate an objective assessment and enhance control over musical expression. Implementing a real-time sound measurement system represents a significant challenge in achieving this goal.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Ethical Committee of Kunitachi College of Music. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KH: Writing – original draft, Writing – review & editing. MM: Writing – review & editing, Writing – original draft.

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Conflict of interest

The authors declare that this research has been conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Antagonistic muscular co-contraction for skilled, healthy piano technique: a scoping review

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Aims: This scoping review aimed to generate a novel evidence-based model of antagonistic muscular co-contraction (AMCC)'s effects on human movement. The review applies this model to the context of skilled, healthy piano playing to enable advances in pedagogy and research that can aid pianists in developing and maintaining skill and task-related health.

Background: Piano playing is a challenging, complex activity that carries significant risk of playing-related neuromusculoskeletal disorder (PRNDs). AMCC is a contentious, terminologically problematic topic in pedagogical and scientific literature, and has scarcely been studied in relation to piano technique.

Methods: Adhering to PRISMA-ScR guidelines, the review adopted the search terms "co-contraction," "piano," "co-activation," and "antagonist," consulting 36 aggregated resources and 100 individual journals. After screening, 188 studies published between 1982 and 2021 were included. From these studies, AMCC-related content was extracted, analyzed in relation to piano technique, and categorized. The resultant categories were synthesized into a model representing the characteristics and effects of AMCC in movement.

Results: AMCC is a prevalent, complex, and learnable phenomenon, exhibiting the capacity for both positive and negative effects on performance and health. These effects are highly relevant to the task-specific challenges of skilled, healthy piano playing. AMCC can affect sensorimotor task control, accuracy, efficiency, coordination, internal model generation, proprioception, range of motion, individuation, neuromuscular signal-to-noise ratio, speed, power, stability, task-related injury, pain, and rehabilitation.

Conclusion: The review and corresponding model suggest that AMCC is a fundamental characteristic of human movement with broad and unique effects on sensorimotor task performance, including piano playing. Of the 188 publications reviewed, none were found to have robust methods investigating AMCC in healthy, skilled pianists; this review underpins ongoing research targeting the nature of AMCC in piano technique.

KEYWORDS

co-contraction, piano technique, human movement, PRNDs, biomechanics

1 Introduction

1.1 Context and rationale

Piano playing is a complex neuromuscular task that can place extreme demands on the body (Kinoshita et al., 2007). Pianists face the highest risk of injury among musicians (Kaufman-Cohen et al., 2018); these injuries can be termed playing-related neuromusculoskeletal disorders (PRNDs). PRNDs are professional musicians' largest health

concern (Stanhope et al., 2020), negatively impacting wellbeing, playing ability, and career (Kenny and Ackermann, 2015; Silva et al., 2015; Baadjou et al., 2016). Lifetime PRND incidence for pianists is likely >50% (Rotter et al., 2020; Baadjou et al., 2016; Guptill, 2011; Foxman and Burgel, 2006), and effective treatments and prevention are needed, but pianists report a lack of both (Ciurana Moñino et al., 2017). Some PRNDs result from poor technique (Furuya et al., 2006; Allsop and Ackland, 2010), which impedes playing, performing, career development, and wellbeing (James, 2018; Kotani and Furuya, 2018; Ascenso et al., 2018). Optimal piano technique can require decades to develop, a process which itself risks injury or failure (Goebl, 2017).

To ease the process of developing piano technique and to reduce the incidence of PRNDs, an accurate and thorough understanding of the muscle use underlying skilled, healthy piano playing is needed. However, centuries-long controversy about pianists' muscle activity persists among pedagogues and researchers (Wheatley-Brown, 2011). This review addresses a particular form of muscle activity: antagonistic muscular co-contraction (AMCC) is the simultaneous contraction of functionally paired muscles, tightening a joint (Saliba, 2019). Resolving the prolonged debate around AMCC in piano technique requires developing an accurate model of AMCC's role in piano technique. This scoping review synthesizes the extant literature to develop a novel theoretical model of AMCC's effects on human movement.

1.2 Research questions

What is the optimal role of antagonistic muscular co-contraction (AMCC) in skilled, healthy piano technique?

How does AMCC relate to skilled, healthy piano playing?

2 Methods

This review follows PRISMA-ScR guidelines. CA consulted databases and libraries to identify papers discussing AMCC in the context of aspects of movement related to piano technique, resulting in the inclusion of 188 studies published between 1982 and 2021. These 188 studies were examined and their discussions of AMCC synthesized to create a theoretical model of AMCC's characteristics and effects.

2.1 Data sources

This review gathered data from 36 aggregated resources (search engines/libraries/research repositories) and 100 individual journals. Supplementary Material 1 provides a complete list of the consulted resources.

2.2 Search strategy

The below search terms (and their grammatical variations, e.g., 'antagonistic') were selected as they pertain to AMCC and piano technique.

- Co-contraction
- Piano
- Co-activation
- Antagonist

To cover a broad range of sources, no date limits or other filters were employed.

2.3 Systematic review protocol

For each resource, CA used the systematic search process outlined in Figure 1.

This process generated 440 initially relevant titles. Full texts were acquired for all 440, which were then processed according to the adapted PRISMA flow diagram in Figure 2.

2.4 Eligibility criteria

English-language articles containing at least one sentence discussing AMCC in relation to aspects of movement pertaining to piano technique were included. For example, an article discussing AMCC's effects on elbow movement would qualify as indirectly relevant to piano technique, because playing the piano involves elbow movement.

Of the 440 initial articles, 167 were excluded because of general topical irrelevance: these articles' full texts lacked discussion of both AMCC and piano technique. This left 273 articles, 85 of which were excluded because of subtopical irrelevance: lacking discussion that could be plausibly linked to the relationship between AMCC and piano technique. For example, Parlitz et al. (1998) studied dynamic finger forces in pianists but made no mention of AMCC, focusing instead on absolute measurements of force (Newtons/N).

2.5 Data extraction and data analysis

All 188 remaining articles were included. CA read each full text and extracted any discussion pertaining to AMCC. Rather than analyzing quantitative data, this scoping review focuses on points of discussion, concept-formation, and definition, aiming to generate a broad theoretical model of AMCC's characteristics and effects.

The extracted discussions were reviewed and synthesized according to the following. Commentary was made for each extract, in order of appearance within each article. Each commentary explored potential significance of the extract, considered it alongside the accompanying commentaries in the review, and tentatively categorized the extract according to its conceptual underpinning. For example, Frey-Law and Avin (2013) proposed that AMCC displays "ubiquitous occurrence across activities" (p. 578); this was categorized into the subheading 'Prevalence of AMCC'. Some articles contained multiple extracts that qualified for more than one conceptual subheading, or one extract that qualified for multiple subheadings; these were discussed anew in each instance.

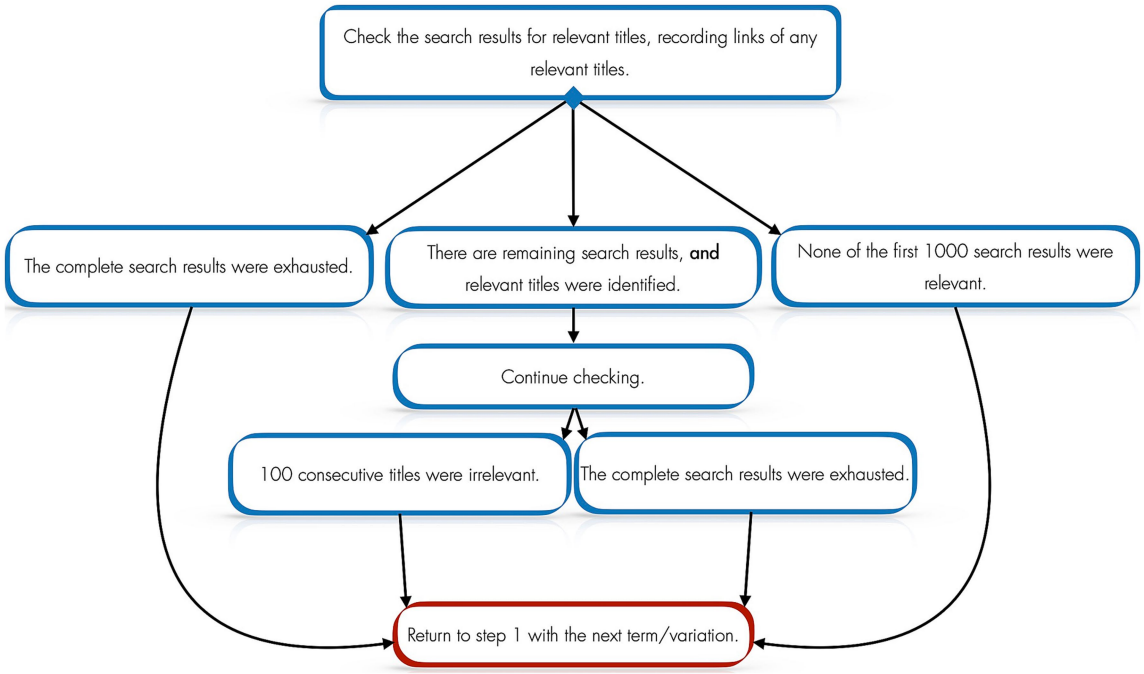

FIGURE 1
Search process for each resource.

CA then reread all extracts and commentaries, finalizing categorizations between interrelated extracts and generating groupings of related categories. This process synthesized findings across the 188 articles into a model of AMCC's characteristics and effects.

The Results section is therefore structured according to this conceptual framework, which is fully visualized at the end of the review as both a tiered list and as a map.

3 Results

The analytical process described above produced a 34-point framework illustrating characteristics of AMCC that have been explored in published research. Due to the large number of articles reviewed (188), it was necessary to condense the results here by omitting discussion of articles that made similar points to other articles. Additionally, sections discussing the negative effects, limitations, origins, learnability, and state of knowledge on AMCC have been omitted; further discussion of these can be found in CA's doctoral dissertation and future publications.

3.1 AMCC is prevalent

According to Tubiana and Chamagne (1988), "even the simplest movement requires the participation of antagonists" (p. 86). Morris (2010) found that "co-contraction can be considered an element of all movements" (p. 66–67). Frey-Law and Avin (2013) proposed that AMCC displays "ubiquitous occurrence across activities" (p. 578). Discussing the wrist in piano technique, McCarthy (2016) found that "each movement direction causes co-activation of agonist–antagonist muscle pairs" (p. 26). Goebl (2017) added that "there is certainly no kind of piano technique that eliminates the muscular fixation of joints, be it only for short durations during a keystroke…despite the statements of some piano schools" (p. 3–4). In fact, kinds of piano technique such as the Taubman Approach (Taubman et al., 2005) do eliminate, or at least seek to eliminate, AMCC. Moreover, it bears questioning whether fixation of joints via AMCC only occurs for short durations during a keystroke, given its numerous demonstrated benefits that apply outside these brief time windows.

Mann (1990) observed that AMCC is "a means of joint impedance control," and therefore "much more prevalent in the activities of daily living than heretofore reported" (p. 73). This demonstrates how the motor control benefits of AMCC contribute to its ubiquity. The use of 'prevalent' here affords greater precision than 'ubiquity' would, as it allows for the possibility of absence of AMCC. As far as can be interpreted from the included graphs of muscle activity, it appears that all pianists in Furuya (2012) used AMCC across all trial conditions (p. 10).

Piscitelli et al. (2017) found AMCC in "the healthy elderly…persons with atypical development…patients with neurological disorders…as well as in young, healthy persons performing tasks associated with a difficult postural component" (p. 14–15). Mengarelli et al. (2018) found AMCC "in both healthy and pathological populations" (p. 117). This presence of AMCC across populations supports its prevalence. Sousa (2018) argued that "the analysis of reciprocal and simultaneous patterns of antagonist and antagonist muscle activation is considered a fundamental way of understanding motor function" (p. 168).

AMCC appears prevalent across populations and movements, and there does not appear to be reason to doubt its prevalence in pianists

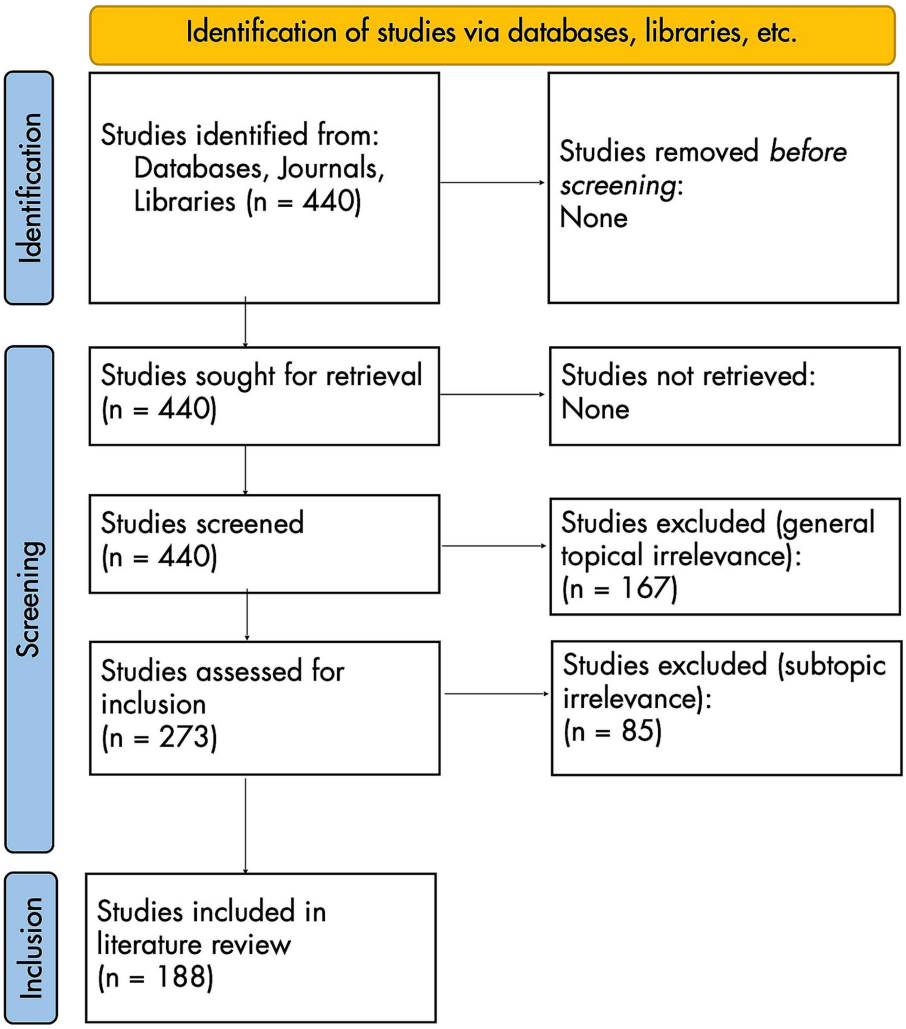

FIGURE 2
PRISMA 2020 flow diagram for new systematic reviews [adapted from Page et al. (2021)].

and in piano technique—yet this prevalence is doubted by influential pedagogues and researchers (e.g., Lister-Sink, 2018).

3.2 AMCC has positive effects

3.2.1 Motor control and motor learning

3.2.1.1 General

Hasan (1986) observed AMCC's ability to reduce necessary alterations in central drive, which is "far from obvious" (p. 373); this apparently occurs because greater stiffness prevents "fairly large excursions of the equilibrium position…to accelerate and decelerate the inertia in order of the initial and final conditions to be met" (p. 376). This could justify Heald et al.'s (2018) hypothesis that increased AMCC during dynamic motor learning phases "[ensure] the limb remains close to the target state" (p. 1).

Winters and Stark (1986) observed AMCC in "voluntary and externally-driven oscillation, external impulsive loading, and fast movements performed without external loading" (p. 471), concluding that "co-contraction may be a more important real-time control strategy than feedback control via muscle sensory apparatus for most tasks" (p. 471). Glasscock et al. (1997) mentioned that AMCC "appears to be associated with the performance of tasks which require assurance that they be realized effectively" (p. 59). Imagawa et al. (2013) found that "human postural control is achieved by synergistic co-activation" (p. 430). This postural control is possible because synergistic antagonistic muscles have "various action directions" (p. 430). Imagawa et al. (2013) defined muscle synergy as "patterns of activation among multiple muscles involved in controlling movements" (p. 430); this definition therefore includes AMCC, which implies activation of multiple muscles for controlling movements. Chen et al. (2014) found "novel evidence that the antagonist muscle activation is critical during practice" (p. 1017). Xiong et al. (2015), observing AMCC in infant crawling, noted that AMCC is "important for providing adequate joint stability, movement accuracy and energy efficiency" (p. 2115).

Saliba (2019) observed that "co-contraction is a common strategy when performing difficult or unstable motor tasks" (p. i), listing some benefits of AMCC: "to directly increase the mechanical impedance… to generate greater instantaneous restoring forces when a limb or joint

is perturbed" (p. i), and also, "the ability to engage both the stretched and shortened muscles in the corrective response" (p. ii). Therefore, AMCC "engages a unique motor strategy" (p. ii). Saliba (2019) also noted a method of reducing the metabolic cost of AMCC: "selective co-activation can optimize the magnitude, shape, and orientation of endpoint impedance to achieve stability at a lower energetic cost than a uniform increase of co-contraction through the limb" (p. 19). This selectivity contributes to the complexity of AMCC, as AMCC can simultaneously vary across joints for varying purposes.

AMCC's beneficial and unique effects on dynamic motor learning, oscillation, loading, fast movements, and performance in difficult or unstable motor tasks have clear applications in skilled piano technique, which demands exceedingly high performance on complex motor tasks involving oscillation (e.g., repeated notes or trills), loading (e.g., to produce the forces required for loud playing), and speed (e.g., for fast playing).

3.2.1.2 Accuracy and precision

Karst and Hasan (1987) studied antagonist muscle activity in forearm movements, finding that more antagonist activation occurred than "is required for braking alone" (p. 391). This additional activation caused AMCC that was hypothesized to "increase joint stiffness in order to facilitate more precise control" (p. 400). Laursen et al. (1998) studied the effects of speed and precision demands on shoulder muscle activity during a repetitive task, observing that "high precision demands may call for increased stability, which can be obtained by co-contraction of antagonist muscles. Similarly, high-speed muscle contractions have been shown to elicit co-contraction… co-contraction is normally not accounted for in modeling, which as a result has been reported to underestimate the muscle load" (p. 544). Laursen et al. (1998) found "factors such as increased co-contraction" (p. 544) occurred as precision and speed increased. Bawa et al. (2000) found that "cocontraction of wrist extensor and flexor muscle creates a stable basis for finger flexor and extensor muscles to produce precise finger movements, such as fine manipulation in pinch grip of pressing buttons on a computer mouse" (p. 116). Bawa et al. (2000) also noted that "the contemporary work environment includes… repetitive, rapid movements requiring a high degree of precision" (p. 116–117). Gribble et al. (2003) studied the role of AMCC in arm movement accuracy, finding that "as target size was reduced, cocontraction activity increased" (p. 2396). Gribble et al. (2003) also found that "[t]rajectory variability decreased and endpoint accuracy improved" alongside this increased AMCC, suggesting that "although energetically expensive, cocontraction may be a strategy used by the motor system to facilitate multi-joint arm movement accuracy" (p. 2396). van Dieën et al. (2003) concluded that one function of AMCC "might be to achieve more precise control over the trajectory of lifted weight" (p. 1829). Osu et al. (2004) studied optimal impedance control for task achievement, observing that "without the need for great accuracy, subjects accepted worse performance with lower co-contraction" (p. 1199). Osu et al. (2004) accordingly found that higher AMCC was associated with greater endpoint accuracy. Kursa et al. (2005) studied finger flexor forces during isometric tasks, noting that "[d]uring dynamic flexion, finger flexor and extensor muscles are…co-activated" (p. 2289). Kursa et al. (2005) found that "the rate of fingertip force application did not affect the amount of force generated by the extrinsic finger flexor muscles per unit fingertip force during the experimental task" (p. 2292), in contrast with prior studies, which found that flexor and extensor activity both increase "with increasing movement rate and frequency" (p. 2289). Kursa et al. (2005) concluded that "[i]n our study, it is likely that the fine motor control needed to generate the precise force ramps required high activation levels of intrinsic and extrinsic finger muscles in order to stabilize the finger and control joint torques. Therefore, we observed no additional increase in FDP and FDS forces at the higher rates" (p. 2292). This would explain differing results compared to prior studies. Alternatively, given that participants were priorly untrained in the experimental task, it is possible that excessive AMCC was used during slower trials, which was maintained at higher speeds. This indicates the importance of considering the effects of motor learning in neuromuscular research. Kursa et al. (2005) also theorized other potential explanations for their results, including "difference[s] in experimental techniques" or "motion artifacts" (p. 2292). Kursa et al. (2005) also cited that "[c]o-contraction of all seven finger muscles has been reported during a low force, precision grip task…indicat[ing] that all fine muscles are involved in isometric fingertip force generation, but their individual contributions and roles may vary with force, finger posture, and force direction" (p. 2292).

Selen et al. (2005) studied the effects of impedance modulation on kinematic variability with neuromusculoskeletal modeling, finding that "[i]increasing the impedance through co-activation resulted in less kinematic variability, except for the lowest levels of co-activation" (p. 373). Takei and Seki (2010) noted "coactivation of finger muscles characteristic of grasping movements" in monkeys' precision control of levers (p. 17042). Observing premotor interneurons, Takei and Seki (2010) found that "inhibitory PreM-INs in finger muscles were silent or suppressed during the precision grip task to enhance coactivation of various intrinsic and extrinsic hand muscles" (p. 17049); this might illustrate a cross-species biomechanical necessity of AMCC for precise movement. Frey-Law and Avin (2013) proposed that AMCC is "an important motor control strategy to improve joint stability and movement accuracy…produc[ing] greater movement accuracy and reduced phase lag to external perturbations" (p. 579). Ueyama and Miyashita (2013) modeled signal-dependent noise, co-contraction, and movement accuracy in reaching tasks, finding that "the strength of co-contraction and joint stiffness increased depending on the required accuracy level" (p. 16). Calas-List et al. (2014) studied aimed limb movements in locusts, noting that "[i]n humans, increased co-contraction of antagonist muscles (and thus joint stiffness) enhances movement accuracy…by filtering out the deleterious effects of signal-dependent noise in the motor command (p. 7509). Calas-List et al. (2014) then stated that "[w]hen making fast, accurate movements, humans prefer a speed modulation strategy to a co-contraction strategy (i.e., they use slower movements, not stiffer ones)" (p. 7509). However, this statement is difficult to interpret; if a movement must be executed at a minimum speed, it is impossible to choose a slower movement, and the stiffer one must therefore be preferred.

Le et al. (2017) postulated that "tasks requiring higher stabilization such as precision placement…or higher levels of controlled movements would require higher coactivation" (p. 15). Dupan et al. (2018) noted that "in a precision grip, all muscles are co-activated, and the muscle activity will increase with force" (p. 225); while it is possible to use a precision grip without co-activating all muscles, the precision of the grip would likely be lesser as a result. Ptashnik (2019) noted that AMCC can enhance "both the accuracy and stability of movements…

even when destabilizing dynamics are present" (p. 3). Saliba (2019) found "a clear improvement in the performance of participants when they co-contract during the postural perturbation task" (p. 42). This clear improvement was an increase in performance "of up to 350%… with a median performance improvement of ~100%" (p. 43–44). Such a large improvement in movement accuracy need not come at a high cost, however: "rapid corrective responses are generated without overshoot even at the lowest level of co-contraction (equivalent to 1 Nm in each muscle group)" (p. 57). Berret and Jean (2020) developed an optimal control theory that models AMCC in movement. Simulating pointing movements, Berret and Jean (2020) determined that "a minimal level of co-contraction is indeed required to perform the task accurately enough," which characterized "a trade-off between effort, speed, and accuracy" (p. 15). Koelewijn and van den Bogert (2021) concluded that "co-contraction was optimal for a subset of the tested tasks with a sufficiently high precision…and difficulty" (p. 9).

Sharma and Venkadesan (2022) observed that "[s]table precision grips using the fingertips are a cornerstone of human hand dexterity," clarifying that "[p]recision grip, as the name implies, is the precise and stable application of fingertip forces. In this grip style, the fingers are relatively stationary while the fingertips exert force" (p. 1). Sharma and Venkadesan (2022) also proposed that "[i]nstabilities that arise when pushing on surfaces can be categorized as those affecting the tip where the force is applied…or the internal degrees of freedom associated with posture…[t]ip instabilities are particularly severe when a stiff finger or limb makes contact with a rigid surface" (p. 1). Sharma and Venkadesan (2022) also report that "[w]hen feedback control is used to precisely apply tip forces, the fingertip's position in space may become unstable and start to oscillate, which also destabilizes the applied force…One strategy is to increase the compliance of the finger or limb" (p. 1).

Skilled piano-playing is often also a task intended to be performed "as fast and as accurately as possible" (Berret and Jean, 2020, p. 15) while requiring "sufficiently high precision" (Koelewijn and van den Bogert, 2021, p. 9). The above research has explored the beneficial effects of AMCC on precision and accuracy, implying its value as an aid to precise, accurate piano technique, with its own "precise finger movements" (Bawa et al., 2000, p. 116), "repetitive, rapid movements" (p. 116), and small "target size" (Gribble et al., 2003, p. 2396).

3.2.1.3 Efficiency

Roebroeck et al. (1994) studied biomechanics during sit-to-stand transfer, finding that "co-contraction of hamstrings and rectus femoris in sit-to-stand transfer was judged to be efficient" (p. 235). This efficiency of AMCC casts doubt on claims that AMCC is inefficient merely due to its metabolic cost. Instead, AMCC can be seen as efficient in situations where the benefits it affords outweigh the accompanying metabolic expenditure, which follows the same logic as for non-AMCC metabolic expenditures. Roebroeck et al. (1994) commented on this distinction, stating that "in light of required joint displacements, co-contraction of a pair of antagonistic muscles can be judged as inefficient. However, this is a paradox…two antagonistic muscles[,] instead of opposing each other, may reinforce one another by using the tendon action of the other muscle" (p. 242). Zakotnik et al. (2006) studied co-contraction in aimed limb movements in locusts, finding that "co-contraction simplified load compensation" (p. 4995). Without co-contraction, "the extensor would need to generate 16-fold more torque" to move a loaded tibia against gravity (p. 5006). Oliveira and Sanders (2017) studied knee action phase and AMCC during swimming, stating that AMCC "provides dynamic joint stabilization and movement efficiency by tonically stiffening a given joint without impeding net joint torque" (p. 83). Although it is possible that AMCC can impede net joint torque if the desired agonist activation is higher than the antagonist activation subtracted from the maximum potential agonist contraction, the statement that AMCC can improve movement efficiency seems to call into question Yamakawa et al.'s (2017) claim that AMCC is inefficient. Koelewijn and van den Bogert's (2021) modeling of AMCC found that "even when it is possible to have no co-contraction, it requires less effort to have feedforward control and thus co-contract both muscles" (p. 9). Koelewijn and van den Bogert (2021) further added that "effort is minimized when an antagonistic muscle pair co-contracts" (p. 14), helping to resolve long-standing questions about whether AMCC is efficient; even in a purely mechanical sense, it is seen here that AMCC is required for optimal efficiency, and therefore does not always constitute a waste of energy. Koelewijn and van den Bogert (2021) state clearly that "co-contraction, contrary to what is often thought… is efficient, and…is not chosen out of necessity…but also because it minimizes effort of movement in systems with uncertainty" (p. 15–16). Finally, Koelewijn and van den Bogert (2021) added that AMCC "is often thought of as inefficient and therefore avoided as much as possible" (p. 18), summarizing many authors' statements on co-contraction, but then concluded that "training and rehabilitation should focus on removing the cause of co-contraction to increase movement efficiency, instead of removing co-contraction itself" (p. 18); this statement potentially undervalues situation-agnostic benefits of AMCC, even those mentioned in the same study. For example, Koelewijn and van den Bogert's (2021) mention of "noise… present internally in sensory and motor neurons" (p. 3) qualifies as a situation-agnostic for which AMCC apparently corrects.

Efficiency of movement is frequently discussed in piano technique pedagogy (Gerig, 2007), and in these discussions AMCC is indeed "often thought of as inefficient" (Koelewijn and van den Bogert, 2021, p. 18). Given AMCC's contributions to movement efficiency noted here, its value in efficient piano technique needs careful appraisal.

3.2.1.4 Inter- and multi-joint coordination and transference

Hogan (1984) hypothesized that "as the hand, forearm, and trunk are in series, a high mechanical impedance of the coupling between object and hand would be of little value in providing support for the object if it were not accompanied by a corresponding high impedance between hand and forearm, forearm and arm, arm and shoulder, and so on" (p. 688). Roebroeck et al. (1994) discussed AMCC in sit-to-stand transfer, observing that "biarticular muscles have the better leverage at the joint on which they act as extensor" (p. 242). In the case of sit-to-stand transfer, "the almost isometrically active rectus femoris transports moment from hip to knee joint," aiding the transfer (p. 243). Furuya et al. (2007) found "strong [AM]CC of the shoulder" when playing faster (p. 40), even though the pianists were playing repeated notes and therefore would not have to reposition their arm around the keyboard. The increased AMCC observed in Furuya et al. (2011) "should allow for a greater transfer of momentum from the limb to the key," allowing proximal joints to provide greater assistance to the fingers, reducing "peripheral muscle fatigue" (p. 11). Lauer et al. (2013) explored AMCC in front crawl swimming, noting "the

importance of the elbow stability in transmitting forces from the hand and the forearm to the body," which "requires joint stiffness" (p. 820). In piano playing, the same might be true, in reverse: the importance of transmitting forces from the body to the forearm and hand implies the importance of elbow stability, which "requires joint stiffness" (p. 820). Kim and Han (2016) theorized that variation in AMCC might occur due to "angular momentum transferred from the thigh" (p. 6). Huber et al. (2017) observed that "modulating limb impedance [via AMCC] allows humans to coordinate complex, multi-joint movements…during physical interactions and tool use" (p. 3053). Mengarelli et al. (2018) commented that "co-activation of GAS [gastrocnemius] and thigh muscles is recognized as a fundamental mechanism for both stabilizing the knee joint and reducing the reliance on [the] ACL" (p. 118). O'bryan et al. (2018) explored knee extensor fatigue in cyclists, finding a "lack of change in co-activation" during fatigue, which acted as an "inter-muscular coordination strategy…to limit the impact of knee-extensor fatigue on maximal power production" (p. 7). Verdugo et al. (2020) explored trunk and upper-limb factors in the production of loud piano tones, finding that "pelvis and thorax motion can modify both upper-limb linear velocities and joint contribution to generate velocities at the hand and fingers" (p. 20). The use of these proximal body segments to affect more distal segments would seem to require the use of AMCC to allow force to pass through the joints in the kinematic chain; however, Verdugo et al. (2020) did not explore AMCC, only theorizing that pianists might use "muscle co-activation at specific joints to support the keystroke impact and, therefore, to effectively apply the desired effective mass on the keys," and also that pianists might be able to effectively "push the key downward if an adequate level of joint stiffness (muscle co-activation) is created at the finger joints" (p. 16).

Contrary to piano pedagogues suggesting that AMCC is fatiguing (e.g., Taubman et al., 2005), the findings above suggest that AMCC is an important component of energy-efficient movement, a common topic in piano technique pedagogy. Efficiency is often seen as important in piano technique because of challenging compositions that contain highly taxing and repetitive passages; pianists attempting to play études (e.g., those of Frédéric Chopin or Franz Liszt) must play efficiently so as not to experience muscle fatigue during even a single étude, let alone during the performance (or practice) of an entire set of études.

3.2.1.5 Internal model generation

Heald et al. (2018) stated that "in addition to improving kinematic accuracy, muscle co-contraction also increases the rate of acquisition of an internal model" (p. 8). This faster acquisition rate could be associated with the improved kinematic accuracy, as "any intervention that increases the overlap between the actual motions experienced and the motion required to reach the target, such as increased muscle co-contraction, could increase the rate of adaptation. Second, error sensitivity is greater for smaller errors. This could explain why muscle co-contraction accelerates adaptation, despite decreasing the size of errors" (p. 9). It was also hypothesized that "it is possible that error sensitivity is a function of muscle co-contraction, such that as muscle co-contraction increases, single-trial adaptation is maximized by progressively smaller errors" (p. 9). Heald et al. (2018) found that AMCC "simultaneously [enhances] present and future motor performance," and that "the modifiable nature of muscle co-contraction suggests that the rate of motor adaptation can be actively modulated" (p. 9). Piano technique, as a form of 'motor performance,' is likely to be similarly enhanced by AMCC, as it should also benefit from internal model acquisition, kinematic accuracy, error sensitivity, and decreased error size (e.g., improved adaptation to wrong notes during learning of a new piece of music).

3.2.1.6 Proprioception

Park et al. (1999) explored proprioception in control of goal-directed movement, claiming that "muscle spindles seem to be the primary source of sensory input about changes in joint position and velocity" (p. 631). Park et al. (1999) continued that "[w]ith an active contraction of muscles, muscle spindles become very sensitive to the irregularities in the speed and range of joint movement" (p. 633). This could suggest that AMCC aids proprioception; Morris (2010) claimed that "multidirectional stiffness, such as that seen in tonic co-contraction" can better process afferent information from the body (p. 67). Itaguchi and Fukuzawa (2012) studied the effect of arm stiffness on position reproduction errors, finding that "both constant and variable errors were larger in the direction of lower stiffness rather than in the direction of higher stiffness," and concluding that "proprioceptive accuracy and precision are positively related to the axis length of elliptically represented arm stiffness, and that exerting muscle effort to maintain the arm against the force of gravity may be supportive of human proprioceptive mechanisms" (p. 757). Itaguchi and Fukuzawa (2012) added that "as stiffness increases, resistance against signal-dependent noise or perturbations of external force also increases. Subsequently, motor commands from the CNS are realized more accurately and precisely in the external workspace" (p. 768). Additionally, Itaguchi and Fukuzawa (2012) explained that "afferent signals from muscle spindles largely contribute to position perception…the sensitivity of muscle spindles increase[s]… accompanied by muscle co-contraction" (p. 770). These mechanisms explain how higher muscle stiffness accomplished through AMCC contributes to improved proprioception. Craig et al. (2017) concluded that "increased co-contraction in older adults is not dependent on contemporaneous proprioceptive input" (p. 3), but this statement appears to discount the contribution of co-contraction itself as a form of proprioceptive input, even though Craig et al. (2017) acknowledged that co-contraction "may be used to increase proprioceptive information" (p. 3). As such, statements like "high muscle co-contraction during the reintroduction of veridical proprioceptive input" (p. 3) risk underemphasizing the potential of co-contraction as veridical proprioceptive input itself, which appears inadvisable given that one of Craig et al.'s (2017) stated purposes is to test whether co-contraction is used to "increase proprioceptive information from muscle spindles" (p. 3). Babadi et al. (2021) found that functional connectivity between the cerebellum and inferior parietal lobule (IPL) was correlated with AMCC, as "one of the functions of IPL appears to be the integration of multisensory information, such as vision and proprioception, in the context of spatial attention and guidance of hand movements" (p. 5674). These findings give a neural basis to AMCC functioning as a proprioceptive aid.

Skilled piano playing demands a refined sense of proprioception; this is evident from the successful performance of compositions with spread-out or quickly leaping hand positions (such that the pianist cannot visually monitor the positions of both hands at once), and additionally from the exceptional abilities of pianists with impaired or no vision (for example, Van Cliburn International

Piano Competition winner Nobuyuki Tsujii, who is unable to see due to microphthalmia).

3.2.1.7 Range of motion and individuation

Fujii et al. (2007) studied wrist co-contraction during wrist extension, finding that "co-contraction of PT [pronator teres] and ECR [extensor carpi radialis] during wrist extension movements occurs to prevent supinating the forearm" (p. 80). This AMCC was necessary to prevent supination because of "cross-connections between the distal tendons of ECRL [extensor carpi radials longus] and ECRB [extensor carpi radials brevis]" (p. 80). These cross-connections "pull the distal end of the radius via the retinaculum in supination direction," a function which had not yet been discussed in prior publications (p. 87). This suggests that, in any situation demanding wrist extension without simultaneous forearm supination, a particular form of AMCC is required. Valero-Cuevas (2005) explored the biomechanical function and neuromuscular control of the fingers, claiming that "co-contraction is necessary to reach most regions of FTS [feasible torque space]" (p. 681). The FTS is important as "to be versatile, the finger should be able to produce net joint torques in all quadrants of torque space" (p. 681). For example, given a particular hand position, there are positions of the fingertip which can only be reached via co-contraction of finger flexors and extensors; to produce joint torques in these spaces therefore demands AMCC. Dupan et al. (2018) studied neural control of hand muscles during single finger pressing, finding that "[i]ntrinsic muscles exhibited individuation, where the agonistic and antagonistic muscles associated with the instructed fingers showed the highest activation.

Given that skilled piano playing requires highly independent, simultaneous movement, positioning, and control of the fingers (particularly evident in the contrapuntal fugues of J.S. Bach, but even required for the playing of a simple C Major chord, and additionally for playing the individual notes of said chord more loudly or softly than one another), AMCC's importance for aiding individuation and range of motion seems relevant to piano technique.

3.2.1.8 Signal-to-noise ratio (SNR)

Osu et al. (2004) found that, "when subjects were asked to increase co-contraction, the variability of EMG and torque both increased, suggesting that noise in the neuromotor command increased with muscle activation…[yet] the effect of this noise on the task performance is reduced" (p. 1199). Meulenbroek et al. (2005) found that AMCC "forms a strategic means to adapt the flow of motion to central information processing demands" in fine motor tasks (p. 331). Notably, in a handwriting task, "during pen-tip acceleration, co-contraction was clearly higher in the between-letter connection strokes than in the within-letter strokes" (p. 345). Meulenbroek et al. (2005) observed that AMCC is "a likely mechanism to slow down movements in complex motor tasks…whenever increased cognitive demands have to be coped with," acting "as a low-pass filtering mechanism to increase the signal-to-noise ratios of neuromotor signals when these signals happen to be impoverished by increased task demands or conditions of physical, emotional, and/or psychosocial stress" (p. 347). These contexts have clear parallels with varying aspects of piano playing, from learning new repertoire, practicing known repertoire, and stressful performance situations.

The increase in AMCC observed in Ueyama and Miyashita (2013) was thought to improve accuracy by "reducing the perturbing effects of joint-interaction torques," and additionally by "suppress[ing] the influence of increased motor noise as a result of rising motor command" (p. 16). Reeves et al. (2016) claimed that "the central nervous system increases muscle activation to account for less precise motor control, possibly to improve the responsiveness of human motor control" (p. 166). Reeves et al. (2016) also noted that increased AMCC "helps minimize the effects of neuromuscular noise" (p. 172). This appears to add a layer of complexity to Fitt's law, which claims "there is a trade-off between speed and accuracy for self-directed movements" (p. 172), because "humans appear capable of moving faster while maintaining accuracy by increasing agonist–antagonist muscle activation" (p. 173). While there are clearly limits on the extent to which speed and accuracy can be dually maintained, and limits on each variable in isolation as well, skilled piano playing appears to be an example of how AMCC can be used as a strategy to partially circumvent Fitt's law. Koelewijn and van den Bogert (2021) studied AMCC's potential in minimizing effort in uncertain situations, hypothesizing that "co-contraction is optimal in practice, due to noise in the movement…present internally in sensory and motor neurons" (p. 3). Koelewijn and van den Bogert (2021) added that "human control should constantly correct any deviations caused by noise…[but] a neural time delay is present in the control due to the travel time required through sensory and motor neurons. Therefore, "the stiffness added by co-contraction prevents any unwanted deviations due to noise" (p. 3). AMCC's ability to prevent noise-based movement deviations could be especially valuable for piano technique, as small errors of positioning or movement can quickly compound to interruptions in playing, particularly during complex and fast passagework. Even a single interruption in playing can have consequences during a live performance, particularly in compositions involving other musicians (for example, piano concerti or chamber music), also increasing the risk of a lapse of context-dependent memory (a 'memory slip') due to the physical interruption (Mishra, 2002).

3.2.1.9 Speed and power output

Stanier (1973) found that "the antagonistic muscles should be tensed prior to the movement" if it is desired to move a limb "as quickly as possible once only through a given straight line" (p. 4–28). Stanier (1973) does not explain why AMCC is required to create the fastest possible movement, but it could be related to differing timings of muscle contraction and relaxation, or preparatory joint stiffness increasing the efficiency of the following contraction. However, Stanier's (1973) discussion of "rotational pressure transfer" (p. 9–13) neglects the benefits that AMCC might provide, and therefore advises that "the antagonistic muscles of these joints could also be applied to give a degree of stiffness, and so for that matter could the finger muscles, but theoretically this is not necessary" (p. 9–10). Barnes (1982) explored the role of pre-stimulus AMCC in elbow flexion movements, finding that "movement times and average angular velocities were significantly improved after pre-stimulus antagonistic contractions were performed" (p. 678). Williams and Barnes (1987) found a positive correlation between elbow AMCC with both "movement velocity and displacement…indirectly support[ing] the notion that the antagonist musculature provides a braking force to arrest rapid limb movements" (p. 933). Gabriel et al. (1993) found that "decrease in movement time associated with practice was accomplished by an increase in the slope of the agonist/antagonist

EMG bursts" in ballistic elbow movements (p. 327). Given that piano playing requires elbow extension (Furuya and Kinoshita, 2008), often at higher velocities, this might imply the need for elbow AMCC in pianism.

Rouard and Clarys (1995) studied AMCC in maximal-effort swimming, finding that "cocontractions are important features of rapid cyclic repetitive movement" (p. 177). Rouard and Clarys's (1995) findings "suggested the presence of cocontraction through different parts of the range of the cyclic arm motion" (p. 182), and concluding that "cocontractions were an important aid in rapid, cyclic, rhythmic and repetitive movement performance" (p. 183). Pezarat-Correia et al. (1996) found that AMCC "seems to represent more than an impulse braking…we must admit its participation in the control of the end of the acceleration phase" of fast throwing movements (p. 486). This AMCC could "control movement time," or "improve the performance of rapid elbow movements…providing a longer time for acceleration and an increase in movement velocity" (p. 487). Furuya et al. (2007), observing highly trained pianists, found "increases in joint angular velocity and co-contraction (CC)… of all upper limb muscles before keystroke" when dynamics, measured in SPL (sound pressure level), were increased (p. 40). Furuya et al. (2007) concluded that "by increasing joint stiffness and movement speed, the pianists increase the amount of the momentum transfer from the hand into the key" (p. 40). Furuya et al. (2007) found "strong [AM]CC of the shoulder" when playing faster (p. 40), even though the pianists were playing repeated notes and therefore would not have to reposition their arm around the keyboard. The AMCC observed in Furuya and Kinoshita (2008) "was clearly larger at a larger sound for both groups of players," suggesting that greater AMCC could be required for loud playing (p. 588). This does not, however, imply a linear relationship between loudness and optimal AMCC. Larsen et al. (2008) noted that "[a]ntagonist muscle force exertion plays an important role in the execution of fast ballistic limb movements in order to make a rapid transition from joint flexion to extension" (p. 578). Andison (2011) studied wrist AMCC in piano playing, finding "significant variations in co-contraction that corresponded to faster note rates and increased loudness" (p. iii). Andison (2011) concluded that "the presence of co-contraction is fundamental to piano playing" (p. iii).

Latash (2018) noted how AMCC prevents delays arising from the distance and speed of CNS-muscle communication: "it can take over 100 ms before neural processes produce visible changes in muscle activation. This is a very long time delay, potentially incompatible with successful performance of everyday motor tasks, such as standing, which rely on quick reactions to unexpected perturbation" (p. 99). AMCC is also advantageous "if the task is to move as quickly as possible," or (in systems with fixed origin, such as piano playing) "if the task is to improve task stability" (p. 100). Schwalbe et al. (2019) explored red muscle activity in bluegill sunfish, finding that "fish co-activated anterior muscle…to stiffen their bodies during acceleration" (p. 2). Schwalbe et al. (2019) noted a trade-off between how "[f]ish with more flexible bodies should…use less energy to swim steadily," yet fishes' "bodies should be stiffer for rapid, impulsive movements" (p. 3). Saliba (2019) found that "co-contraction reduces the overshoot of the return to target by between 0.7 cm and 1.7 cm compared to when the agonist is stretched or shortened" in a reaching task (p. 75). A single centimeter can be the difference between a correct or incorrect note on the piano keyboard. Additionally, "co-contraction also reduces the return time to the target at all levels of background activity" (p. 75); this could have implications for passages in piano music that require moving rapidly between different hand positions (e.g., Franz Liszt's *Réminiscences de Don Juan*, S. 418).

The findings of this review so far provide thorough underpinning to Andison's (2011) claim that "co-contraction is fundamental to piano playing" (p. iii). Because AMCC is seen as essential to a diverse range of mechanisms underlying human movement, its value in piano technique should not be dismissed – despite the insistence of anti-AMCC pedagogues past and present (e.g., Matthay, 1908; Stannard, 2014).

3.2.1.10 Stability (general)

Bautmans et al. (2012) stated that AMCC "might be a physiologic compensation…to increase joint stiffness and maintain joint stability" (p. 3), while Lauer et al. (2013) noted that "coactivation is the most robust strategy to counteract perturbations" (p. 820). Lee et al. (2017) noted that AMCC "plays an important role in enhancing joint stability for movement regulation during motor learning activities" (p. 1). Saliba (2019) stated that "the primary benefit of co-contraction is from neural feedback responses," breaking from prior literature supporting impedance control as the primary benefit of AMCC (p. 111). Saliba (2019) explains that "the effects of neural feedback have been incorrectly characterized as mechanical impedance," but "that is not to say that the effects of impedance are not significant" (p. 111). It might be possible, however, that the primary benefit of AMCC is context-dependent and differs across varying situations, especially given the communication delays between the CNS and muscles observed by Latash (2018), which would imply impedance as more valuable than neural feedback response in situations demanding instantaneous reaction. Babadi et al. (2021) found that "the cerebellum appears to play the predominant role in regulating co-contraction, as it is "ideally structured to register errors in motor commands…and, therefore, to implement countermeasures such as co-contraction to counteract external disturbances" (p. 5674).

Given that piano playing involves external disturbances resulting from the equal and opposite reactions of the key against the impact of the fingers via Newton's Third Law, and the above findings that AMCC appears to have an important role in counteracting external disturbances, it seems that a further function of AMCC in piano technique is the counteraction of these key-reactions, which if not counteracted can interrupt the position and trajectory of the fingers, hand, and even arm.

3.2.1.11 Stability (upper limb)

Stanier (1973), an early doctoral thesis on piano technique, also was possibly "the first time that piano playing has been studied with a computer" (p. 2–2). Stanier (1973) found that prior authors show "almost complete unanimity over the state of antagonistic muscles during rapid oscillation…[both] must be used simultaneously" (p. 4–15). As to why many authors insist that this AMCC must be of a high intensity for rapid oscillatory movement, Stanier (1973) hypothesized that "perhaps a large amount of antagonistic muscle force is necessary to give stability to the joint" (p. 4–17), a hypothesis borne out by later research. Stanier (1973) continued: "how is it possible for a joint to be made rigid? As each joint is equipped with a pair of antagonistic muscle groups, the answer would seem to be that the muscle groups both switch on and thus work in opposition to each

other" (p. 4–26). This is an accurate description of AMCC creating joint rigidity. Hogan (1984) observed AMCC "under normal physiological conditions…increas[ing] as gravitational torques increase" to "offset gravitational destabilization," increasing stability (p. 688). Hasan (1986) noted that "if joint stiffness were an undesirable property for the performance of movement, one would expect that during self-initiated movement there would be no coactivation of antagonists muscles…[yet] there is considerable evidence for the coactivation of antagonists for part or whole of the duration of many normal movements" (p. 373). This statement argues inductively that joint stiffness, and therefore AMCC, must be necessary. Hasan (1986) found that "seemingly wasteful coactivation may serve to optimize the stiffness. The stiffness, therefore, need not be viewed simply as a means of resisting imposed perturbations, but as a means of reducing the alterations in the central drives necessary for the performance of movement, thereby reducing the effort" (p. 373). This combats claims that AMCC is necessarily energetically inefficient, wasteful, or excessively effortful. De Serres and Milner (1991) found that "cocontraction [increased] dramatically" (p. 451) to increase wrist stiffness when loads were unstable, while phasic stretch reflexes did not contribute to stiffness. Piano playing arguably includes unstable loading, as heavy loads can be transferred to keys through fingers during fast, complex movements.

Gribble and Ostry (1998) studied independent control of shoulder and elbow AMCC, finding that "shoulder muscle co-activation was… independent of the co-activation of elbow and double-joint muscles" (p. 359). Between-joints, independent AMCC can "stabilize the limb in the face of external perturbing forces and forces arising from multipoint dynamics" (p. 355). Damm and McIntyre (2008) advised that "[a]rm stiffness is a critical factor underlying stable interactions with the environment…[and] seems to increase in free space compared with constrained motion through the use of coactivation" (p. 2577). Damm and McIntyre (2008) found that "[the] CNS uses coactivation of antagonists to deal with unexpected external forces when performing unconstrained movements in free space" (p. 2584). Wong et al. (2009) argued that in "highly unstable" environments, "the only functional solution available to the motor system is to produce an increase in limb stiffness," and therefore suggesting that "it is thus important to address whether the nervous system uses stiffness control to facilitate movement accuracy in more naturalistic tasks that do not involve external destabilizing force loads" (p. 1542). Wong et al. (2009) found that "the motor system uses stiffness control to augment movement accuracy during movement and does so in the absence of external unstable force loads, in response to changing accuracy requirements conveyed using visual cues" (p. 1542). Wong et al. (2009) concluded that "neural control of limb stiffness is an integral part of the voluntary control of movement" (p. 1548). This conclusion has clear implications for piano playing, which itself is a form of voluntary, controlled movement.

Brookham et al. (2011) argued that "Upper limb control and end effector precision depend on effective elbow stability, which makes co-activation especially important at this joint" (p. 1582). Furuya and Soechting (2012) studied independent control of finger movements in pianists, finding "maintenance of independent finger movements across tempi" suggesting speed invariance of these movements in expert pianists, and also that "an increased finger muscular coactivation may enable maintained rhythmic accuracy of keystrokes across tempi," because "augmented stiffness ensures mechanical robustness against spontaneous variability of motor commands" (p. 2067). Blache et al. (2014) studied co-activation of superficial shoulder muscles during lifting tasks, discovering that "more co-contraction" occurred during the dropping phase compared to pulling and lifting phases (p. 355). This co-contraction was thought to "be a solution to increase glenohumeral joint stiffness" (p. 355). Sangwan et al. (2014) found that "the hypothesis that rotator cuff muscles show co-activation to provide joint stability was partially supported" (p. 7). Additionally, "the maximum EMG amplitudes were in expected directions," providing further support for the stability theory of rotator cuff AMCC (p. 9). Holmes et al. (2014) observed that "co-contraction increased in all pairs as grip force increased" in perturbed forearm gripping (p. 1). This increase in AMCC corresponded to "a 36% increase in overall wrist joint stiffness," which aided control of the wrist, especially during perturbations (p. 1). Kawai et al. (2014) simulated AMCC and movement control, noting that "co-contraction of antagonist muscles play an important role for joint stiffness and stability and experimental results show the existence of co-contraction during volitional movements" (p. 3316). Kawai et al. (2014) concluded that "co-contraction is useful…also to control the output force direction," reducing "tracking errors" (p. 3320). Dupan et al. (2018) found that "activation in both agonistic and antagonistic muscles appears to facilitate finger stabilisation" (p. 224). This AMCC is also likely active in piano playing, as finger stability presupposes wrist stability. Dupan et al. (2018) found that "extrinsic muscles show an activation independent from instructed finger in both agonistic and antagonistic muscles, which appears to be associated with stabilization of the wrist" (p. 224). Rinaldi et al. (2018) studied biomechanics of the Junzuki karate punch, finding that "the upper limb is more stiffer [sic] than both trunk and lower limb in order to generate more powerful movements" (p. 9). Rinaldi et al.'s (2018) analysis of this higher AMCC in the upper limb is difficult to follow, however: "force creates faster movement, but the corresponding stiffness slows the change of muscle shape and joint velocity" (p. 8). How does one force create both faster movement and slower joint velocity? Rinaldi et al. (2018) also stated that "rapid relaxation may be helpful to enhance the speed strength" (p. 9), but it is unclear what 'speed strength' entails and the source of this 'rapid relaxation' is not specified.

Schinkel-Ivy and Duncan (2018) noted that "external perturbations that are unpredictable, continually changing, and multi-directional" require "both feedforward responses for the oncoming perturbation, and feedback mechanisms for the perturbation at hand. Consequently, an adequate response must be produced for the current perturbation without compromising stability for the oncoming perturbation. These responses require complex patterns of muscle activity" (p. 42). Though perturbations experienced during piano playing are not typically unpredictable, they do qualify as both continually changing and multi-directional, and therefore also are likely to require simultaneous feedforward and feedbackward responses. For example, responding to the current reaction from the keyboard due to playing a note might ideally occur simultaneously with a reaction to the upcoming note(s). Huber et al. (2019) noted that "the challenge of controlling physical interaction arises from the fact that, when you apply forces on an external object, the object simultaneously applies forces back onto you. The object's dynamics are coupled to your dynamics, and this can destabilize the physically coupled hand-object system" (p. 51). Although 'controlling physical

interaction' offers more than one challenge, the forces applied in reaction (via Newton's Third Law) are indeed an important factor in destabilization. Huber et al. (2019) also observed that "extensive prior work suggests that humans are able to ensure robust stability during physical interaction by modulating the mechanical impedance of their limbs," which occurs via AMCC (p. 51). Snyder et al. (2019) investigated visuomotor control of arm stability, noting that "[d]uring movement, agonist muscles are activated to move the limb toward the target, which is followed by antagonist muscle activation to provide braking" (p. 2156). However, antagonist muscle activation does not only 'follow' agonist activation, but also occurs simultaneously, for reasons including braking. Snyder et al. (2019) then clarified that "[i]ncreasing the co-contraction of the arm during arm movements and postural maintenance tasks results in better movement accuracy and less positional error, respectively, providing increased stability to the limb during reach" (p. 2156). Snyder et al. (2019) concluded that "visuomotor control of arm posture involves co-contraction of antagonistic muscles" (p. 2165); given that piano playing requires visuomotor control of arm posture, these findings appear to imply that piano technique requires AMCC.

Forman et al. (2020) found that forearm "[c]o-contraction ratios were higher in the flexion conditions…likely a contribution to wrist joint stability" in dynamic wrist flexion-extension (p. 1). Notably, during extension conditions, co-contraction was still present, with flexors at "only ~32% the activity of the wrist extensors" (p. 7). Sharma and Venkadesan (2022) concluded that "people are significantly cocontracted when producing fingertip forces, likely for stability" (p. 7).

Beyond the external disturbances addressed in 3.2.1.10, the "multipoint dynamics" (Gribble and Ostry, 1998, p. 355) of upper limb movement are a relevant source of internal disturbances when operating complex motor tasks, piano playing being no exception (Kinoshita et al., 2007); this further suggests the importance of AMCC in piano technique.

3.2.1.12 Stability (lower limb)

Nissan (1980), found that "[a]gonistic and antagonistic activity of muscles and loading of ligaments were shown to be possible and helpful in balancing the knee" (p. 375). Hirokawa et al. (1991) noted that "during execution of a specific motion, the agonist muscles supply most of the force needed to accomplish the set objective while the antagonist muscles exhibit low-level activity ranging from 5 to 50% of their maximal force" in cadaver knee stability (p. 199). Hirokawa et al. (1991) continued that "much data supports the hypothesis that such muscular co-contraction is the "modus operandi" in most limb joints and is a significant factor in providing brisk, accurate movement with regulation against various internal and external disturbances such as the changing direction of the gravity vector, motion speed, external load, dynamic braking, muscle movement arm variations, and skill development" (p. 199). Gravitational adjustment offers a further justification for omnipresent AMCC, as gravity is a constant factor in human movement. Hirokawa et al. (1991) concluded that "muscular coactivation serves at least four important physiologic functions; providing brisk precise control of limb motion, allowing development of skill, regulating against various internal and external disturbances, and maintaining joint stability" (p. 207). Hirokawa et al. (1991) also cautioned that "joint stability…could be severely compromised if agonist muscles were the only active actuators during motor tasks" (p. 207), conflicting with anti-AMCC piano pedagogy. Bernardi et al. (1995) found that "when the muscle acts as antagonist most motor units are recruited up to 50% of the maximal voluntary force, whereas when the muscle acts as antagonist motor units are recruited up to 40% of the maximal voluntary force" in knee AMCC (p. 493). However, this statement is self-contradictory; it is likely that 'agonist' was meant rather than the first instance of 'antagonist.' Bernardi et al. (1995) noted that AMCC can produce "a dynamic braking at the end of the motion," and that "the importance of muscular coactivation in low-level contractions…is effectively reducing the anterior displacement and the internal rotation of the tibia, preventing excessive stress of the joint by providing synergistic action to the anterior cruciate ligament. The role of the coactivation results in a regulatory stabilizing function…and a more accurate performance of each motor task" (p. 497–498). Kellis and Baltzopoulos (1999) studied antagonistic muscle force during isokinetic efforts in the knee, noting that "hamstrings activation when acting as antagonists is considered very important for knee joint stability" (p. 19). Aagaard et al. (2000) explored AMCC during knee movements, finding "[s]ubstantial hamstring coactivation," "potentially counteract[ing] the anterior tibial shear and excessive internal tibial rotation…to assist the mechanical and neurosensory functions of the anterior cruciate ligament," causing "improved stability" (p. 58). Zhang and Wang (2001) discovered that "differential co-contraction of muscles crossing the medial and lateral sides of the knee…helped to reduce the abduction-adduction joint laxity…increase stiffness…and viscous damping" (p. 1107). This knee AMCC increased "natural undamped frequency," which "presumably makes the neuromuscular system operate more quickly at higher contraction levels" (p. 1114). Additionally, the AMCC and corresponding stability were hypothesized to make the knee "a quicker system during strenuous tasks involving strong muscle contraction" (p. 1107).

Zakotnik et al. (2006) found that "in cockroaches, joint stiffness attributable to co-contraction is a key parameter for running speed and adaption to different surface compliances…and stabilizes the impact when the leg touches ground at the beginning of the stance movement" (p. 5006). Larsen et al. (2008) studied AMCC during stair walking, noting that AMCC "serves to increase joint stiffness and provide protection against external impact forces as well as enhancing the stiffness of the entire limb" (p. 569). Rao et al. (2009) studied the effects of loading on knee muscle activation, confirming "the advantageous role of cocontraction because the contribution of active stiffness to joint stability depends both on the knee angle and on the external load" (p. 464). Rao et al. (2009) also found that "with higher loads, requiring a higher stability of the knee joint, the peak of cocontraction is shifted to an angular range where the efficiency of the hamstrings muscles to actively stabilize the knee is maximal" (p. 464). Di Nardo et al. (2015) assessed ankle AMCC during normal gait, finding "significantly increased complexity in muscle recruitment strategy beyond the activation as pure ankle plantar/dorsiflexors" (p. 347). This strategy "suggests that co-contractions are likely functional to further physiological tasks as foot inversion, balance improvement, control of ankle stability and knee flexion" (p. 347).

Di Nardo et al. (2016) found that "in healthy children co-contractions are likely functional to further physiological tasks as balance improvement and control of joint stability" (p. 161), and "useful to stabilize and smooth the double-to-single support

transition" in walking (p. 165). Strazza et al. (2017) found "three different co-contractions among QF [quadriceps femoris] and hamstring muscles during able-bodied walking" (p. 228). These co-contractions were seen to "augment ligament function in maintenance of joint stability, providing resistance to rotation at a joint and equalizing pressure distribution at joint surfaces" (p. 228). Craig et al. (2016) argued that "[o]lder adults use a different muscle strategy to cope with postural instability, in which they 'co-contract' the muscles around the ankle joint" (p. 251). This statement could imply inaccurately that younger adults do not co-contract the muscles around the ankle joint to combat postural instability. Craig et al. (2016) found that "despite suggestions from previous research…better proprioceptive acuity predicts more co-contraction" (p. 251). This conflict with prior research might be explained by the fact that AMCC can both increase proprioceptive acuity and also itself be increased in individuals with compromised proprioceptive acuity, perhaps as a result of the former. Given the assumption that AMCC cannot increase proprioceptive acuity to such an extent that it would outweigh any observed impairments in proprioceptive acuity, this might explain the existence both of studies finding AMCC in proprioceptively impaired populations, and of studies such as Craig et al. (2016) finding higher AMCC in populations with higher proprioceptive acuity. However, Craig et al. (2016) concluded that AMCC is not used "to compensate for age-related proprioceptive deficits" (p. 251), stating that "[o]ur findings contradict the recurrent prediction that muscle co-contraction is a compensatory strategy for age-related proprioceptive decline by emphasizing that co-contraction is employed more by older adults with good proprioception" (p. 257). Craig et al. (2016) made this statement despite AMCC's ability to increase proprioceptive function due to the fact that "no muscle co-contraction was witnessed" during the proprioceptive task (p. 258). The conclusion that AMCC is not a compensatory strategy for proprioceptive decline is questionable: given that AMCC is known to improve proprioception and is "employed more by older adults with good proprioception" (Craig et al., 2016, p. 258), it is perhaps more likely that the particular proprioceptive task, or which muscles' AMCC was measured, were not conducive to elicitation and/or detection of AMCC. Craig et al. (2016) also theorized that "in everyday life muscle co-contraction is an ineffective and risky postural strategy" because of findings that voluntary AMCC can increase postural sway amplitude and frequency (p. 252). However, this claim seems not to distinguish between necessary vs. excessive AMCC, instead oversimplifying AMCC as an undesirable and simplistic phenomenon. Craig et al. (2017) investigated proprioception, postural sway, and AMCC in older adults, finding that "increased co-contraction in older adults is not dependent on contemporaneous proprioceptive input…it is more likely that cocontraction is a general postural strategy used to minimize postural sway" (p. 2). This could overlook the benefit of AMCC itself improving proprioceptive input. Le Mouel and Brette (2019) advised that "[i]ncreasing ankle stiffness in advance of a perturbation can improve robustness to perturbations, by reducing the amplification of perturbations during the neural feedback delay" (p. 3). Le Mouel and Brette (2019) also noted that AMCC "allows perturbations to be canceled faster, with less overshoot…and less increase in contraction" (p. 8). Jafarnezhadgero et al. (2021) found that AMCC aids "foot inversion, balance improvement, control of ankle stability and knee flexion" for females with genu varus (p. 76–77).

In piano technique, AMCC could similarly aid the upper-limb parallels of these lower-limb functions. Additionally, an easily overlooked and under-researched area of piano technique is the usage of the foot pedals; while pedaling itself is perhaps a simpler task than playing on the foot pedals of a pipe organ, skilled pianists still must maintain balance on the piano bench while accomplishing complex pedaling (Rosenblum, 1993), and the effects of AMCC on lower limb stability seem likely to be relevant for this challenging task.

3.2.1.13 Stability (trunk)

Thelen et al. (1995) found that "co-contraction is a major determinant of spinal loading" in trunk movement (p. 390). This AMCC served multiple purposes: "to stiffen the joint so as to minimize the effect of potential internal and external disturbances… to equilibrate moments at other joints in the case of multiarticular muscles, or…to regulate the loads at the joint" (p. 397). Given that piano playing involves trunk movement, it is possible that trunk AMCC is an important component of piano technique, but it has apparently not been discussed priorly. Choi (2003) found that "neck muscle co-contractions are necessary to provide stability to the human cervical spine around its neutral posture by stiffening the joint" (p. 139). This neck AMCC could be important in piano technique as particularly forceful passages might otherwise perturb the neck and head, which could upset listening, proprioception, and other crucial mechanisms of skilled playing. It appears that neck AMCC has not been discussed in the context of piano technique, except for instructions to avoid "unnecessary tightening of neck muscles" (Lister-Sink, 2018, p. 40); these instructions are potentially counterproductive when not accompanied by definition of *necessary* neck tension. Gribble et al. (2003) noted that AMCC "affects joint impedance, which provides technical stability in the presence of external perturbations and forces due to limb dynamics" (p. 2396). These increases in AMCC were observed "despite the energetic cost of muscle coactivation" (p. 2396). van Dieën et al. (2003) found that "[a]bdominal coactivation was significantly higher" when lifting unstable loads, supporting "the interpretation of abdominal cocontraction during lifting as subserving spinal stability (p. 1829). Lee et al. (2006) determined that "[t]runk stiffness increased 37.8% ($p < 0.004$) from minimal to maximal co-activation" (p. 51), which "empirically validate[d] the assumption used in published models of spine biomechanics that co-contraction influences trunk stiffness" (p. 5). Borghuis et al. (2008) claimed that "a low level of co-contraction of the trunk muscles is important for core stability," providing "a level of stiffness, which gives sufficient stability against minor perturbations" (p. 894). This attenuation is important so that the CNS can "[create] a stable foundation for movement of the extremities through co-contraction" (p. 894). Borghuis et al. (2008) also noted that "joint stiffness increases rapidly and nonlinearly with muscle activation, so that very modest levels of muscle activity create sufficiently stiff and stable joints" in the context of core stability (p. 896). Additionally, many tasks "could not be performed without this co-activation…result[ing] in stabilization of the excessive mobility of the extremities" (p. 899). Relevant to pianists, "the art, especially for athletes, is to enhance mobility, while at the same time preserving sufficient stability" (p. 899). McCook et al. (2009) studied co-contraction of lumbo-pelvic muscles, noting that "[c]o-contraction of the lumbo-pelvic muscles is required even in neutral upright postures because the passive structures of the spine are inadequate to

maintain stability of the lumbar spine" (p. 754). This claim appears to presuppose that stability of the lumbar spine is a desirable goal; it should be possible (though difficult) to remain upright without co-contraction (e.g., by contracting only agonists, balancing against the pull of gravity). However, stability is widely seen as desirable. Murray et al. (2018) found that mice react to external perturbations "by generating a motor program of muscle extension, followed some 30 ms later by co-activation of antagonist muscles in the hindlimb" (p. 1336). In piano technique, perturbations occur as the keys react against the fingers with equal and opposite force due to Newton's Third Law; however, as these perturbations are not unpredictable, reactive AMCC should not occur 30 ms post-perturbation, but instead, as a preemptory response (Le Mouel and Brette, 2019). Homayounpour et al. (2021) studied neck AMCC during harmless head impacts, finding that preparatory AMCC helped "reduce the kinematic response after the impulsive force to the head," demonstrating that AMCC is an important mechanism to resist perturbations (p. 4).

Given the importance of stability in complex and difficult movements, the contributions of AMCC to stability across the upper and lower limbs as well as the trunk and neck further imply its importance in piano playing, which itself is a highly complex and difficult form of movement (Kinoshita et al., 2007).

3.2.2 Medical benefits of AMCC

3.2.2.1 Therapeutic

AMCC can aid ligament injuries: O'Connor (1993) found that "simultaneous contraction…can unload the cruciate ligaments entirely at flexion angles above 22°" (p. 410), completely protecting knee ligaments after injury or repair. This AMCC strategy could "help the design of rational regimes of rehabilitation after ligament injury or repair" (p. 410). Lee et al. (2012) found that injured ballet dancers "had greater co-contraction…for the non-dominant ankle" (p. 693), which was thought to "take over the function of damaged ligaments to maintain joint stability" (p. 695). This AMCC was "considered as an efficient mechanism to protect joints against potentially dangerous loads" (p. 695). Gallego et al. (2013) developed a neuroprosthesis which "employed transcutaneous neurostimulation to apply mechanical loads…in co-contraction—in such a way that joint impedance was adequately manipulated" (p. 2), which "constitutes a feasible approach to tremor management…through the control of muscle co-contraction" (p. 7). Notably, "all patients reported that the sensation generated…was tolerable and not unpleasant, and the overall impression was that they could habituate to it…a few patients spontaneously declared that when the [neuroprosthesis] was activated they could control better their limbs" (p. 7). The 100% positive response rate was especially valuable given that "a significant proportion of those suffering from tremor do not respond to medication" (p. 10). This application of neuroprosthetic AMCC stimulation as a viable therapeutic tool, alongside research of AMCC as being therapeutic for other disorders (Overbeek et al., 2018), demonstrates AMCC's restorative potential. Biscarini et al. (2016) found that "voluntary quadriceps cocontraction…can yield considerable levels of quadriceps activation while preventing the tibia from translating forward relative to the femur," therefore qualifying as "one of the most appropriate quadriceps strengthening interventions in the early phase of ACL rehabilitation" (p. 1). Biscarini et al. (2016) also noted that "hamstring cocontraction is inherent to natural knee extension and serves important physiological functions, such as stabilizing the tibiofemoral (TF) joint and reducing the mechanical landing of the ACL" (p. 3). Rosa et al. (2014) argued that AMCC is important "for providing optimal joint stability, good movement accuracy and energy efficiency during functional activities" for neurologically impaired individuals (p. 3). Rosa et al. (2014) concluded that AMCC shows strong relationships with "kinematics, dynamic strength, postural stability, walking speed and walking independence in subjects with stroke" (p. 14), also noting that "Similar relationships have been reported in osteoarthritis…cerebral palsy…Parkinson's disease…and in healthy elderly people" (p. 14). Rosa et al. (2014) also found increased AMCC "during walking after stroke in both the affected and non- affected limb, most likely as an adaptation strategy to increase walking stability" (p. 14), also observing that "[s]lowest walking speeds post-stroke are usually associated with inability to recruit additional MCo [AMCC]" (p. 14). Al-Khlaifat et al. (2016) found that osteoarthritic knee patients displayed increased knee AMCC compared to healthy controls, which "might be a protective mechanism to improve knee joint stability during gait in the presence of muscle weakness with knee OA [osteoarthritis]" (p. 63).

Kolk et al. (2021) found that patients with subacromial pain syndrome (SAPS) used "less antagonistic activity of the teres major" than healthy controls, and that "[m]any authors linked deficits in shoulder muscle activation to SAPS pathogenesis" (p. 16). Resultantly, Kolk et al. (2021) recommend to "increase co-contraction" (p. 19) for SAPS patients. Overbeek et al. (2018) found that increased shoulder AMCC was "associated with a favorable course" in SAPS (p. 1925). Specifically, AMCC of arm adductors during arm abduction helped to significantly reduce complaints of pain, even at a four-year follow-up evaluation. This reduction in pain was thought to be caused by "widening of the subacromial space" (p. 1925), helping to prevent "painful upward migration of the humerus" (p. 1926) due to compromised shoulder stability. This resulted in "significantly increased quality of life…indicating a clinically relevant improvement" (p. 1928). Conversely, "unchanged activation patterns…were associated with persistent complaints" (p. 1928). Yuan et al. (2019) found that rectus femoris AMCC "contributes to the stability of the knee and lower limb function…[and] should be considered in the rehabilitation of knee stability during gait" in hemiplegic stroke patients (p. 7443).

Because of the prevalence of playing-related neuromusculoskeletal disorders (PRNDs) among pianists (Kaufman-Cohen et al., 2018), and the general importance of AMCC in piano technique as proposed in this review, AMCC displays potential as a therapeutic activity in the context of practicing the piano while attempting recovery from a PRND (or indeed from other types of task-related disorders). For this reason, it is especially concerning that much of injury-preventative piano pedagogy recommends against AMCC, especially during attempted rehabilitation (e.g., Mark, 2004). This review provides ample reason to reexamine such recommendations. An important caveat to be discussed in future publications is that *excessive* and/or *static* AMCC can have injurious, rather than rehabilitative or preventative, effects. This is not unique to AMCC, but seems true for any kind of muscular activity or energy expenditure.

3.2.2.2 Preventative

Baratta et al. (1988) cautioned that a "reduced coactivation pattern of the unexercised antagonist…increases the risk of ligamentous [knee] damage" (p. 113), therefore recommending that AMCC could reduce "risk of knee injuries in high performance athletes" (p. 113). Baratta et al. (1988)

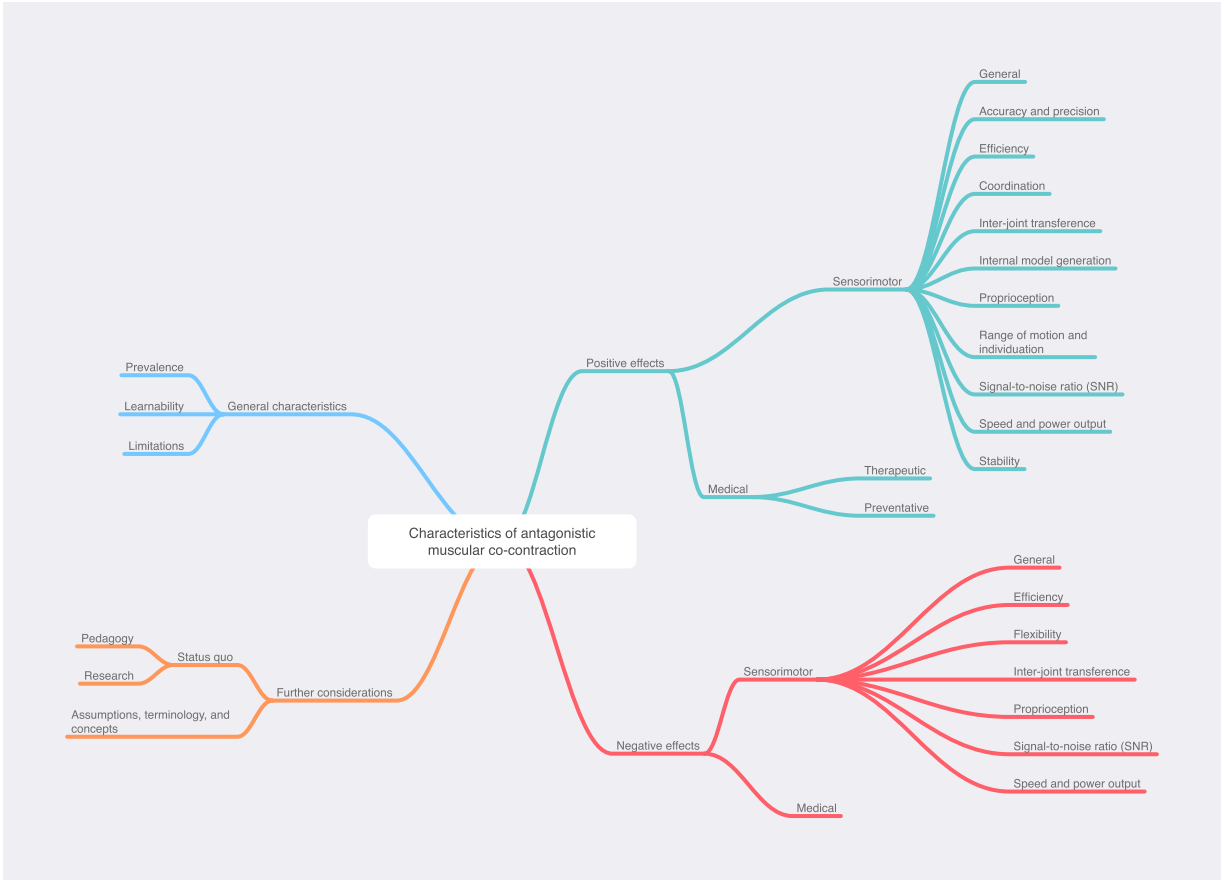

FIGURE 3
Characteristics of antagonistic muscular co-contraction (network).

also noted that AMCC is important to distribute "articular surface pressure…under various loading conditions"; without this AMCC, articular surface separation "will create a focused stress point that will rapidly contribute toward focal deterioration along the articular surface and result in early tissue damage and osteoarthritis" (p. 120). By extension, it is apparent that AMCC could reduce the risk of PRNDs by creating "nearly equal pressure distribution over the complete articular surface contact area," arrangements which "reduce the overall articular surface pressure, prevent focal surface damages, and elongate the period over which good functional service could be provided by the articular interface" (p. 120). Additionally, in regards to muscle hypertrophic imbalance, "the coactivation pattern of the antagonist to hypertrophied muscle is significantly inhibited and subjects the joint to a high risk of injury. A complementary resistive exercise for the antagonist…may restore the muscular balance and reduce the exposure to ligament injury risk" (p. 121).

Hirokawa et al. (1991) noted that "additional evidence…supports the notion that hamstring antagonist co-contraction serves to relieve strain in the ACL…and also to reduce rotary laxity of the knee significantly" (p. 199), hypothesizing that "hamstrings co-contraction, during knee extension, can prevent anterior or rotary displacement of the tibia and thereby reduce the strain on the ACL" (p. 199). Hirokawa et al. (1991) additionally found that "significant anterior displacement and internal rotation of the tibia occurred during isolated quadriceps loading, whereas significant reduction in anterior displacement and rotation occurred upon simultaneous low-level loading of the hamstrings" (p. 199). Hirokawa et al. (1991) also commented that "voluntary increase in hamstring co-contraction, coupled with the fact that increase in its force increases its effectiveness as a synergist to the ACL, could be used advantageously as effective therapy in ACL-deficient patients" (p. 206). Aune et al. (1995) found that "hamstrings and gastrocnemius co-contraction protects the anterior cruciate ligament against failure" in rats (p. 147). This protection occurred as "the simultaneous contraction of the quadriceps, hamstrings, and gastrocnemius controlling knee flexion may unload the cruciate ligaments entirely" (p. 150). Rothmuller and Cafarelli (1995) argued that AMCC helps to "avoid excessive strain on the joint capsule… safeguard[ing] the agonist muscle against complete exhaustion" (p. 864).

Yeadon et al. (2010) noted that "[i]n landings from a flight phase the mass center of an athlete experiences rapid decelerations" (p. 364). Through observing muscle use during an elite martial artist's landings with sEMG, and simulating these landings in a computer model, Yeadon et al. (2010) found that "co-activation…was necessary to land successfully from heights greater than 1.05 m" (p. 367), and moreover that this lack of preemptive co-contraction can place the knee in an "inappropriate and possibly dangerous position for landing" (p. 364). Yeadon et al. (2010) suggested that "[t]he same considerations apply in any activity where rapid changes in net joint torque are required" (p. 369). Billot et al. (2014) found that, despite elevated knee AMCC in older males, "antagonist torques were not responsible for age-related declines" in knee joint torques (p. 899). These findings suggest that increased AMCC in aged

populations is not a contributing factor to impaired function, instead being "mainly described as a protective mechanism at a joint" (p. 900). Holmes et al. (2014) noted that "uncoordinated muscle actions may lead to wrist joint instability and/or injury," and that AMCC "aided control of the wrist," establishing the value of AMCC for healthy movement (p. 1). Ranavolo et al. (2015) developed a new index to evaluate AMCC in work activities, noting that AMCC helps to "provide added protection and avoid LBDs [low-back disorders]" (p. 1).

Shiba et al. (2015) explored electrically stimulated AMCC in an astronaut on the International Space Station, attempting to mitigate disuse muscle atrophy. Shiba et al. (2015) found that electric stimulation of AMCC during exercise had a "preventive effect…on an astronaut's musculoskeletal atrophy" (p. 12). Le et al. (2017) hypothesized that sedentary work "may require intermittent periods of increased coactivation in order to encourage blood flow and muscular substitution to mitigate myalgia or myofascial pain from prolonged loading" (p. 3). Oliveira and Sanders (2017) found AMCC throughout the eggbeater kick, which was highest in the "final phase of knee flexion" (p. 88–89), which allowed "rapid reversal of the motion from flexion to extension while also stabilizing the joint to prevent injury…requiring increased muscle co-activation" (p. 89). DeMers et al. (2017) found that "strong preparatory co-activation…prevented ankle inversion from exceeding injury thresholds" in landings, while "conversely, stretch reflexes were too slow to generate eversion moments before the simulations reached the threshold for inversion injury" (p. 1). High-force impacts between fingers and keys also pose stability and injury concerns, especially given the physically repetitive nature of pianism.

Sousa (2018) proposed that "assuming the hypothesis that the activity of all muscles within the system is independent…it can be hypothesized that subjects with chronic ankle instability…would present deregulation of antagonist co-activation at the ankle joint level during compensatory postural responses to an external perturbation" (p. 169). Sousa (2018) found "differences between groups for antagonist co-activation…only observed in MLR [medium latency responses]" (p. 171). These responses are considered important because "only MLR responses [sic] have a stabilizing effect during perturbations of stance" (p. 172). Specifically, these differences were "increased antagonist co-activation of MLR of SOL/TA [soleus/tibialis anterior] in a support position and decreased antagonist co-activation of MLR in TA/P [tibialis anterior/peroneus] in the uninjured limb in the support position and in the injured lim [sic] in the perturbed position" (p. 172). However, this "bilateral decrease of antagonist co-activation…would be [sic] probably lead to decreased mediolateral functional ankle stability" (p. 172). Overbeek et al. (2019) explored AMCC in arm movements across age groups, noting that AMCC "may be crucial for counteracting deltoid forces, depressing the humerus and ensuring free passage of subacromial tissues underneath the acromion during abduction" (p. 1). Overbeek et al. (2019) found that middle-aged individuals used more shoulder AMCC than young adults, concluding that "[t]his may indicate that during ageing, alterations in activation patterns are required for preserving pain-free shoulder function" (p. 1). Flaxman et al. (2021) found that "quadriceps hamstring co-activation was associated with knee abduction" in weightbearing (p. 1). These results "highlight the importance of muscular co-activation of all muscles crossing the knee to support it during injury-inducing loading conditions such as externally applied knee abduction and rotation" (p. 1).

Musicians, including pianists, are athletes of the small muscles (Quarrier, 2013); AMCC's injury-preventative function also imply the importance of developing a piano pedagogy that seeks the proper integration of AMCC in piano technique from the early stages of beginner-level training; this should help reduce the incidence of PRNDs faced by the developing pianist.

3.3 Limitations; assessment of risk of bias

Perhaps the foremost limitation of this review is that it omits sections regarding the negative effects, limitations, origins, learnability, and state of knowledge on AMCC, due to limitations of space. These topics are to be discussed in future publications. A second limitation of this review is its English-centric approach. Because only English-language articles were considered for inclusion, this review cannot offer perspective on AMCC and piano technique research outside the English-speaking research sphere; particularly, Chinese-language articles, given the piano's popularity in China, and steady rises in Chinese-language research output, are a notable omission here. A further limitation of this review is that it was conducted primarily by one individual (CA), though with supervision by GW and AW; CA's personal understanding of AMCC and his own perspective on piano technique both contributed to the analysis and synthesis of concepts in this review. Nevertheless, we propose that the findings of this review do not depart significantly from the included studies themselves, and furthermore, that the propositions made here regarding the nature of skilled, healthy piano technique (for example, that it requires refined proprioception and efficient movement) are uncontroversial.

4 Discussion

4.1 Conceptual framework of AMCC, in summary

This review has illustrated the nature of AMCC via its synthesized conceptual framework, which manifested into the following meta-categories:

- General characteristics (section 3.1)
- Positive effects (section 3.2)
- Negative effects*
- Further considerations*

*As noted, the "Negative effects" and "Further considerations" sections are not published in this article due to space considerations, but are to be discussed in future publications.

These categories and their sub-areas represent a 34-point framework suggesting AMCC's duality and complexity, providing a rich theoretical base for subsequent inquiry into AMCC's role in healthy, skilled piano playing.

Figure 3 depicts the characteristics of AMCC identified by this review.

Given the characteristics and effects of AMCC outlined here, more targeted investigation of AMCC's roles specifically in piano technique is required to sufficiently fulfill the aims of this inquiry; CA's doctoral thesis proceeds along these lines. Of the 188 publications included in this literature review, only 14 discuss AMCC in piano technique directly, and of these, a single study (Furuya and Kinoshita, 2008; see section 3.2.1.9)

TABLE 1 Summary of highest-relevance publications.

	Discusses AMCC in piano technique	Investigates AMCC in piano technique	Focuses on AMCC in piano technique	Real participants	Selected satisfactorily for healthy, skilled pianists	Robust, valid methodology
Furuya and Kinoshita (2008)	√	√	√	√	Partially	√
Furuya et al. (2007)	√	√	√	√	?	√
Andison (2011)	√	√	√	√	No	No
Wheatley-Brown (2011)	√	√	√			
Furuya (2012)	√	√		√	Partially	No
Ortmann (1929)	√	√		√	?	
Yoshie et al. (2009)	√	√		√	?	
Stanier (1973)	√	√				
Furuya and Soechting (2012)	√			√	Partially	No
McCarthy (2016)	√			√	Partially	Yes
Taubman et al. (2005)	√					
James (2012)	√					
Goebl (2017)	√					
Lister-Sink (2018)	√					

had the requisite methodology and design to begin to directly answer the research questions posed by this review. Table 1 summarizes these 188 publications. As such, the present ongoing research continues to explore AMCC's characteristics, accounting for its aspects of duality and complexity and handling the set of yet-unaddressed considerations raised in the development of the above framework, which provides a foundation for this further inquiry, synthesizing AMCC's known characteristics. As such, the findings of the review constitute a valuable step toward situating AMCC in our understanding of healthy, skilled piano technique, which remains a key need for pianists.

Data availability statement

The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding author.

Author contributions

CA: Writing – original draft, Writing – review & editing. GW: Supervision, Writing – review & editing. AW: Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2025.1386273/full#supplementary-material

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A scoping review of mental health literacy in performing and creative artists: identifying current gaps and future directions

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Introduction: Mental health literacy is a multifaceted construct that consists of helping individuals recognize the early warning signs of mental health conditions, understanding the concept of stigma and misconceptions associated with mental illness, encouraging appropriate help-seeking behaviors, and facilitating access to mental health services. However, mental health literacy remains a largely unexplored topic in artists' health literature. This scoping review examines the conceptualization, operationalization, and measurement of mental health literacy in performing and creative artists.

Methods: We conducted a comprehensive search across multiple databases, including MEDLINE, CINAHL, PubMed, EMBASE, PsycINFO, Web of Science, and Cochrane. Our search was designed to identify articles relevant to mental health literacy among artists, encompassing aspects related to the understanding, identification, and education of mental health conditions. Two independent reviewers conducted both abstract and full-text screenings. Our findings are synthesized using the four components of mental health literacy as a framework for organization.

Results: Of the 669 unique citations, 26 articles met the inclusion criteria; of these, 23 focused on performing artists. The articles were published between 1997 and 2024, with at least 4,710 participants from nine countries. Only one study included a definition of mental health literacy. Sixteen articles included one of the four components of mental health literacy, nine included two, four included three, and one had all four components.

Discussion: Despite the high prevalence of mental health challenges among performing and creative artists, there is a disproportionately low number of interventions aimed at increasing mental health literacy compared to other fields, such as sports medicine and education. This highlights the need for more comprehensive efforts to increase awareness and understanding of mental health issues among artists. Furthermore, the lack of consensus on the conceptualization, operationalization, and measurement of mental health literacy in this field prompts further research. A standardized definition and validated instrument could facilitate more robust research on mental health literacy in the artists' health literature and help identify effective interventions. Future research can build on this review to develop and evaluate interventions aiming to improve mental health literacy in artists.

KEYWORDS

mental health literacy, scoping review, artists, mental health, performing arts

Introduction

Performing and creative artists, such as actors, sculptors, painters, musicians, acrobats, and dancers; are at an increased risk of mental health challenges, including depression, performance anxiety, burnout, and substance abuse, compared to the general population (van den Eynde et al., 2016; Power et al., 2015). For instance, individuals in creative industries have experienced rates of depression five times greater (van den Eynde et al., 2016) and were treated for mental health problems more frequently than the general population (Kyaga et al., 2011, 2013). Among musicians, higher symptoms of both anxiety and depression were reported when compared to the general population, as demonstrated in Norwegian (Détári et al., 2020; Vaag et al., 2016) and United Kingdom (UK; Gross and Musgrave, 2016) samples. Specifically, musicians' tendency to have maladaptive perfectionism (excessive concerns about being evaluated) is significantly correlated with anxiety, which leads to heightened risks of long-term mental health challenges (Alpheis and Altenmüller, 2024). Heightened risks of mental health challenges in the artistic population have been associated with a range of contextual factors unique to the arts industry, including the intense pressure to perfect their artistic practice (Dwarika and Haraldsen, 2023; Patston and Osborne, 2016; Pecen et al., 2018), the social isolation and rejection that can come with the industry (Duarte, 2020), financial precarity (King et al., 2019; Loveday et al., 2023), and the inevitable scrutiny and negative evaluation of their practice (Osborne et al., 2005). In addition, a recent study using a social-ecological model to map the health determinants of artists found that artists' identities are deeply intertwined with their creative work. Their sense of self-worth is often closely linked to their artistic productivity, making them particularly vulnerable to mental health challenges during periods when they are unable to create or encounter setbacks in their artistic careers (Li et al., 2024). Perhaps more concerning is the additional evidence suggesting that mental health problems are already prominently reported among college and university arts students (Dempsey and Comeau, 2019; Kenny et al., 2014) or even earlier, particularly for performing artists, during training in adolescence and childhood (Anderson, 2011; Kaleńska-Rodzaj, 2020).

Despite the prevalence of mental health challenges in performing and creative artists, help-seeking behaviors in this subpopulation have been reportedly low. A recent study found that help-seeking behaviors are even lower among musicians who have greater depressive symptoms (Rosenbaum and Weibelzahl, 2023). Researchers in sports medicine have long recognized that (i) one of the main barriers to seeking mental health treatment is low mental health literacy (Castaldelli-Maia et al., 2019), and (ii) mental health literacy interventions are effective in increasing help-seeking behaviors and reducing self-stigma among athletes (Breslin et al., 2018; Bu et al., 2020; Gorczynski et al., 2021; Kern et al., 2017). In school settings, mental health literacy interventions are frequently embedded in educational curricula to decrease stigmatizing attitudes and support early detection of mental health disorders (Kutcher et al., 2013; Mcluckie et al., 2014; Merritt et al., 2007). In one of the few studies that examined mental health literacy in performing artists, investigators found that musicians with lower mental health literacy experienced higher levels of performance-related health issues (Guptill et al., 2022). Researchers recognize the importance of educating performing and creative artists about mental health and enhancing help-seeking attitudes to prevent or manage mental health conditions; however, the topic of mental health literacy is rarely addressed in the artists' health literature.

Mental health literacy is an evolving concept. Since 2000, it is considered a multifaceted construct that comprises of four major components: (i) recognition of mental health disorders, (ii) knowledge of their risk factors and of seeking mental health information and support services, (iii) attitudes that promote recognition and appropriate help-seeking; and (iv) understanding the concept of stigma, which promotes self-help strategies and help-seeking efficacy (Jorm, 2000; Sampaio et al., 2022). The recognition of mental health risks and their symptoms in artists are critical to their well-being, since awareness and appraisal of the problem allow for healthy help-seeking behaviors (Rickwood et al., 2005). It is particularly important for artists to understand the symptoms of mental health problems that are common in their discipline (Cardinal and Hilsendager, 1997). Knowledge of risk factors can be used to help prevent mental health problems, and it may also influence decisions related to seeking help and uptake of treatment (Jorm, 2012). Similarly, knowledge related to information and support services may also impact the individual's ability to receive treatment and respond to treatment instructions (Jorm, 2000). An artist with adequate mental health literacy may be more likely to recognize the early warning signs of a mental health condition, such as depression or anxiety, and seek help and support before the condition becomes more severe. They may also be more likely to understand how to manage and cope with the stress and pressure that comes with the industry, which can help prevent the onset of mental health challenges and reduce the stigma surrounding mental health conditions (Bennett et al., 2023).

While the existing literature in other fields, such as sports medicine and education, demonstrates the importance of mental health literacy and has operationalized this concept, its status in artists' health literature remains unclear. The objectives of this scoping review are to identify the literature on mental health literacy in the artists' health discipline, clarify how mental health literacy is conceptualized, operationalized, and measured in artists' health literature, and summarize our main findings of these publications. Conceptualization involves defining or specifying the meaning of mental health literacy. Different researchers may conceptualize a concept slightly differently. Operationalization is the process by which a researcher precisely specifies how a construct will be empirically investigated. Operationalization works by recognizing specific indicators that are measurable and/or observable in research. Measurement represents the process of observing and recording the observations that are collected as part of the inquiry (Jiao et al., 2022).

Research questions

The following research questions (RQ) are used to guide our scoping review:

> *RQ1:* What types of research designs, methods, publication sources, and populations are conducted in the research on mental health literacy in the artists' health literature?
>
> *RQ2:* How has mental health literacy been conceptualized, operationalized and measured within the artists' health literature?

To address the research questions, we developed a protocol (Moher et al., 2015) in alignment with the objectives of a scoping

review, which aims to delineate the extent or range of a body of literature on a specific topic, elucidate research methodologies employed, and provide an overview of existing literature (Munn et al., 2018). Table 1 presents the definitions and parameters that guided our approach to conceptualize, operationalize, and identify measures of mental health literacy within the context of our scoping review. We also used the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist (Tricco et al., 2018) to guide our scoping review protocol development and reporting (Appendix 1).

Methods

Databases searched

We sought relevant articles pertaining to mental health literacy in artists, including the understanding, identification, and treatment of mental health conditions. MEDLINE, EMBASE, PubMed, CINAHL, Web of Science and PsycINFO databases were searched from database inception to week 1 of June 2025.

Search strategy

A search strategy was created in a consultation meeting with a University of Toronto librarian. We followed the Peer Review of Electronic Search Strategies (PRESS; McGowan et al., 2016) guidelines to optimize sensitivity and specificity of our search results. The search strategy for MEDLINE (see Appendix 2) was adapted to PubMed, PsycINFO, and EMBASE databases. The strategy included separate terms related to artistic professions, as well as health literacy, mental wellness, and a variety of psychiatric illnesses.

Eligibility criteria of included studies

We included publications that (i) investigated artists, art workers, art students, or art educators; (ii) assessed mental health literacy, mental health education, and/or mental health promotion; and in English language. Articles could be of any study design or publication (peer-reviewed articles, conference abstracts, protocols, dissertations and theses, and book chapters). We excluded publications that: (i) reported only on the prevalence, etiology, treatment or assessment of any mental disorder classified in the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition Text Revised (DSM-5-TR), (ii) investigated or described the use of art to improve health and/or to promote health education of individuals who are not creative or performing artists, (iii) reported only on the physical health of creative or performing artists, (iv) are not written in English language, and (v) are not peer-reviewed.

Study selection

The database search produced 625 unique citations (Appendix 3: PRISMA 2020 flow diagram). Two investigators (SAL, NS) independently screened the title and abstracts for inclusion. Discrepancies were resolved in two consensus meetings. An additional 44 papers with relevant titles and abstracts were found through handsearching of the reference list of included articles eligible for full-text screening ($n = 53$). Three papers could not be retrieved. Of the 50 articles available, 26 remained upon completion of the review process (see Appendix 3 for reasons for exclusion).

Data abstraction

To extract data from the included studies, we used the following categories: first author and setting, study design, sample, data collection methods, main findings, and specifically noted whether the included studies had a definition of mental health literacy.

Analysis and presentation of results

Narrative summaries were included to complement the tabular results, and we discussed how the findings relate to the research question and objectives (Khalil et al., 2021). For all parameters of investigation (conceptualization, operationalization and measurement) in this review, we used the existing components of mental health literacy (Jorm, 2000) as a guiding framework of our analysis. In addition to this descriptive narrative summary, we conducted a thematic analysis of the literature using qualitative description (Sandelowski et al., 2009) for the operationalization parameter of mental health literacy. We used thematic analysis specifically for this parameter because it involves identifying concrete indicators aligned with the four established components of mental health literacy. This level of detail benefits from thematic analysis to systematically categorize how components were applied across studies. In contrast, data within the conceptualization measurement parameters of the included studies were more varied and

TABLE 1 Description of key terms and parameters for data extraction.

Term	Operational definition	Parameters for data extraction to inform understanding of mental health literacy
Conceptualization	Assigning meaning to something	Definition of mental health literacy, and main components of mental health literacy
Operationalization	Selecting observable phenomena to represent abstract concepts	Dimensions and indicators of mental health literacy Based on our indicators, what questions were asked to represent mental health literacy, what observations were made, what specific attributes are measured?
Measurement	Process of observing and recording observations, or assigning numbers to a phenomenon	Level of measurement such as nominal, ordinal, interval or ratio and type of measures such as survey, scaling, qualitative, used for mental health literacy

straightforward (e.g., whether they used an individual interview or questionnaire to assess mental health literacy constructs), respectively, making them better suited to remain as descriptive narrative syntheses rather than thematic categorization. In the thematic analysis, we (i) applied a within-case approach, which included a synthesis of the main findings of all studies identified, (ii) identified and developed descriptive themes and categories across the studies, (iii) summarized and developed overarching main findings within topics from a between-case approach (i.e., categories), and (iv) meta-analyzed the findings to answer the research questions (Dwarika and Haraldsen, 2023). The findings were categorized in accordance with an understanding of mental health as a complete and dynamic state (Keyes, 2002; Lazarus and Folkman, 1984). The thematic analysis followed the guidance of Clarke and Braun (2013).

Specifically, two coders independently read the included studies twice to familiarize themselves with the articles, and made written notes about the main points of each article. Next, an initial codebook was developed based on the four pillars of mental health literacy as a guiding framework, which contained each code and its definition, with at least one illustrative quote that represented the concept of the code. Coding and re-recoding was an iterative process that involved coders moving back and forth throughout the dataset to explore the breadth of mental health literacy and depth (how it was being operationalized). As coding progressed, two consensus meetings were held between the two coders to refine the codes across the included studies. In alignment with the qualitative description, coders stayed close to the report of each included study to ensure that codes were descriptive (semantic), capturing obvious surface meanings in the data rather than interpretative (latent) that captures implicit meaning.

We used the 15-point checklist of criteria for thematic analysis (Clarke and Braun, 2013) to ensure rigour in collating and summarizing the results. NVivo 12 Pro was used to organize the abstracted data into themes and codes, which were further explored in the results section of this review. Findings were organized into thematic categories including methodological design and key findings, but also by categories that specifically highlighted the theoretical and operational linkages such as context, conceptual and operational features, and measurements used.

Consultation with stakeholders

We consulted with 8 knowledge stakeholders, who were either leaders in the research and practice of performing arts medicine, performing and creative artists in Canada and the United States; or practitioners who specialize in providing care to artists of all disciplines. We asked whether they knew of mental health literacy documents, literature, or peer-reviewed studies that pertain to artists. None of the stakeholders have identified any information regarding this topic. Findings from this scoping review will be returned to these stakeholders.

Results

Characteristics of included studies

Supplementary Table 1 presents the characteristics of the 26 included studies. The studies were published between 1997 and 2024 and were based in nine countries. At least 4,710 participants were included in the review. At least 32% (n = 1,502) of the participants included in this review were musicians, followed by participants in artistic disciplines such as dance (n = 608; 13%), circus art (n = 87; 1.8%), writing (n = 87; 1.8%), and visual art (n = 276; 6%). Most studies included students as the participants (n = 3,848; 82%), as the purpose of these studies was to evaluate strategies of health promotion and injury prevention in secondary and post-secondary education programs. Two of the studies included participants who were in administrative and leadership roles at these educational institutions, while 6 (23%) studies included participants who identified as professional working artists. Out of the 26 articles, eight referenced interventions for Music Performance Anxiety (MPA). These interventions included physical techniques such as deep breathing exercises, workshops during which students would perform for one another, instruction on coping mechanisms such as time management skills and self-care techniques, and group education programs.

Conceptualizing mental health literacy

Only one study included a definition of mental health literacy (Barnett et al., 2019), and it conceptualized mental health literacy as knowledge of mental health issues and services. The included studies that conceptualized at least one component of mental health literacy sampled dancers, musicians, visual artists, circus artists, and novelists. Thirteen articles (46.2.%) included one of the four components (Atkins, 2009; Barnett et al., 2019; Bartos et al., 2022a, 2022b; Cardinal and Hilsendager, 1997; Griffith, 2023; Guptill et al., 2022; Harrison et al., 2019; Kaufman et al., 1996; Qu, 2022; Smith, 2021; Stuckey et al., 2021; Torres-McGehee et al., 2011; Walker and Nordin-Bates, 2010), eight (30.7%) included two components (Barton and Feinberg, 2008; Cardinal et al., 2020; Clements-Cortés et al., 2024; Ginsborg et al., 2012; Moore et al., 2024; Shaw et al., 2020; Uriegas et al., 2024; Žilinskas and Lesinskienė, 2023), four (15.4%) had three components (Mathisen et al., 2022; Rosset et al., 2022; Washington-Simon, 2024; Williamon et al., 2006), and one (5%) had all four components (Perkins et al., 2017). The following sections report how our included studies conceptualized each of the four mental health literacy components.

Recognition of mental health disorders

The recognition of mental health disorders was reflected in nine studies through either educating artists on mental health disorder symptoms (Cardinal and Hilsendager, 1997; Clements-Cortés et al., 2024; Mathisen et al., 2022; Shaw et al., 2020; Smith, 2021) or developing self-awareness (Harrison et al., 2019; Perkins et al., 2017; Qu, 2022; Rosset et al., 2022). There was one qualitative, three experimental, one mixed method, two cross-sectional, and two case studies. Cardinal and Hilsendager (1997) defined the ten curricular components of their dancer wellness education model, which included "psychology." Under this curriculum component, they emphasized the importance of recognizing early warning signs of mental health disorders to facilitate appropriate access to services. The cross-sectional study by Cardinal et al. (2020) examined the dancer wellness education provided by post-secondary institutions. "Psychology" was identified as one of the possible course offerings in dance wellness education. The case study conducted by Shaw et al. (2020) discovered

that a music teacher without psychotherapy training successfully identified a music student with problematic levels of MPA by identifying common MPA symptoms. The authors discussed the potential advantages of training music teachers to recognize symptoms of mental health issues in their students and the importance of self-awareness, which requires the individual to be attuned to their mental state. This may facilitate the recognition of mental health disorders.

Clements-Cortés et al. (2024) provided music psychotherapy sessions designed to cover the recognition of MPA symptoms. Participants of this study reported having a refreshed recognition of MPA symptoms and more self-awareness and adaptive cognitions about MPA. Mathisen et al. (2022) acknowledged that improving mental health literacy included raising awareness about mental health disorders and symptoms. These authors included understanding "physical and mental health (definition, understanding, symptoms, frequency)" (p. 4) as part of an intervention designed to increase mental health literacy in dancers. Finally, Žilinskas and Lesinskienė (2023) found that arts students ranked second highest in suicide literacy, following biomedical students, in higher education settings in Lithuania. Overall, most studies included the recognition of symptoms of mental health issues more generally instead of mental health disorder-specific symptoms.

Knowledge of risk factors and causes and use of mental health information and support services

Fourteen studies discussed the knowledge of risk factors and uptake of mental health information and use of support services (Atkins, 2009; Barnett et al., 2019; Cardinal et al., 2020; Ginsborg et al., 2012; Kaufman et al., 1996; Mathisen et al., 2022; Rosset et al., 2022; Perkins et al., 2017; Stuckey et al., 2021; Torres-McGehee et al., 2011; Walker and Nordin-Bates, 2010; Washington-Simon, 2024; Williamon et al., 2006).

Five studies were intervention studies (Kaufman et al., 1996; Mathisen et al., 2022; Rosset et al., 2022; Stuckey et al., 2021; Torres-McGehee et al., 2011), and were or are being conducted in school or university settings. Eight studies were descriptive (Barnett et al., 2019; Cardinal et al., 2020; Ginsborg et al., 2012; Perkins et al., 2017; Walker and Nordin-Bates, 2010; Williamon et al., 2006; Washington-Simon, 2024; Uriegas et al., 2024). Of these, five sampled student populations. Atkins' (2009) case studies on seven conservatoires in Britain found that conservatoires conceptualized provision of support services as offering psychological services such as counseling as well as accessibility to information, support, funding, and treatment. Williamon et al. (2006) highlighted a need for more curriculum initiatives aiming to increase music students' knowledge of mental health after finding that students primarily sought advice from their instrument teachers rather than healthcare professionals. Conservatory students reportedly had little awareness of existing support services and mental health risk factors (Perkins et al., 2017). It is possible that the psychology courses by Cardinal et al. (2020) could include knowledge of risk factors and causes related to mental health literacy, but this was not explicit. Finally, a cross-sectional study surveying gender diverse marching band musicians in US collegiate institutes found that almost all (96%) previously identified a mental health condition, and most of them (79.5%) sought mental health support (Uriegas et al., 2024).

Four studies focused on or included professional populations. An exploratory study by Walker and Nordin-Bates (2010) found that dancers in one elite dance company primarily relied on self-learned strategies when dealing with mental health challenges. Although not stated in the article, this could imply a lack of use of professional services. Barnett et al. (2019) found that participating in an exhibition designed to reduce stigma related to mental health within the general community increased knowledge of mental health issues and services in the exhibiting visual artists themselves. The literature review by Ginsborg et al. (2012) highlighted the need for musicians, including professionals, to be aware of personal risk factors and the underlying causes of various physical and mental health problems, such as music performance anxiety. Finally, Washington-Simon's (2024) dissertation highlighted that Hip Hop musicians perceived that financial instability, differential treatment from society (because of stereotypes specific to Hip Hop community about being preoccupied with drugs, violence and sex), are risk factors to mental health disorders.

Attitudes that promote recognition and help-seeking

Ten studies investigated attitudes related to mental health, most of which studied musicians. Of these studies, three investigated the attitudes held by musicians towards mental health (Ginsborg et al., 2012; Perkins et al., 2017; Rosset et al., 2022), one discussed the importance of attitude in promoting healthy behaviors (Barton and Feinberg, 2008), one delivered an intervention that included fostering positive perspectives during adversity (Bartos et al., 2022a, 2022b), and one administered a music psychotherapy intervention in a group setting, which allowed participants to foster a sense of connection and support with their peers, allowing them to discover that they can reach out to others as a tool for helping them cope with MPA (Clements-Cortés et al., 2024). A study evaluating psychological help seeking attitudes among higher education students in Lithuania, which included arts students, but the report did not provide any subgroup analyses for arts students (Žilinskas and Lesinskienė, 2023).

In their literature review, Ginsborg et al. (2012) noted that professional musicians were either unable or not motivated to prioritize physical and mental wellness despite high levels of health issues within the profession. Music students tended to place greater importance in mental health, as demonstrated by Perkins et al. (2017) and Rosset et al. (2022). Rosset et al. (2022) also found that music students relied primarily on social support as a coping strategy in stressful situations. Marching band musicians were reported to be open to seeking mental health support, which positively correlated with their favorable attitudes toward mental healthcare (Moore et al., 2024). Furthermore, the authors noted that participants did not frequently cite a lack of knowledge about available services or the belief that no one would understand their mental health problems as significant barriers to seeking support (Moore et al., 2024). However, a gender-diverse subgroup of marching band artists from the same study (Uriegas et al., 2024) reported slightly less positive attitudes toward seeking mental health support, expressing concern that "no one will understand their problems." Hip Hop musicians expressed that the perception of being undervalued coupled with financial barriers limited their options to mental healthcare accessibility (Washington-Simon, 2024).

Although perspective towards health was not measured in this study, Barton and Feinberg (2008) reflected after completion of a study designed to promote healthy behaviors in music students that future health promotion strategies should target changing attitudes towards

health and well-being. Bartos et al. (2022a, 2022b) employed a yoga and mindfulness intervention that focused on cultivating positive perspectives towards adversity, which resulted in enhanced empowerment and positive attitudes towards help-seeking in music students. Finally, one of the studies (Study 1) in Griffith's (2023) dissertation reported that visual artists used art to process emotions, helping them better understand and recognize their mental health challenges. Art was also seen as a way to "open the door" for communicating about mental health conditions and reaching out for help—particularly through digital platforms like Instagram, where artists described the benefits of building an online support system that encouraged help-seeking for themselves and for others.

Understanding the concept of stigma

Seven studies conceptualized mental health stigma within the artistic environment, four of which were in music, one in visual arts, and one in dance. Four of these articles reported that music students tend to not discuss mental health issues (Mathisen et al., 2022; Perkins et al., 2017; Smith, 2021; Williamon et al., 2006); however, support from instrumental teachers and from the musical community emerged as facilitators of the mental and physical well-being of students. The fifth study, Shaw et al. (2020), identified that there is stigma around working with healthcare professionals and found that one possible solution may be to train music teachers to offer mental skills training. Although stigma was mentioned in the four articles above, it was not the core focus of any of them. Mathisen et al. (2022) acknowledged that culture- and self-stigma contribute to low mental health literacy among dancers. Smith (2021) suggested that concealment of mental health challenges within the music industry may be due to fear of negative judgment or related to employment prospects. Among Hip Hop musicians, stigma had a substantial impact on mental health attitudes and hindered their willingness to seek support. They also expressed concern that potential judgment from fans, peers, and industry partners often limited their ability to prioritize their own mental health (Washington-Simon, 2024).

Operationalizing mental health literacy

We summarize how the authors of the included studies operationalized the four components of mental health literacy (Figure 1). All studies in our review operationalized at least one component of mental health literacy. In these studies, the investigators operationalized these components through interventions (such as mobile applications), assessments (using validated instruments or qualitative assessments that target at least one aspect of mental health literacy), and educational sessions (courses). Table 2 presents the categorized operationalizations for each component of mental health literacy along with relevant, illustrative excerpts from the respective studies.

Recognition of mental health disorders

Seven studies operationalized the first component of mental health literacy. Harrison et al. (2019) investigated the impacts of a mobile application that monitors various well-being components of physical and psychological well-being. Although this study did not specifically target mental health disorders, the psychological components monitored by the application included stress, fatigue, and sleep quality, which can be symptoms of mental health disorders depending on the frequency and intensity at which they are experienced. Perkins et al. (2017) found that 95% of university music students and recent graduates reported high levels of self-awareness; however, this referred to an overall mental state and was not specific to the recognition of mental health disorders. An experiment by Rosset et al. (2022) included self-awareness as part of a general health course for musicians. The course itself contained mental health components, but it was not specified as to whether self-awareness was for physical or mental health purposes. Shaw et al. (2020) conducted a study examining whether students with MPA would achieve similar results when receiving acceptance and commitment coaching (ACC) from a singing teacher compared to receiving it from a clinical psychologist. As self-awareness was integrated into the ACC, we decided to include this component as representative of operationalizing mental health literacy. Qu (2022) found that after participating in an expressive art therapy intervention, post-modern novelists developed a greater sense of self-awareness. Clements-Cortés et al. (2024) incorporated recognizing performance anxiety symptoms in an intervention for musicians. Barnett et al.'s (2019) Rural Art Show allowed creative artists to increase their knowledge about mental health issues, symptoms and services.

Knowledge of risk factors and causes and use of mental health information and support services

Seven studies operationalized the second component of mental health literacy. Kaufman et al. (1996) examined the impact of an intervention targeting dieting behaviors and stress fractures on adolescent ballet students. The intervention consisted of lectures on medical, nutritional, and psychological issues, as well as additional counseling and physical therapy support. The lectures provided information on the causes of eating disorders, which are classified as a mental health disorder under the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (2013). Mathisen et al.'s (2022) intervention aimed to increase mental health literacy by teaching university dance students about nutrition, eating disorders, and recovery strategies. The intervention by Torres-McGehee et al. (2011) focused entirely on the prevention and consequences of eating disorders by providing information on nutrition, exercise, and depression to collegiate dance students.

Three studies examined populations outside of dance. Rosset et al. (2022) examined the impacts of a musicians' health course on post-secondary music students. The authors observed moderate baseline health knowledge among music students, with the intervention group showing increased knowledge post-test. The intervention encompassed general health and stress management strategies, but it was unclear whether the intervention had any focus on mental health risks. Stuckey et al. (2021) is conducting an ongoing longitudinal study on the impacts of a holistic, resilience-focused intervention program on the mental well-being, creativity, and lifestyle habits of college circus students. The intervention targets physical literacy and is based on the Circus for Development Model. This model encapsulates psychology as a component of physical literacy. This particular intervention will include teaching participants about community resources that are available, but the article does not specify whether these community resources are mental health-specific or more relevant to general health. Guptill et al. (2022) investigated the validity and reliability of the MHL-Q19, which is a tool that assesses general

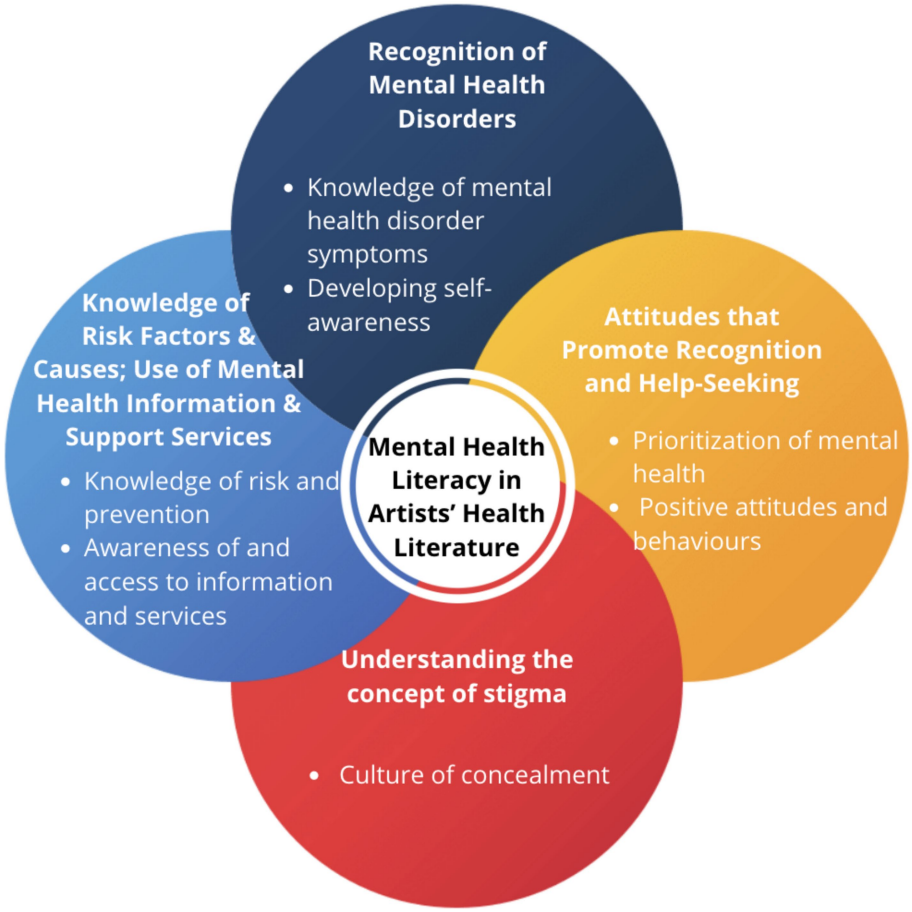

FIGURE 1
Four components of mental health literacy (Jorm, 2000) operationalized in artists' health literature.

health literacy, in musicians. The tool assesses the individual's ability to access, understand, appraise, and apply information related to performance health. Participants in this study were post-secondary music students. Even though the MHL-Q19 did not include specific components of mental health literacy, three of the questions may be adapted to understand mental health literacy, including finding risks about performance health, understanding risks related to performance health, and finding reliable information on performance health. Griffith (2023) interviewed visual artists about mental health and social media. Lack of information and ability to navigate health systems were identified as two barriers to mental health treatment in artists. Advocacy and mental health awareness were identified as two protective factors.

Attitudes that promote recognition and help-seeking

Six studies operationalized the third component of mental health literacy. Barton and Feinberg (2008) investigated the impacts of an educational intervention targeting health promotion and injury prevention; however, it is unclear whether these interventions are specifically targeting mental health promotion. Bartos et al. (2022a, 2022b) investigated the impacts of a multi-faceted yoga and mindfulness intervention designed to enhance well-being during the COVID-19 pandemic. The intervention aimed to foster positive perspectives towards adversity by developing non-judgmental attitudes toward emotional and cognitive experiences. After qualitative analysis, the authors found the intervention led to an enhanced sense of empowerment in participants regarding their mental health, which they attributed to the multi-faceted nature of the program. Rosset et al. (2022) assessed the importance of mental health and perceived health consciousness to music students through questionnaires. Washington-Simon (2024) found that hip hop artists juggle competing work and financial demands that impede the prioritization of mental health. Similarly, Uriegas et al. (2024) identified lack of time as the primary barrier to marching band artists receiving professional mental health services. This was supported by Moore et al.'s (2024) findings where marching band artists had varied perceptions of the necessity of professional help for mental health services.

Stigma

Stigma was operationalized in four studies. Uriegas et al. (2024) identified that marching band artists are fearful of directors knowing about their mental health issues. Similarly, Washington-Simon (2024) found that fear of vulnerability occurs as artists face expectations and judgement from colleagues and fans. Griffith (2023) discussed how artists may internalize these judgements made by others and develop self-stigma. Three articles also alluded to a culture of concealment of

TABLE 2 Operationalization of mental health literacy in included studies.

Components and categories	Description	Illustrative quotes from included studies
Component: Recognition of mental health disorders	This component pertains to knowledge of symptoms of mental health conditions and developing self-awareness. Self-awareness is included under this component because artists can identify symptoms in themselves using self-awareness.	
Category: Knowledge of mental health disorder symptoms	This category focuses on knowledge of the symptoms of various mental health conditions. Information in studies that included the recognition of symptoms of mental health challenges (not specific to disorders) is placed under this category.	"Artists discussed how the Rural Art Roadshow allowed them to increase their knowledge of mental health issues and services. This occurred by artists engaging with service providers that attended the Rural Art Roadshow and others who also had a mental health illness, or were caring for someone with mental health challenges: 'Just knowing about the art show actually helped me to learn more about my illness and develop skills around managing it. But I've also been in the opportunity where I've been able to gain knowledge and information (Participant 1)'" (Barnett et al., 2019, p. 6)
Category: Developing self-awareness	This category consists of developing awareness of the individual's mental state, which includes their thoughts and emotions. The development of self-awareness was often not specifically for the purpose of identifying mental health disorder symptoms. However, if combined with the knowledge of mental health disorder symptoms, self-awareness could be used by artists to recognize mental health disorder symptoms in themselves.	"It can help individuals understand their own mental health from the aspects of emotion, thinking, consciousness, and living habits." (Qu, 2022)
Component: Knowledge of risk factors and causes and use of mental health information and support services	This component contains two categories: provision of preventive information or coping strategies, rather than symptom identification, and ability to find and use mental health services.	
Category: Knowledge of risk and prevention	This category focuses on the knowledge of risk factors of various mental health issues as well as preventive actions artists can take. Some interventions focused specifically on preventing specific conditions, while others aimed towards overall well-being. Topics such as nutrition and stress management strategies were addressed by interventions targeting the development of knowledge in this area.	"The questionnaire further asked about the perceived level of knowledge about health risks for musicians… and about health protective measures for musicians." (Rosset et al., 2022, p. 5)
Category: Awareness of and access to information and services	This category encompasses the availability as well as the ability to access and select appropriate support services. Availability of services constitutes literature that discusses support services offered by institutions. The uptake of services and the ability to identify when one should use a support service is included under this subtheme.	"The aim of the first part of the programme is to raise students' consciousness of their own health by providing them with a basic theoretical knowledge of the physiological processes that underlie music performance including movement and breathing, and the neurological basis of learning. They are also introduced to some selected aspects of applied psychology, learning, for example, how relaxation procedures and psychotherapy can be used for coping with stress." (Ginsborg et al., 2012, p. 360) "It may be that this apparent reliance on instrumental teachers for advice and guidance is symptomatic of a general deficiency of information – reflecting, in other words, not a positive decision but one reached through lack of knowledge of the alternatives." (Williamon et al., 2006, p. 425)
Component: Attitudes that Promote Recognition and Help-Seeking	This component constitutes two categories: the prioritization of mental health and changing attitudes towards help-seeking.	

(Continued)

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TABLE 2 (Continued)

Components and categories	Description	Illustrative quotes from included studies
Category: Prioritization of mental health	This category focuses on the level of importance artists ascribe to mental health. Prioritization of time, financial, and cognitive resources in relation to mental health were discussed.	"On average, the respondents reported to be rather health conscious (M = 3.98) and ascribed high importance to health overall (M = 4.45) and especially to health for musicians (M = 4.68)." (Rosset et al., 2022, p. 7) "Financial barriers to mental health support highlight the financial constraints and limited access to comprehensive health insurance faced by Hip Hop artists, underscoring the financial barriers to mental health support within the industry." (Washington-Simon, 2024, p. 70)
Category: Positive attitudes and behaviors	This category focuses on changing one's attitude towards both mental health symptoms and health-promoting behaviors. Three types of changes in attitude are covered within this category: cultivating non-judgemental attitudes, maintaining positive perspectives, and fostering empowerment to pursue health-promoting behaviors.	"It is important for music educators and health professionals to understand that college students beginning an intensive course of music study often have generalized anxiety and insecurity that might be reduced if they are encouraged to have a positive attitude towards health behaviors." (Barton and Feinberg, 2008, p. 52) "In discussing these results, we postulated that the program's focus on invoking a sense of agency and self-responsibility—drawing from both yoga and mindfulness—might have raised students' consciousness to self-engage in meaningful actions for independently taking care of their own health." (Bartos et al., 2022a, 2022b, p. 16)
Component: Understanding the concept of stigma	This theme refers to the perception of mental health disorders within performing arts communities.	
Category: Culture of concealment	This category focuses on the culture of hiding ailments and lack of disclosure of mental health challenges within the performing arts. The category also includes issues such as fear of vulnerability and fear of judgement in addition to the internalization of societal these mechanisms.	"One participant reported that they had at times not spoken about their mental health because they felt ashamed of their mental illness, however, the Rural Art Roadshow provided them with an opportunity to speak out and feel empowered: 'It's something that has given me an opportunity to talk in public. There's been a lot of secrecy around my mental illness. My family of origin are still in denial about it so for me to be able to speak out about it has been really empowering. So through the Roadshow I feel I've been given a voice and been able to talk about issues around mental illness. (Participant 1)'" (Barnett et al., 2019) "Secondly, students reported that health and wellbeing is something discussed infrequently at the conservatoire (n = 2, 10%) or that people choose not to disclose (n = 4, 20%)" (Perkins et al., 2017, p. 9) "You can face some sort of a stigma or you can face some sort of misunderstanding… when you are truly feeling horrible, but people can just ask you, 'Why cannot you just…feel normal?' Or, 'Just do not worry'…people just do not understand that it does not work that way unfortunately." (Griffith, 2023, p. 32)

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mental health challenges in fear of receiving judgment or negative biases from others (Mathisen et al., 2022; Smith, 2021; Williamon et al., 2006). Despite this, Moore et al. (2024) found that stigma was not a significant barrier to help-seeking in marching band artists.

Measuring mental health literacy

We extracted how mental health literacy was measured using two categories and eight subcategories: type of measurement (survey, scaling, qualitative, and observational), and level of measurement (nominal, ordinal, ratio, and open-ended).

Table 3 displays the type of study (descriptive, intervention, literature review, instrument development) and the measure that was utilized, organized by mental health literacy component for each included study. Among the 18 studies incorporating a quantitative component (4 with mixed methods), none measured all four components of mental health literacy. Component Two, focused on Knowledge of Risk Factors and Causes; Use of Support Services, was the most frequently measured ($n = 9$; 50%). More than half ($n = 11$; 61.1%) of the 18 studies employed an ordinal level of measurement, six used a nominal scale, and one included open-ended questions in their questionnaire. Additionally, one study used both an ordinal and a ratio level of measurement. Out of the 26 studies identified in this review, eight explored various components of mental health literacy through individual interviews and one used a focus group. Meanwhile, two studies consisted of literature reviews and consequently did not measure any component of mental health literacy in artists.

The questionnaires administered in studies that measured mental health literacy components varied considerably, many of which were developed by the study investigators and were not validated instruments. Eleven studies utilized measures to examine the impact of mental health literacy related interventions on various outcomes for participants. For instance, Rosset et al. (2022) measured three of four mental health literacy components after administering the courses on musician's health over two semesters. Harrison et al. (2019) assessed users' level of recognition of mental health disorders after using the wellness monitoring mobile application. Guptill et al. (2022) developed a validated instrument for measuring musicians' health literacy; however, it is worth noting that this instrument asked questions about performance health issues and therefore, does not make any explicit inclusion of any of the components of mental health literacy. The validated questionnaire that was most commonly administered was the Attitudes Toward Seeking Professional Psychological Help-Short Form Scale (Picco et al., 2016) which measures Component Three, Attitudes that Promote Recognition and Help-Seeking (see Table 1 for list of validated questionnaires administered in studies).

Discussion

This scoping review aimed to identify and summarize how mental health literacy is conceptualized, operationalized, and measured in the performing and creative arts literature. Surprisingly, only one included study explored all four components of mental health literacy, and just one study provided a definition of this concept. These findings suggest that components of mental health literacy are not commonly investigated in the artists' health literature, despite the fact that mental health literacy was defined over two decades ago (Jorm, 2000), and that mental health literacy assessments and interventions have been established in other performance-related disciplines, such as sports medicine (Bu et al., 2020; Vella et al., 2021; Wang et al., 2022). In elite sports, seven consensus statements from prominent sports psychiatry and psychology associations have all declared that increasing mental health literacy is one of the primary strategies for preventing and treating mental health disorders and symptoms, as well as preventing stigma, in elite athletes (Gorczynski et al., 2021).

The limited exploration of all components of mental health literacy in the included studies raises concerns about the perpetuation of stigma around mental health in the artist community. Mental health stigma is recognized as a multidimensional process of objectifying and dehumanizing an individual or self who is known to have or appears to have a mental disorder (Corrigan and Watson, 2004; Pescosolido and Martin, 2015). Previous studies revealed that mental health stigma predicted a reduced level of help-seeking attitudes and behaviors (Clement et al., 2015; Mendoza et al., 2015; Vassallo et al., 2019). Mental health stigma is significantly inversely related to the recognition of need for psychotherapeutic help, stigma tolerance, and interpersonal openness (Mendoza et al., 2015). Interestingly, mental health stigma was also the least explored in all of the included studies. The concept of stigma within the artistic environment was almost exclusively examined among musicians, which reported that musicians tend to conceal medical concerns, with limited open discussions about health and well-being. Our findings highlight the need for further research to examine stigma within all artistic disciplines and develop strategies to combat it effectively. By addressing stigmatizing attitudes and misconceptions of mental health through interventions based on a comprehensive understanding of mental health literacy, institutions can encourage help-seeking attitudes of artists so that they can access support services without fear of judgment or discrimination.

In our review, over half of the included studies investigated only one of the four components of mental health literacy, suggesting a lack of comprehensive awareness of all mental health literacy components in the artists' health literature. Our findings are consistent with the current state of the literature on mental health literacy in all disciplines, indicating that studies often do not simultaneously address all facets of this concept (Kutcher et al., 2016). The second component of mental health literacy, Knowledge of Risk Factors and Causes, and the Use of Mental Health Information and Support Services, was explored in a larger number ($n = 14$) of studies. Studies on musicians underscored the importance of understanding risk factors, with interventions and courses addressing musicians' knowledge of mental health risks and protective measures. However, it was noted that the type and degree of support services offered to music students varied across institutions, indicating a need for more standardized and comprehensive support. In non-musician artists, several studies highlighted the importance of educating performing artists on mental health disorder symptoms and developing self-awareness. For example, interventions aimed at increasing mental health literacy in dancers included educating them about the symptoms of psychological disorders and understanding physical and mental health. Similarly, studies involving musicians emphasized the need for awareness of

TABLE 3 Type of study and measure organized by mental health literacy component.

Article	Type of study and its description	Recognition of mental health disorders	Knowledge of risk factors and causes; use of support services	Attitudes that promote recognition and help-seeking	Understanding the concept of stigma
Atkins (2009)	Descriptive study. Case studies on uptake and perception		Self-report questionnaire (nominal)		
Barnett et al. (2019)	Descriptive study. Data on experiences of artists participating in an exhibition.		Individual interviews		
Barton and Feinberg (2008)	Music and health course on health promotion and prevention strategies. 8 sessions over 8 weeks given by researcher		Assessment of baseline vs. acquired knowledge (ratio) Self-report questionnaire (ordinal)	Assessment of baseline vs. acquired knowledge (ratio)	
Bartos et al. (2022a, 2022b)	CRAFT Intervention consisting of yoga, mindfulness, emotional intelligence, and positive psychology. 23 weeks, 1 h per week + 2 h of weekly practice. Course delivered in-person and virtually.			Self-report questionnaire of open-ended questions (descriptive)	
Cardinal and Hilsendager (1997)	Literature review followed by a descriptive study	Individual interviews			
Cardinal et al. (2020)	Descriptive study.		Self-report questionnaire (nominal)		
Clements-Cortés et al. (2024)	Group music psychotherapy offered for six weeks in-person or via online.	Individual interviews and self-report questionnaire (nominal).		Individual interviews.	
Ginsborg et al. (2012)	Literature review.		Data synthesis	Data synthesis	
Griffith (2023)—Study 1	Descriptive study.			Individual interviews	
Guptill et al. (2022)	Validation study.		Self-report questionnaire (ordinal)		
Harrison et al. (2019)	Wellness monitoring mobile application.	Self-report questionnaire(nominal) and focus group interviews			
Kaufman et al. (1996)	Lectures (lasting 12 months) given by a physical therapist, an endocrinologist, a nutritionist, and a clinical psychologist.		Self-report questionnaire (nominal)		
Mathisen et al. (2022)	Physical and mental health (definition and symptoms), nutrition, recovery strategies, and impacts on performance Monthly 90-min workshops over 3 months	Self-report questionnaire (ordinal)	Self-report questionnaire (ordinal)	Self-report questionnaire (ordinal)	
Moore et al. (2024)	Cross-sectional study		Self-report questionnaire (ordinal)	Self-report questionnaire (ordinal)	
Perkins et al. (2017)	Descriptive study.	Individual interviews	Individual interviews	Individual interviews	Individual interviews

(Continued)

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TABLE 3 (Continued)

Article	Type of study and its description	Recognition of mental health disorders	Knowledge of risk factors and causes; use of support services	Attitudes that promote recognition and help-seeking	Understanding the concept of stigma
Qu (2022)	30-day reception music therapy intervention.	Self-report questionnaire (ordinal)			
Rosset et al. (2022)	Courses on musicians' health for two semesters.	Self-report questionnaire (ordinal)	Self-report questionnaire (ordinal)	Self-report questionnaire (ordinal)	
Shaw et al. (2020)	Acceptance and commitment intervention for six, 60-min sessions over 3 months.	Self-report questionnaire (ordinal)			Self-report questionnaire (ordinal)
Stuckey et al. (2021)	1-year. Intervention consisting of group webinars, small group information sessions, one-on-one Zoom meetings, and sending external resources.		Self-report questionnaire (ordinal)		
Torres-McGehee et al. (2011)	Intervention consisting of an education program to prevent eating disorders. Eight, 45-min sessions over 8 weeks (2 sessions per week) led by peers.		Self-report questionnaire (nominal)		
Walker and Nordin-Bates (2010)	Descriptive study.		Individual interviews		
Washington-Simon, 2024	Descriptive study.		Individual interviews	Individual interviews	Individual interviews
Williamon et al. (2006)	Introductory seminar on music and health.	Self-report questionnaire (ordinal)	Self-report questionnaire (ordinal)	Self-report questionnaire (ordinal)	
Smith (2021)	Literature review of existing programs in post-secondary institutions.		Data synthesis		
Uriegas et al. (2024)	Cross-sectional study.	Self-report questionnaire (nominal)		Self-report questionnaire (ordinal)	
Žilinskas and Lesinskienė (2023)	Cross-sectional study.	Self-report questionnaire (ordinal)		Self-report questionnaire (ordinal)	

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personal risk factors and causes of performance anxiety. These findings suggest that interventions facilitating recognition of mental health disorders can enhance the artists' ability to identify and address potential mental health issues.

The implications of the findings from this review are far-reaching, spanning clinical practice, research, and community levels. For clinical practice, determining the level of mental health literacy in artists allows practitioners and arts educators to tailor educational programs that address specific areas of limited knowledge. As recommended by Barton and Feinberg (2008), health literacy promotion interventions should also include educational strategies designed to specifically affect attitudinal change with appropriate measurements used to measure mental literacy outcomes. Mental health literacy interventions should include all four components and be contextually developed and applied in the artists' workplace settings. Kutcher et al. (2016) suggested that mental health literacy interventions must fit the context in which they are to be deployed. Therefore, tailored mental health interventions that consider the unique occupational contexts of each artistic discipline may prove more effective than a one-size-fits-all approach. It is possible, for example, that mental health literacy interventions for dancers may focus more heavily on recognizing the early signs of eating disorders and performance anxiety, both of which have been considered as prominent psychological disorders among dancers (Dwarika and Haraldsen, 2023), compared to creative writers, who tend to suffer from melancholic states and mood disorders (Andreasen, 2008).

Mental health literacy interventions have demonstrated their effectiveness in promoting resilience, reducing stigma, and increasing confidence in seeking mental health information and professional support across different population samples including athletes (Bu et al., 2020; Vella et al., 2021), medical students (Kurki et al., 2021), and school-aged children (Renwick et al., 2022). Performing arts education programs should incorporate mental health literacy education and training to support performers in maintaining their mental well-being. Research indicates that performing arts students often establish a trusting relationship with their teachers, and consult them (Mahony et al., 2022; Williamon et al., 2006). Therefore, one effective approach to introducing mental health literacy concepts among students may include enhancing the mental health literacy of teachers so that they can more proactively recognize early signs of mental health risk factors in their students. At the research level, a robust knowledge base on mental health literacy in artists would allow researchers to gain a deeper understanding of artists' mental health literacy and identify effective interventions to support artists' mental health. To advance our understanding in mental health literacy in artists, there is a pressing need for a standardized definition and measurement tool that could facilitate more robust research investigations. Future research could also explore the specific relationship between mental health literacy and common mental health challenges faced by performing artists, such as performance anxiety, burnout, and depression. By unraveling these connections, tailored interventions and support mechanisms can be developed to promote mental health literacy. Furthermore, longitudinal studies could be conducted to track changes in mental health literacy among artists over time, examining how factors such as training, experience, and exposure to different artistic environments impact mental health literacy development. Comparative studies across different artistic disciplines and cultural contexts may also add valuable insights into the universality of mental health literacy concepts and the effectiveness of interventions across diverse artistic disciplines.

Finally, collaborative efforts between researchers, educators, mental health professionals, and arts organizations can open dialogue and create synergies on designing and implementing comprehensive mental health literacy interventions tailored for different artistic professions. This scoping review has several limitations. The inclusion criteria restricted the review to English language publications, which may have excluded relevant studies published in other languages. Although the researchers attempted to be as comprehensive as possible of all artistic disciplines during the search process, due to the vast array of artistic disciplines, it is possible that articles focusing on extremely niche disciplines may not have been found during the search process. In addition, due to the imbalance in research that has been conducted across the artistic disciplines, the conceptualization of mental health literacy may evolve as research develops in artistic disciplines outside of dance and music.

A key limitation of the included literature was the lack of clear and consistent definitions of mental health literacy. Many studies did not define the term or failed to incorporate all four core components of the construct—recognition of disorders, knowledge of support and risk factors, attitudes promoting help-seeking, and understanding of stigma. This inconsistency introduces subjectivity in interpretation and limits the comparability and generalizability of findings across studies. Furthermore, the absence of validated tools for measuring mental health literacy among performing and creative artists represents a major gap in the field, which discourages the ability to measure mental health literacy or evaluate education interventions.

In alignment with scoping review methodology, we did not conduct a formal appraisal of the methodological quality of included studies. This limits our ability to comment on the strength of the evidence base, as some findings may be drawn from lower-quality or exploratory research. In addition, our review can be at risk of publication bias, as we relied on peer-reviewed literature, potentially excluding unpublished or non-traditional forms of scholarship that may be particularly relevant in artistic contexts. Thematic synthesis also involves a degree of subjective interpretation, especially when reviewing studies that lack conceptual clarity.

Despite these limitations, the review provides a valuable foundation by mapping the current state of mental health literacy research in performing and creative artists and highlighting important gaps in the literature. These include the need for (1) more consistent use of mental health literacy; (2) greater representation of diverse artistic disciplines and contexts; (3) development and validation of context-specific mental health literacy measurement tools; and (4) more robust study designs that allow for assessment of outcomes and intervention effectiveness. Addressing these gaps is essential to advancing the field and promoting mental health literacy in artist populations in meaningful and equitable ways.

Our scoping review underscores the importance of advancing research and practice in mental health literacy in artists. By addressing the gaps in conceptualization, operationalization, and measurement of this construct, researchers and practitioners can develop targeted interventions, reduce stigma, improve treatment outcomes, and foster a supportive environment that recognizes and prioritizes mental health in the context of artistic expression and creativity.

Author contributions

S-AL: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. NS: Conceptualization, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. GD: Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2025.1329029/full#supplementary-material

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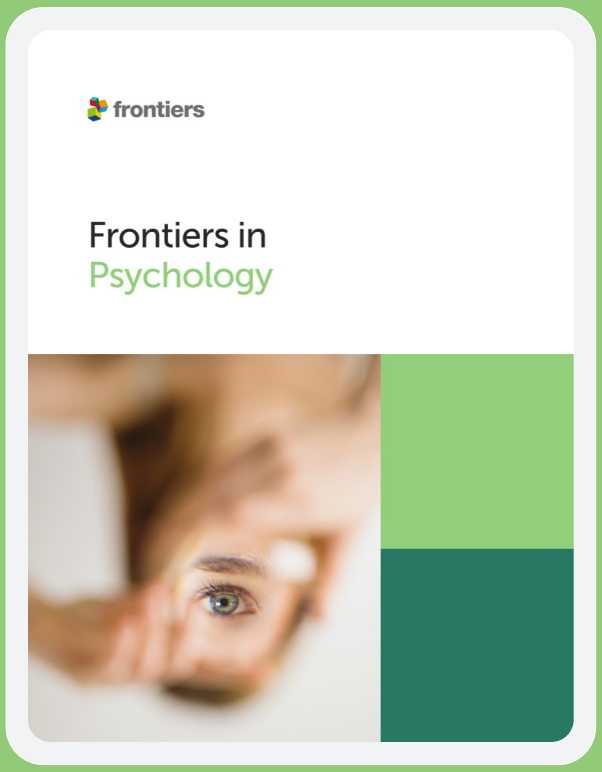

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