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Exploring effects of group and partnership dynamics in dance on mental and physical health

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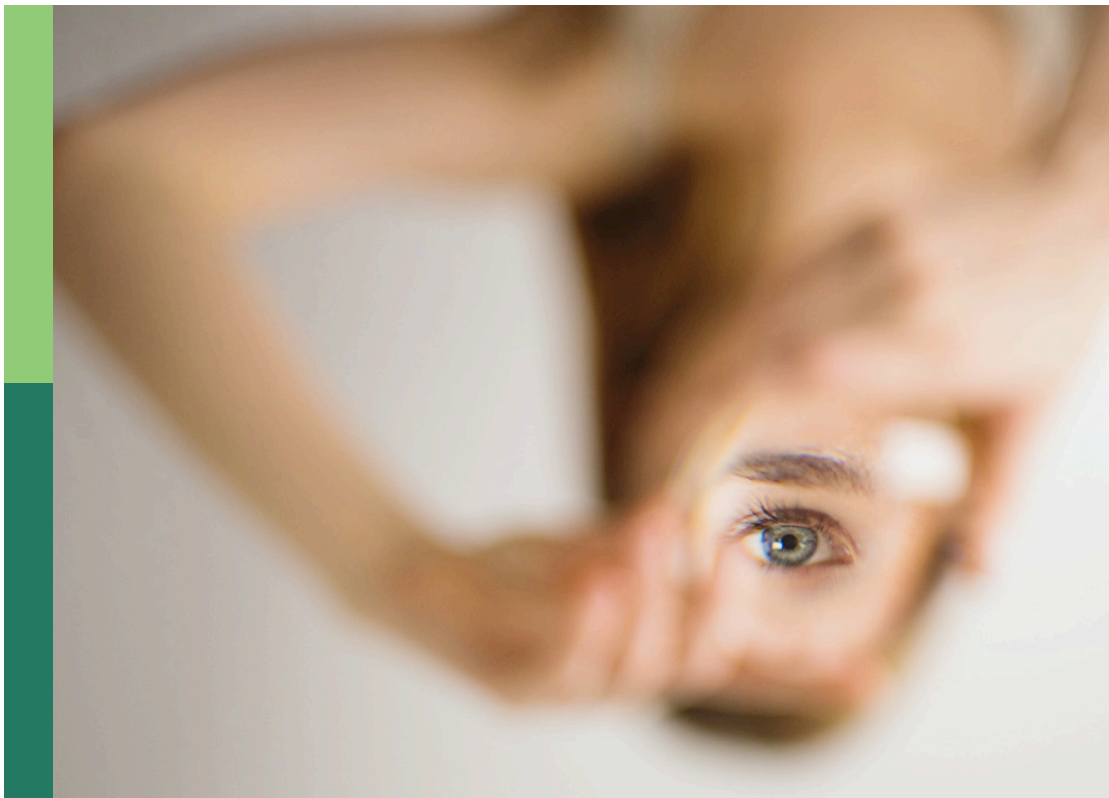
Published in
Frontiers in Psychology



ISSN 1664-8714
ISBN 978-2-8325-7045-6
DOI 10.3389/978-2-8325-7045-6

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Exploring effects of group and partnership dynamics in dance on mental and physical health

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Citation

Hackney, M. E., Jehu, D. A., Bek, J., eds. (2025). *Exploring effects of group and partnership dynamics in dance on mental and physical health*.

Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-7045-6

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frontiers | Frontiers in Psychology

TYPE Editorial
PUBLISHED 13 October 2025
DOI 10.3389/fpsyg.2025.1697858

OPEN ACCESS

EDITED AND REVIEWED BY
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RECEIVED 02 September 2025
ACCEPTED 17 September 2025
PUBLISHED 13 October 2025

CITATION
Jehu DA, Bek J and Hackney ME (2025) Editorial: Exploring effects of group and partnership dynamics in dance on mental and physical health. *Front. Psychol.* 16:1697858. doi: 10.3389/fpsyg.2025.1697858

Editorial: Exploring effects of group and partnership dynamics in dance on mental and physical health

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KEYWORDS

dance, exercise, cognition, neuroplasticity, intervention, partnered dynamics, remote, digital

Editorial on the Research Topic
Exploring effects of group and partnership dynamics in dance on mental and physical health

Introduction

Dance is a universal human expression that transcends cultural and temporal boundaries. As an activity that engages motor, cognitive, neurophysiological, and psychological dimensions, dance has emerged as a rich field for interdisciplinary research. This Research Topic, comprising 14 diverse and insightful articles, explores the intricate interplay between dance and cognitive functioning, mental wellbeing, and physical health across varied populations and contexts. By delving into the mechanisms that underlie dance's transformative potential, these studies illuminate its role as both an artistic pursuit and a therapeutic tool, offering evidence-based insights into its capacity to enhance human health and resilience.

Cognitive and neurophysiological dimensions of dance

Dance is a cognitively demanding activity that engages processes such as memory, attention, spatial awareness, and executive functioning. Neuroimaging research has identified key neural markers and adaptive brain changes associated with dance training, pointing to dance's role in fostering neuroplasticity and network connectivity (Hackney et al., 2024). Several articles in this Research Topic highlight the cognitive benefits of dance and the neurophysiological mechanisms that underpin them. Mao et al.'s ethnological analysis of the Tujia dance provides a compelling example, identifying nine therapeutic

principles, including neuroplasticity and network connectivity, that underscore dance's capacity to reshape brain function. These findings align with the growing body of evidence suggesting that dance training enhances cognitive reserve, potentially mitigating age-related cognitive decline (Mitterová et al., 2021).

Yu et al.'s randomized controlled trial (RCT) with 90 female university students further illustrates dance's cognitive and physical benefits. Their study demonstrates that various dance genres improve strength, power, agility, and flexibility, with genre-specific benefits offering a rationale for integrating dance into higher education curricula. These findings suggest that dance not only bolsters physical fitness but also enhances cognitive processes critical for academic and professional success, such as attention and executive functioning.

Shimizu et al.'s experimental study of expert break dancers provides a novel perspective on the cognitive demands of dance in competitive contexts. By simulating a battle scene, Shimizu reveals how dancers coordinate movements and manage relative distances in a time- and context-dependent manner. This study highlights the unique cognitive and motor synchronization required in performing arts, which may distinguish dance from other interpersonal activities like sports. Such insights underscore the need for further research into the cognitive mechanisms that enable dancers to navigate complex, dynamic environments.

Psychological and emotional benefits of dance

Dance can also have profound psychological benefits, influencing mood regulation, stress reduction, and mental resilience. Liu et al.'s systematic review of 16 articles demonstrates that dance interventions enhance physical self-esteem and self-confidence while reducing social physique anxiety among adults. Similarly, Li et al.'s study on Chinese children cared for by family members reveals that a 12-week dance intervention significantly improves social anxiety and self-concept, emphasizing dance's therapeutic potential in vulnerable populations. These findings suggest that dance fosters a positive self-image in an enjoyable, non-judgmental context, making it a powerful tool for addressing body image concerns and social anxiety.

Dwarika and Haraldsen's scoping review of 115 articles on mental health in dance provides a comprehensive overview of the field, identifying stressors, mental processes, and outcomes that conceptualize mental health as a dynamic state. Most of the articles focused on pre-professional ballet dancers, highlighting a gap in research on professional dancers across diverse styles, and calling for broader investigations to capture the complexity of mental health in dance.

Kawase and Eguchi's research on community festival dancing further underscores the psychological benefits of dance in fostering social bonding and reducing loneliness. Their findings indicate that dance-based festivals create stronger community ties than non-dance festivals, regardless of participants' prior festival attendance or willingness to participate. This highlights dance's unique ability to forge social connections, which are critical for mental wellbeing.

Therapeutic applications of dance

The therapeutic potential of dance is a central theme of this Research Topic, with several articles exploring its application in clinical and community settings. Jehu et al.'s exploratory analysis of a randomized controlled trial examining tango vs. walking interventions for people with Parkinson's disease revealed that baseline social support influences physical function outcomes, with those having low social support benefiting more from walking interventions. This finding suggests that social context plays a critical role in the efficacy of dance-based interventions, warranting further exploration.

Bek et al.'s perspective piece on digital dance programs for Parkinson's disease highlights the feasibility and flexibility of virtual interventions, while acknowledging barriers such as limited internet access and reduced opportunities for creative expression, as well as important safety considerations. Furthermore, Qiu et al.'s study on digital dance therapy demonstrates its efficacy in reducing anxiety and enhancing positive emotions among both professional and amateur dancers, with widespread acceptance of digital tools. These findings suggest that digital platforms can expand access to dance therapy, though careful consideration of social and creative elements is needed to maximize benefits.

Jehu et al.'s perspective on group and partnered dance for people with dementia offers practical guidance on intervention design, emphasizing mirroring techniques, simple instructions, and caregiver support to enhance adherence and outcomes. Similarly, Fontanesi and Newman-Bluestein's opinion article advocates for movement therapy to support caregivers and individuals with dementia, highlighting its role in fostering group support, synchrony, and meaningful relational dynamics. These studies collectively underscore dance's potential to address neurological and psychological challenges, and to promote a shared sense of presence and connection.

Interpersonal coordination and social dynamics in dance

The synergy between individuals in group and partnered dance provides a unique lens through which to explore social interaction, communication, and physical movement. Whitehead et al.'s study on interpersonal coordination in dance improvisation among healthy young dyads employs advanced methodologies, such as maximum correlation vectors and normalized symbolic transfer entropy, to measure movement dynamics and perception. Their work lays a foundation for future research using advanced quantitative methods into the complex interplay of motor and cognitive processes in dance.

Liu et al. address another critical gap by developing and validating the Partnership Scale-DanceSport Couples (PS-DSC) questionnaire, enabling researchers to quantify the dynamics of dance partnerships. This tool has significant implications for understanding how interpersonal relationships influence dance performance and psychological outcomes.

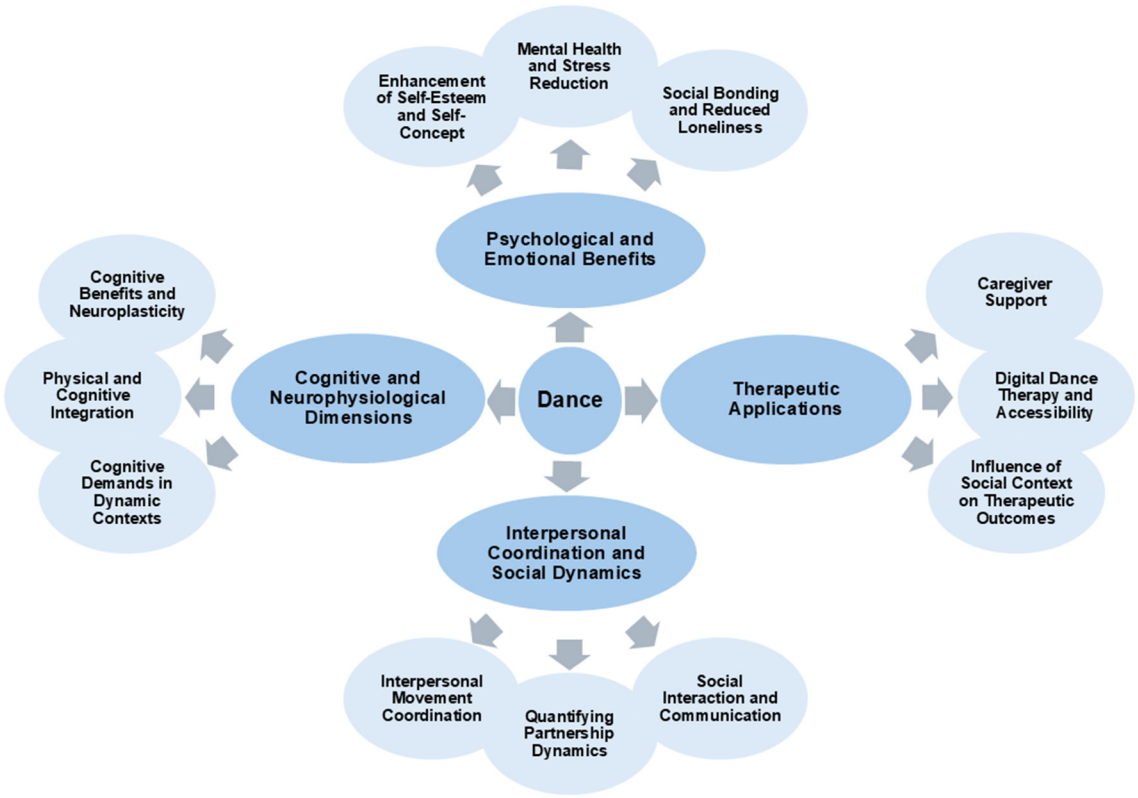

FIGURE 1
Conceptual diagram of topics exploring the psychological and emotional benefits, therapeutic applications, interpersonal coordination and social dynamics, and cognitive and neurophysiological dimensions of dance.

Future directions and interdisciplinary synergy

Figure 1 provides a conceptual diagram illustrating the multidimensional themes of dance research in this Research Topic. The literature in this Research Topic underscores the need for deeper interdisciplinary exploration to elucidate the mechanistic relationships linking dance to cognitive, psychological, and physiological outcomes. The diverse methodologies employed, including systematic reviews, RCTs, and ethnographic analyses, highlight the richness of this field. However, gaps remain, particularly in understanding the long-term effects of dance interventions, the role of specific dance genres, neural underpinnings of any effects, and the applicability of findings across diverse populations and cultural contexts.

The integration of cognitive neuroscience, neurophysiology, psychology, and movement science offers a promising path forward. For instance, combining neuroimaging with other biomarker analyses could further clarify the neural mechanisms underlying dance-induced brain adaptations. Similarly, longitudinal studies could elucidate the sustained impact of dance on mental health and cognitive function, particularly in clinical populations such as those with Parkinson's disease or dementia.

The therapeutic potential of dance warrants further exploration in both traditional and digital formats. As digital interventions become more prevalent, researchers must address barriers to access and ensure that these programs preserve the social and creative elements that make dance uniquely impactful. Finally, the development of standardized tools, such as the PS-DSC, will enable more rigorous investigations into the social dynamics of dance, fostering a deeper understanding of its role in promoting community and connection.

Conclusion

This Research Topic represents a significant step toward unraveling the multifaceted impact of dance on human cognitive, psychological, and physical health. By bringing together cutting-edge research, theoretical perspectives, and evidence-based practices, these 14 articles illuminate the health benefits of dance across diverse populations. From enhancing self-esteem and reducing anxiety to fostering social bonding and promoting neuroplastic changes, dance emerges as a powerful tool for promoting mental and physical health. As we move forward, interdisciplinary collaboration and innovative methodologies will be essential to fully harness dance's potential as a transformative force in both artistic and therapeutic contexts. This Research Topic not only advances our understanding of dance but also inspires future research to explore the boundless possibilities in dance and health.

Author contributions

DJ: Writing – review & editing, Writing – original draft. JB: Writing – review & editing, Funding acquisition. MH: Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. JB was supported by funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement no. 101034345. The funder did not play a role in the manuscript preparation.

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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Publisher's note

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frontiers | Frontiers in Psychology

TYPE Review
PUBLISHED 23 February 2023
DOI 10.3389/fpsyg.2023.1090645

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

RECEIVED 05 November 2022
ACCEPTED 24 January 2023
PUBLISHED 23 February 2023

CITATION
Dwarika MS and Haraldsen HM (2023) Mental health in dance: A scoping review. *Front. Psychol.* 14:1090645. doi: 10.3389/fpsyg.2023.1090645

Mental health in dance: A scoping review

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Research in dance psychology and mental health is rapidly growing. Yet, evidence in the field can seem dispersed due to few existing meta overviews that outline research in dance related to mental health. Therefore, the aim of this scoping review is to strengthen future dance research by gathering and contextualizing existing findings on mental health in dance. Following the PRISMA guidelines and protocols, 115 studies were included in the review. Overall, the data analysis shows a predominant adoption of quantitative research but a lack of applied interventions of preventive and reactive procedures in mental health. Similarly, there is a tendency to study pre-professional dancers, whereas research into professional dancers, especially aged 30–60 is underrepresented. Dance genres have been unevenly investigated, with classical ballet being the most researched, whereas different dance styles and freelance employment are in dire need of in-depth investigation. Conceptualizing mental health as a dynamic state, the thematic analysis identified three main categories: *stressors, mental processes,* and *outcomes*. These factors appear to be in a complex interaction. Overall, the existing literature gives indications of components essential to understanding dancers' mental health but has several blind spots and shortcomings. Therefore, a lot of in-depth understanding and research is still needed to fully grasp the dynamic complexity of mental health in dance.

KEYWORDS

mental health, dance, ballet, dancers, dance education, stressors, mental process

1. Introduction

Research in dance psychology and mental health is rapidly growing. Yet, evidence in the field can seem dispersed due to few existing meta-overviews collecting and outlining research in dance and mental health. As dance science is a relatively new, vibrant, and evolving field, a scoping review of dance and mental health could strengthen future research by gathering and contextualizing existing findings (Moher et al., 2015). Therefore, we aimed to (a) examine how research is conducted in dance and mental health, (b) identify the scope of available evidence in the field of dance and mental health, and (c) identify factors that appear to represent and influence mental health in dance. In what follows, we begin by conceptualizing the scope and some crucial terms essential to the depicted data.

1.1. Mental health

In 2004, the World Health Organization redefined mental health 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, 2022). This marked a much-welcomed shift from seeing mental health not just as the absence of mental illness but encompassing mental well-being and thriving. However, it has been argued that this conceptualization is far from flawless (Galderisi et al., 2015). Scholars have argued that regarding well-being as a state of purely positive affect might be difficult to reconcile with certain complex circumstances we encounter in life (Keyes, 2002). People with good mental health might, for example, experience fluctuations of emotions such as fear, anger and sadness, or they can thrive in one environment or area of life and struggle in another (Galderisi et al., 2015; Henriksen et al., 2020). Also, different life events and transitions, such as change of schools or workplace, marriage and adolescent crises require that aspects of our mental health need to be reorganized, re-oriented or re-balanced (Galderisi et al., 2015). Therefore, it has been suggested to view mental health as a complete, dynamic state that encapsulates a broad spectrum of both the presence (flourishing) and absence (languishing) of mental health and the presence and absence of mental illness (Keyes, 2002; Küttel and Larsen, 2020). It further acknowledges that the strategies designed to reduce distressing symptoms might not be the same as those designed to enhance thriving or flourishing (Keyes, 2002; Küttel and Larsen, 2020). These mental strategies entail certain resources, such as the ability to relate to others, demonstrate psychological flexibility and cope with diverse stressors (Lazarus and Folkman, 1984; Galderisi et al., 2015). Additionally, this conceptualization of mental health also acknowledges that there exists a mutual relationship between the individual and its environment. An individual is influenced by the environment (e.g., amount and type of stressors) he or she is embedded in, and the environment is, in turn, affected by the persons in it (Keyes, 2002; Galderisi et al., 2015). Thus, it is not only the absence of psychological flexibility, relatedness or the ability to cope with diverse stressors, but also diverse and complex interactions between an individual and its environment that can result in mental health issues (Galderisi et al., 2015).

Recent headlines in the media remind us that the topic of mental health in dance seems of high relevance. Several European ballet institutions have currently been accused of sexual, physical and mental abuse of their dancers (Henley, 2019; Münch, 2019; Gregoris et al., 2022). In these accounts, young ballet students describe how they have been body shamed, humiliated or sexually harassed over several years. As a consequence, many of them are suffering from Post-traumatic stress disorder, depression or anxiety (Gregoris et al., 2022). Mental health in dance is, in other words, a pressuring matter. Therefore, this review examines existing literature on mental health in dance and discusses and promotes future research and attention in this area. Factors that might underpin this endeavor are *stressors*, *mental processes* and *mental health outcomes*.

1.1.1. Stressors

An individual's mental health resources are likely to be tested by *stressors* at different moments in their life (Fletcher and Sarkar, 2016). Such stressors can be defined as «environmental demands encountered by an individual» (Sarkar and Fletcher, 2014, p. 8; Mellalieu et al., 2006, p. 359) and are usually more modest disruptions to our everyday lives than major catastrophes (Sarkar and Fletcher, 2014). They are multifactorial and experienced on personal, cultural, and environmental levels. In this respect, sports research has investigated stressors in relation to their different states and recovery processes, or categorized them as competitive, organizational or personal (Kellmann, 2010; Sarkar and Fletcher, 2014). One dance-specific study has further identified physical stresses related to dance training, such as a high physical workload, and requirements concerning technical skill and choreographic demands; as well as psychosocial stressors related to the environment, such as managing finances and obligations, interrelations, and major life events (Blevins et al., 2020). Yet, a clear picture of the range and relevance of dance specific stressors do not exist to date.

1.1.2. Mental processes

Mental health entails that individuals are affected by various factors such as context, situation and stressors but also encapsulates how they respond to and deal with these impacts and experiences (Lazarus and Folkman, 1984). Mental processes are therefore vital mechanisms that are often comprised of many steps towards a mental health outcome.

Sports research confirms that these processes are not linear but complex mechanisms that are comprised of many factors interacting with each other (Williams and Andersen, 1998; Fletcher and Sarkar, 2016). *Personal qualities* and the *environment* are essential overarching groups of resources in these mental processes. They can act in either protective or debilitative directions and increase or decrease mental health outcomes, respectively. They also represent and comprise several of the components identified to restore or strengthen mental health, such as the ability to relate to others, demonstrate psychological flexibility, and cope with challenging life events (Galderisi et al., 2015). Given the importance of these factors, it is vital to identify and map out an overview over these components to better grasp and address these complex mental processes in dance.

Personal qualities can be described as psychological factors that either protect or negatively influence individuals and must be distinguished from psychological skills (Fletcher and Sarkar, 2012, 2016). Personality, or personality characteristics, is a more stable, yet flexible, multilayered personal quality consisting of dispositional traits, characteristic adaptations, and self-narrative identities that "contribute to an individual's distinctive patterns of feeling, thinking, and behaving" (Fletcher and Sarkar, 2016, p. 5). Psychological skills, on the other hand, are more adaptable cognitive and affective techniques and processes that are used to enhance and optimize an individual's functioning or mental readiness in encountering stressors (Fletcher and Sarkar, 2016). A study in an academic setting, for example, has shown that students who become aware of the possibility of enhancing their personal qualities by training in psychological skills seem to enhance their flexibility and ability to cope with adversity (Yeager and Dweck, 2012). Therefore, an individual can train to acquire certain psychological skills that will enhance or improve their personality traits that thus act as protective factors against challenging life events.

Individuals are in a complex interaction with their environment. Consequently, their mental health is greatly influenced by different factors embedded in this climate. These can range from social and cultural circumstances or occurrences, such as auditions, transitions, injuries, deselection, and defeat (Fletcher and Sarkar, 2016), to stakeholders wielding power that influence the mental state of others. Therefore, environments can either be protective by nourishing a person's mental health, or debilitative, by jeopardizing the balance of an individual's mental health components and thus causing mental health challenges and disorders (Henriksen et al., 2020).

1.1.3. Mental health outcomes

Mental processes can lead to either positive or negative *mental health outcomes*. Positive outcomes indicate the presence of mental health (flourishing; Keyes, 2002). In this case, the individual has enough personal resources to be protected from, adapt to, withstand, or swiftly rebound from an encounter with a stressor to avoid a permanent decrease in one's mental health (Fletcher and Sarkar, 2016; Keyes, 2002). Consequently, this can lead to, increased task engagement and optimal performance. Negative outcomes can imply that stressors have exceeded available resources, leading to that the individual moves on a spectrum between the absence of mental health (languishing) and the presence of mental illness (Keyes, 2002). This can result in either mental health challenges, like distress, loneliness and exhaustion or mental illness as for example, depression, self-harm, and/or substance abuse (Howells and Fletcher, 2015). Yet, it is important to acknowledge the dynamic state of mental health and that individuals can thrive in one area of life and struggle in another (Henriksen et al., 2020). That means that individuals might sometimes succumb to a stressor but still experience states of mental well-being or that they benefit from the psychological and behavioral changes induced by this experience (Collins and MacNamara, 2012; Fletcher and Sarkar, 2016). Therefore, a *negative outcome* is not a permanent sentence of doom. Rather, it can lead to growth required for re-evaluation and reflection, and stimulate learning (Galderisi et al., 2015). To date, several studies in dance research have highlighted prevailing negative outcomes such as eating disorders, fatigue and trauma following injury occurrence (Schluger, 2010; Dantas et al., 2018; Kenny et al., 2019; van Winden et al., 2020). Yet, there exists, to our knowledge, no overview over positive and negative outcomes in dance research and little insight into which of these are prominent or obscure.

1.2. Research questions

Based on the relevant indications presented so far, this scoping review formulated the following research questions:

RQ1: What types of research designs, methodologies, publication sources, and populations are conducted in the research on dance and mental health?

RQ2: What are the identified stressors and mental health outcomes faced by Western theatre dance students, teachers, and professional dancers?

RQ3: Which factors appear to influence the dance students', teachers', and dancers' mental health outcomes?

2. Methods

2.1. Context and population

To address the research questions, we created a protocol (Moher et al., 2015) in line with the purpose of a scoping review, that was to determine the scope or coverage of a body of literature on a given topic, how research has been conducted, and present an overview over its focus and existing literature (Munn et al., 2018). In contrast, a systematic review aims to identify and retrieve concrete evidence relevant to a particular question, establish the quality of the relevant evidence, and address uncertainty or variation in practice that may be occurring (Munn et al., 2018). Hence, we developed eligibility criteria framing the population, context, and concepts for the initial search phase. As the number of studies focusing on dance is still limited, this scoping review also included grey literature. Consequently, included studies were (a) peer-reviewed original research, or literature reviews, or systematic reviews, or master and PhD theses from 1980 to present. These studies were written in (b) Nordic or English language and (c) included samples of dance teachers, dance students and professional dancers age 13 and older (d) in the context of Western theatre dance (e.g., ballet, jazz, contemporary) and (e) the studies had to address mental health processes and outcomes according to the studies' stated conceptualization.

2.2. Search strategy and procedure

The PRISMA guidelines were used during the screening and analysis process (see Table 1; Arya et al., 2021). The systematic search process consisted of several phases: initial search screening, main search screening, and supplemental manual search screening (Page et al., 2021). Librarians in a higher arts education institution assisted with conducting the initial and main screening procedures.

Based on the protocol and its eligibility criteria, key terms, both in English and Norwegian, were formulated for the search string. The latter was then fed into each database according to the respective parameters. Search terms were tested individually and in different combinations to ensure viability within the search string. During this phase, a decision of removing conceptual words in the search string defining mental health concepts was taken, due to test searches indicating that concepts were limiting the scope, thus risking to

TABLE 1 Database research.

Database platform	Database	Number of results
EBSCOhost	International Bibliography of Theatre and Dance	1,065
	Education source	635
	ERIC	318
	Academic Search Ultimate	617
	SPORTDiscus	580
	Medline	214
Ovid	PSYCInfo	139
BIBSYS	Oria	325
–	(DUO)	(56)

narrow search outcomes. Instead, the authors decided to evaluate concepts manually during the first screening of the abstracts. Consequently, the search screened for population and context only. This resulted in the final search string in English that consisted of these terms and combinations: ("dance student*" OR dancer* OR "dance teacher*" OR "dance leader*" OR "ballet student*" OR "ballet teacher*" OR "ballet lead-er*") AND ("western theatre dance" OR "dance education" OR "dance pedagog*" OR "classical ballet" OR "jazz dance" OR "contemporary dance" OR conservato* OR "talent identification" OR "development in dance" OR "aesthetic learning" OR apprentice). These terms and combinations were searched in relevant databases (see Table 1). The pre-determined limitations for each search within the databases were "apply equivalent subject" and "peer reviewed only."

Final searches were conducted on 16 February, 2021, which resulted in 3,893 retrieved articles prior to the removal of duplicates in Endnote ($N = 1{,}865$; Figure 1). Additional manual searches in the Norwegian thesis database, journals, and Google Scholar were

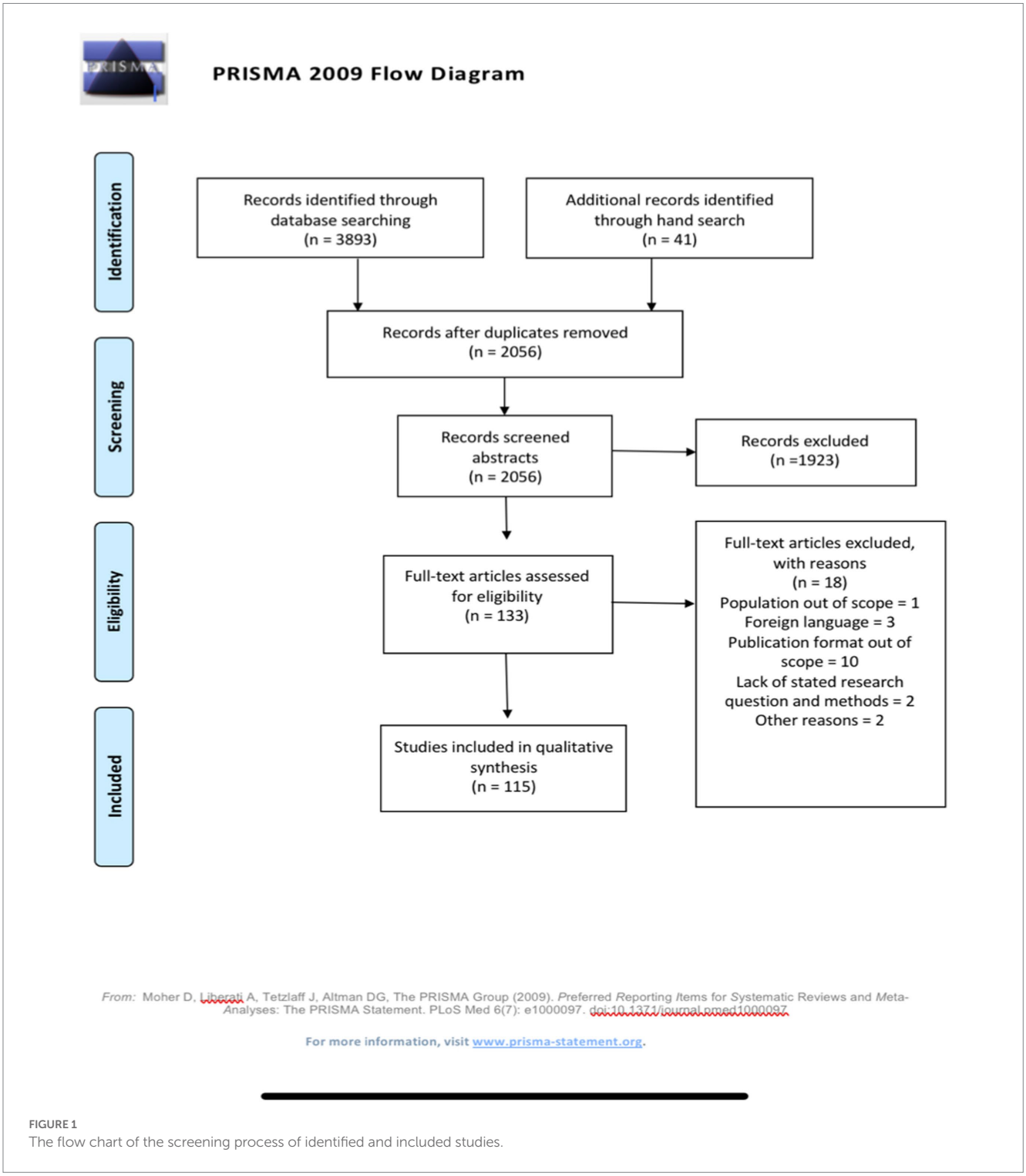

FIGURE 1
The flow chart of the screening process of identified and included studies.

undertaken to identify articles and theses that either were published recently (2020 to 2021) or were not identified by the initial search. Eventually, 2028 articles were uploaded to Rayyan, a free web-based app (Ouzzani et al., 2016), which the authors used as a screening tool to expedite the initial screening of abstracts and titles. A blind function in Rayyan enabled to execute a first screening on the abstract level, and labeling identified articles separately. After the first screening, a third party removed the blind function, and the authors then reviewed and discussed discrepancies in the excluded and included articles, rereading the abstracts and, if necessary, the articles in full text for further evaluation. Thereafter, the first author reviewed all articles in full text, taking the first steps toward data analysis and categorization. This resulted in the exclusion of further articles due to either (a) population out of scope, (b) foreign language, (c) publication format out of scope, (d) lack of stated research question and method section in the article and (e) other reasons, such as limited availability, which made up a new total of 115 included studies, as displayed in the flowchart (see Figure 1 for the flowchart and Table 1 for the overview over the included studies).

2.3. Data analyses and categorization

To extract data from the included studies, we created table sheets for (a) methodological categorization, (b) population and context information, (c) publishing sources, and (d) major foci of the studies. The first author filled in the different tables.

2.4. Thematic analysis and synthesis

We chose a qualitative and thematic approach (Booth et al., 2016) for presenting and synthesizing the results of this scoping review due to the wide range of research designs and thematic scope (Booth et al., 2016; Gough et al., 2017). In the thematic analysis, we (1) took a within-case approach, which entailed summarizing the main findings of all studies identified, (2) identified and developed descriptive themes and categories across the included studies, (3) summarized and developed overarching main findings within topics from a between-case approach (i.e., categories), and (4) meta-analyzed the findings to answer the research questions. The findings were categorized in accordance with an understanding of mental health as a complete and dynamic state (Keyes, 2002; Lazarus and Folkman, 1984). That means that individuals move on a broad spectrum between the presence (flourishing) or absence of mental health (languishing), and the presence or absence of mental illness (Keyes, 2002). The authors met regularly during the analysis process to discuss, and peer debrief the emerging meanings and results (Barber and Walczak, 2009).

3. Results

3.1. Scope of research design and methodology

Research question 1 of this scoping review examined, how research is conducted in dance and mental health. Data analysis from the categorization of the included studies showed that there were 52 quantitative studies, 39 qualitative investigations, and 25 mixed study designs (Supplementary Table S2). Of these, 32 were longitudinal, and 83 were cross-sectional studies.

The distribution of the methodology and type of data (Figure 2) shows that the majority of the studies in this review were non-experimental and descriptive (155), followed by experimental (5) and reviews (2). Regarding types of data, questionnaires, interviews, and scales dominated. Scales were describing all kinds of tests or pre-determined screening tools that were used to test variables such as eating disorders.

The population distribution (see Figure 3) indicated that pre-professional dance students in high school or higher education programs (46 studies), professional dancers (20), and mixed population (20 studies, i.e., different combinations of pre-professional and professional dancers or recreational dancers) were the most

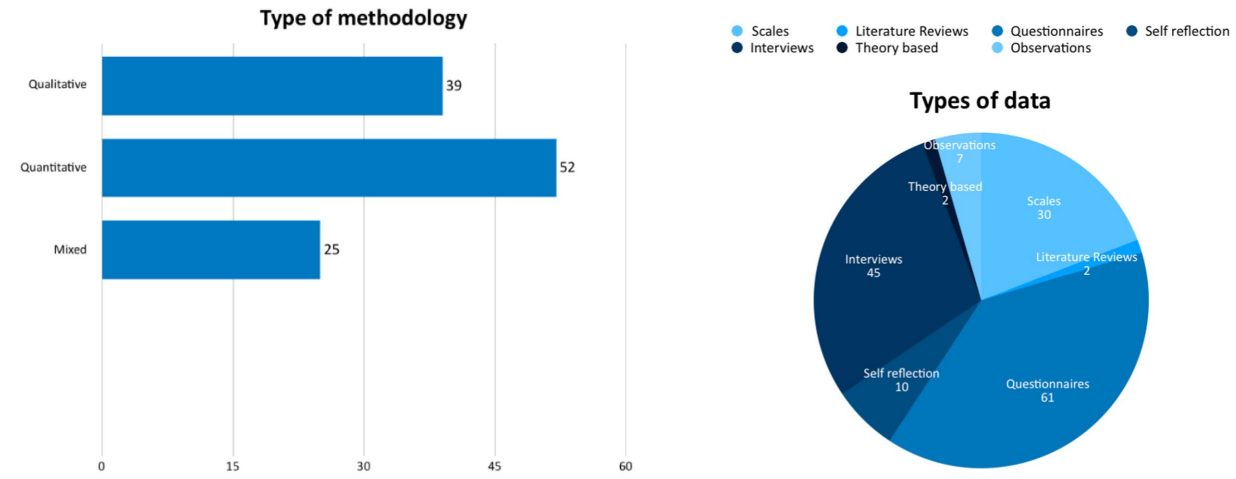

FIGURE 2
Distribution of research design and methodology.

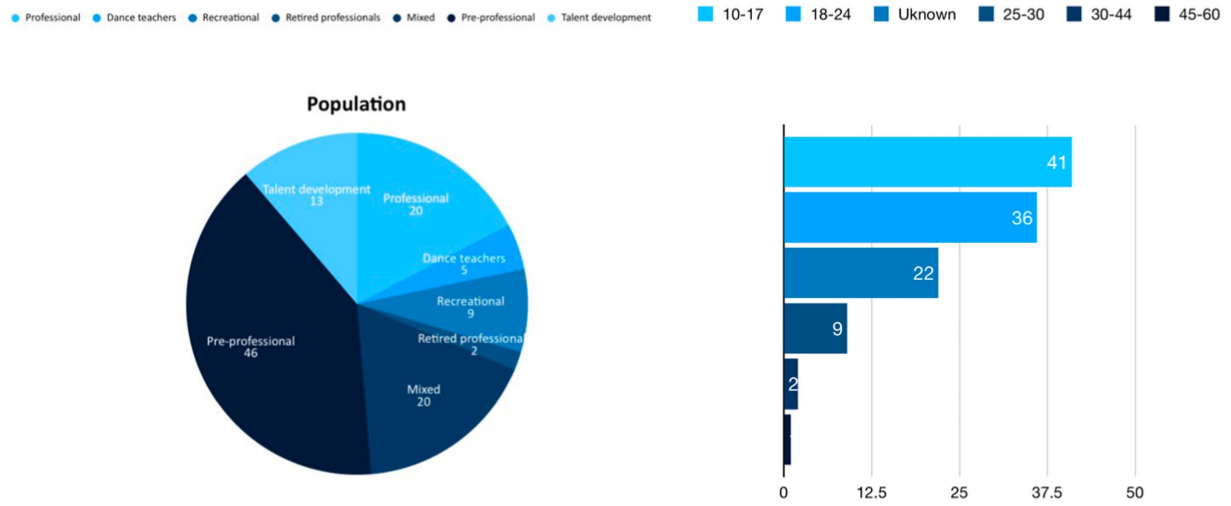

FIGURE 3
Overview of researched population and age-range.

TABLE 2 Journals with more than one publication.

Publishing Source	Studies	Ratings
Journal of Dance Education	49	**0.7** CiteScore
		0.295 SJR
Research in Dance Education	27	**1.5** CiteScore
		0.310 SJR
Journal of Dance Medicine and Science	17	**0.7** CiteScore
		0.288 SJR
Dissertation Abstract International	6	
Theatre, Dance and Performance Training	6	**0.4** CiteScore
		0.279 SJR
NTNU Open	5	
UBIRA e-theses	5	
Collections of Canada	4	
Dance Research Journal	4	**0.49** CiteScore
		0.19 SJR
Medical Journal of Performing Arts	3	**1.5** CiteScore
		0.307 SJR
Frontiers in Psychology	3	**4.232** CiteScore
		0.947 SJR
Journal of Dance and Somatics	2	**0.24** CiteScore
		0.109 SJR
High Ability Studies	2	**3.2** CiteScore
		0.334 SJR
Sex roles	2	**4.24** CiteScore
		1.309 SJR

researched population. This may be due to the easy access to participants and relevance to the examined topics. Dancers in specified talent development programs were investigated in 13 studies. Dance teachers (5) and retired professionals (2) seemed generally underrepresented in research. This is also reflected in the age distribution, with dancers aged 10–17 dominating the analyzed studies (45), followed by participants aged 18–24 (36) and 25–30 (9). Dancers aged 30–44 were researched in two studies, whereas those aged 45–60 were represented in only one study.

Further, dance genres were unequally represented, with classical ballet being the most researched (76), followed by contemporary/modern dance (32), jazz (5), and hip hop (3). However, these numbers also combine studies examining several dance genres. In these cases, the examined dance genres were counted separately.

Examining the representation of different nationalities and diversity in the research, the Western countries positioned in West Europe and North America dominated the analyzed studies. The review also revealed that a few dance journals dominated and contained the majority of publications on general mental health investigations (see Supplementary Table S1).

3.2. Thematic scope and synthesis

The thematic analysis identified numerous stressors and diverse resources needed to meet and cope with the stressors, as well as aspects of both positive and negative mental health outcomes. This resulted in the following three main themes: (1) stressors, (2) mental processes and (3) mental health outcomes. Each will now be presented in turn.

3.2.1. Stressors

Several studies in this review describe how individuals encountered various environmental demands, also called stressors. They are organized as *situational*, *interpersonal, or cultural.* Each group of stressors is presented in turn in the following paragraphs (see Table 2).

Situational stressors (20 studies) in general include career uncertainty, time management issues, limited economic means and injuries. Only a few articles in this category describe how

limited financial means and career uncertainty represent issues negatively affecting dancers' development and potential future (Sanchez et al., 2013; Lopez, 2019). On the other hand, injuries are a much more discussed topic (Liederbach and Compagno, 2001; Kenny et al., 2019; van Winden et al., 2020; Pentith et al., 2021). Injuries negatively affect dancers in many ways, hindering training and performance, and thus, hampering the learning and development process (Macchi and Crossman, 1996). Also, dealing with an injury is mentally tough, and dancers' mental states appear to influence how effectively these are coped with (Macchi and Crossman, 1996; Mainwaring et al., 2001; Kenny et al., 2019). Therefore, several studies stress the importance of therapists, sport psychologists, medical professionals, and teachers to provide a holistic approach to injury management (Macchi and Crossman, 1996; Mainwaring et al., 2001; Pollitt and Hutt, 2021).

Interpersonal stressors (26 studies) are related to asymmetric power exerted by authority figures, perceived pressure and expectations from others, and body image pressure from peers and teachers. Several studies describe that these factors place tacit and rigid demands on the dancers (Benn and Walters, 2001; van Staden et al., 2009; Dantas et al., 2018; Haraldsen et al., 2021a). Power exerted by authority figures, such as teachers and choreographers, seem to influence dancers' outward agreements with a set cultural system (Benn and Walters, 2001; Parker, 2011; Pickard, 2013; Dantas et al., 2018). Peers are often part of this system and influence, alongside the teachers, dancers' body image, eating attitudes and overall ideals (Table 3).

Cultural stressors (42 studies) describe factors inherent in dance culture, such as cultural hegemony, set physical ideals, narrow minded identity ideals, cult-like behavior expectations, traditional gender roles, and hierarchical and top-down organizations. Ballet is described as an authoritarian, hierarchical, cult-like power achievement culture where dancers accept abuse and unreasonable behavior in a state of «silent conformity» (Benn and Walters, 2001; Parker, 2011). Part of this culture are set, physical ideals which affect dancers to strive for thinness to attain a ballet physique or ideal dancers' body (Benn and Walters, 2001; Dryburgh and Fortin, 2010; Pickard, 2013; Mitchell et al., 2020). Other studies describe narrow minded identity ideals inherent in the dance culture. That means that dancers are expected to possess and display certain personality characteristics, such as being docile, humble, hard working, dedicated, mentally tough and persistent (van Staden et al., 2009; Parker, 2011; Aujla et al., 2014, 2015; Haraldsen et al., 2019, 2020). Finally, male adolescent dancers appear seven times more likely than the general public to be bullied, teased or harassed – regardless of their sexual orientation (Risner, 2014). Negativity, stereotypes, bias, and harassment are accepted as commonplace and thus expected, negotiated, and endured (Risner, 2014). In particular, male ballet dancers report engaging in a system that is characterized by gendered rules in both technique and performance, highly stigmatized as effeminate and gender codified (Haltom and Worthen, 2014).

TABLE 3 Overview over themes and their meanings.

Stressor	The mental process	Mental health outcomes
Situational stressors (20) Career uncertainty Time management issues Limited economic means Injury **Interpersonal stressors (26)** Asymmetric power relations Perceived pressure and expectations from others Body image pressure from peers and teachers **Cultural Stressors (42)** Cultural hegemony Physical ideals Narrow-minded identity ideals Cult-like behavior Traditional gender roles Hierarchical and top-down organizations	**Facilitative process** **Protective factors:** *Protective Personal qualities* Proactive personality (37) Relatedness (21) Confidence (13) Harmonious passion (7) Optimism (4) *Facilitative environment* (23) Mastery-climate Task-oriented learning culture Autonomy supportive teachers Focus on self-development Psychologically safe and caring Progressive and student-centered teaching style **Debilitative process** **Debilitative factors:** *Debilitative personal qualities* Perfectionism (16) Obsessiveness (14) Ego-orientation (10) *Unrelenting environment* (49) Expectations of conforming to cultural ideals Performance pressure Ego-involving climate Pressure to fit into the dance world Authoritarian teaching style Competition and comparison	**Positive outcome (53)** *Presence of mental health (Flourishing)* Increased life quality Positive emotional states Increased confidence Proactive self and career management Increased self efficacy Critical thinking ability and autonomy Holistic and diverse identity Work / life balance **Negative outcome (76)** *Absence of mental health (Languishing)* Lack of relatedness, loneliness Fatigue and exhaustion Trauma following injury occurrence Distress Decreased self worth Feelings of inadequacy and failure Debilitated life quality *Presence of mental illness* Eating disorders Depression Burnout (Performance) Anxiety

3.2.2. Mental processes

The processes of handling stressors described in the studies are broadly categorized either as *facilitative* or *debilitative*. Facilitative processes comprise proactive and more robust personal qualities on the one side and protective aspects of the dance environment on the other. Together, these factors appear to either restore or strengthen mental processes and thus act as protective factors in coping mechanisms. Debilitative processes comprise dysfunctional personal qualities and unrelenting features in the dance environments that seemingly jeopardize or imbalance mental health processes. The results of how each of these were identified in the data will now be presented in turn.

3.2.2.1. Facilitative process

3.2.2.1.1. Protective personal qualities

According to the data analysis, five personal qualities were associated with individuals who withstand stressors: *positive personality, confidence, relatedness, harmonious passion, and optimism*.

Positive personality (37 studies) describes dancers that are striving for self-actualization, self-assessment, self-efficacy, self-management, autonomy, self-development, flexibility, and versatility. Several studies suggested that these factors aid dancers to form a holistic identity or buffer stressors they encounter (van Staden et al., 2009; Klockare et al., 2011; Mitchell et al., 2017; Blevins et al., 2020; de Las Heras Fernández et al., 2020). However, according to the included studies, these qualities are deemed in need of development, nurturing, and strengthening, not only in dance but in future dance research in general.

The data analysis identified several studies examining the role of *confidence* (13 studies) in the dance literature. The majority of these articles describe dancers' lack of confidence in relation to body image, career transitions, and gender identity. Yet, they also present suggestions on how to increase confidence. This entails enhancing autonomous, creative explorations, developing skills beyond the dance world and nurturing relationships (Green, 1999; Dearborne et al., 2006; Watson et al., 2012; Aujla et al., 2014; Haltom and Worthen, 2014). Similar to previous factors, it is recommended that confidence and its related themes should be further examined in future research.

Relatedness (21 studies) describes the ability to establish and maintain social relationships with friends, family, peers, teachers, and organizations. Apart from acknowledging these relationships as essential, dance research also repeatedly points to the stress-buffering effect of the perception and experience of social support (Li, 2011; Walker et al., 2012; Aujla et al., 2014; Risner, 2014; Reis et al., 2019).

Harmonious passion (7 studies) is considered a flexible and autonomous approach to involvement in dance, in which the individual participates of his/her own volition, and the activity does not dominate his/her identity (Aujla et al., 2015). This entails striking a dance-life balance that offers room for the building and maintenance of friendships and nurturing other interests/hobbies outside of the dance realm. Our results showed that harmonious passion strengthened support systems, contributed to the shaping of more flexible identities and increased motivation and adherence, which potentially eases career transitions (Aujla et al., 2015).

Optimism (4) is explicitly mentioned in the data of a few studies, either describing the lack of optimism dancers have or suggesting measures to increase optimism in this population (Macchi and Crossman, 1996; Kveton-Bohnert, 2017; Wenn et al., 2018; Senning, 2020). Generally, these articles identified optimism as important for mental health, but also in need of further investigation.

3.2.2.1.2. Facilitative environment

Generally, *facilitative environments* (23) are mastery-oriented motivational climates that are task-oriented, nurture dancers' autonomy and self-development and are perceived as psychologically safe (Benn and Walters, 2001; Mainwaring et al., 2001; Critien and Ollis, 2006; Quested and Duda, 2009; Haraldsen et al., 2020). Several studies highlighted that dancers regulated by self-determined motivation appeared more robust and engaged in a healthier, harmonious way in their development (Quested and Duda, 2009; Hancox et al., 2017; Haraldsen et al., 2020, 2021a). Teachers play an essential role in both the creation and in the perception of these climates (Carr and Wyon, 2003; Hancox et al., 2017; Wenn et al., 2018). In this respect, studies show that an autonomy supportive and student-centered teaching style nurture high motivational quality, dancers' self-determined motivation, and create more harmonious development paths in dance (Quested and Duda, 2009; Haraldsen et al., 2019, 2020, 2021a).

3.2.2.2. Debilitative process

3.2.2.2.1. Debilitative personal qualities

Data analysis identified three main personal qualities that appeared to nurture stressors that jeopardize or imbalance mental processes: *perfectionism, obsessiveness and ego-orientation*.

Perfectionism (16 studies) is related to fear of failure, self-critique, overly evaluative processes, and linking self-worth to achievements (Stornæs et al., 2019). Maladaptive perfectionism can entail a large perceived discrepancy between performance and personal standards, that individuals doubt themselves and avoid negative consequences (Van Staden et al., 2009). This might result in conditional self-worth, risk of over-training or the use of avoidance strategies (Haraldsen et al., 2021a). Therefore, perfectionistic tendencies might contribute to color the perception of and the way dancers cope with the dance environment (Liederbach and Compagno, 2001; Nordin-Bates et al., 2014; Kenny et al., 2019; van Winden et al., 2020; Pentith et al., 2021).

Obsessiveness (14 studies) describes the way dancers exhibit compulsive striving, which can be described as a perceived need for progress and internalized pressures for achievement at the expense of their social and emotional needs and development (van Staden et al., 2009). These strivings appear to be nurtured by the dance cultural ideals, pre-determined identities and expected behaviors, such as dedication and mental toughness, and for male dancers, they may also include debunking stereotypes and enduring homophobia, heterosexism bias, and harassment (van Staden et al., 2009; Polasek and Roper, 2011; Radell et al., 2014; Haraldsen et al., 2021a). Thus, compulsive striving often entails forms of self-objectification that can lead to lack of self-awareness, self-alienation, and to dancers isolating themselves from their social life (van Staden et al., 2009). Similarly, evidence showed that these ideals and ingrained values can lead to obsessive passion, which is described as a rigid persistence to participate in dance, often resulting in dancing taking up disproportionate importance in an individual's identity and leaving little space for other interests, decreasing their overall life quality (Aujla et al., 2015; Cahalan et al., 2019).

Ego orientation (10 studies) is a form of external motivation that depicts a tendency to focus on outperforming others and demonstrating superior ability (Carr and Wyon, 2003). To ego-oriented individuals, high effort implies low ability whereas low effort indicates high ability. This view is negatively affecting their efforts and learning opportunities. It is also linked to avoidance strategies concealing lack of competence and fear of failure (Carr and Wyon, 2003). A strong sense of competitiveness and comparison seems to enhance ego-orientation. Studies point to environmental factors, such as teaching style, motivational climate and cultural ideals as strong contributing factors to ego-orientation (van Staden et al., 2009; Pickard, 2013; Haraldsen et al., 2020).

3.2.2.2.2. Unrelenting environment

Overall the majority of studies describe the dance environment as *unrelenting* (49 studies). This is a climate that has tacit or explicit expectations to conform to ideals, exerts pressure to perform and to fit the mould dictated by the dance world. Gatekeepers, such as teachers, choreographers, and artistic directors, have often been successful performers themselves and, thus, wield a lot of power and authority in this climate and dance culture in general (van Staden et al., 2009; Dryburgh and Fortin, 2010; Haraldsen et al., 2020).

Teachers in an *unrelenting environment* often adopt an authoritarian teaching style and tend to compare their students and thus enhance peer-competition (Benn and Walters, 2001; Quested and Duda, 2009; van Staden et al., 2009; Haraldsen et al., 2019, 2020). Consequently, revealing incompetence or disloyalty, or disappointing these stakeholders represents a risk to hamper dancers' social position, career opportunities, or their chances for further development (Haraldsen et al., 2020). Overall, characteristics of an unrelenting environment within dance showed little care for dancers' mental health, unhealthy competition, and the tacit or explicit expectation to conform to ideals and expectations were the most important features.

3.2.3. Mental health outcomes

Depending on the number of perceived stressors, as well as the features and interaction of the personal qualities and environment at hand, diverse mental health outcomes seemingly increased or decreased (see Figure 4).

3.2.3.1. Positive outcomes (53)

The results identified a range of positive mental health outcomes in dance. Life quality, confidence and self efficacy and positive emotional states, proactive self and career management, and the nurturing of holistic identities are among the most reported outcomes of flourishing mental health characteristics. However, these results were mostly identified in studies that also reported the absence of mental health. Positive outcomes were often presented as possible, future effects rather than being identified as prevalent. Moreover, dancers seem generally to have low confidence and possess little knowledge related to how to manage their careers and increase their quality of life (Hoffer, 1981; van Staden et al., 2009; Haraldsen et al., 2021a). Yet, studies indicated that the dancers' life quality could increase if measures, such as psychological skills training and psycho-education, were systematically applied in their education and professional life (Redding and Quested, 2006; Solomon et al., 2002; Diaz et al., 2008; van Staden et al., 2009; Klockare et al., 2011; Carattini, 2020; Kim et al., 2022). So far, positive outcome evidence appeared dispersed and lacked coherence, which made it difficult to detect an overall prevalence.

3.2.3.2. Negative outcomes (61)

Generally, the absence of mental health (languishing) led to mental health challenges, such as distress, loneliness, stress and tiredness. Mental illnesses like, anxiety, and eating disorders are among the most described negative outcomes (Slater and Tiggemann, 2002; van Staden et al., 2009; Risner, 2014; van Winden et al., 2020).

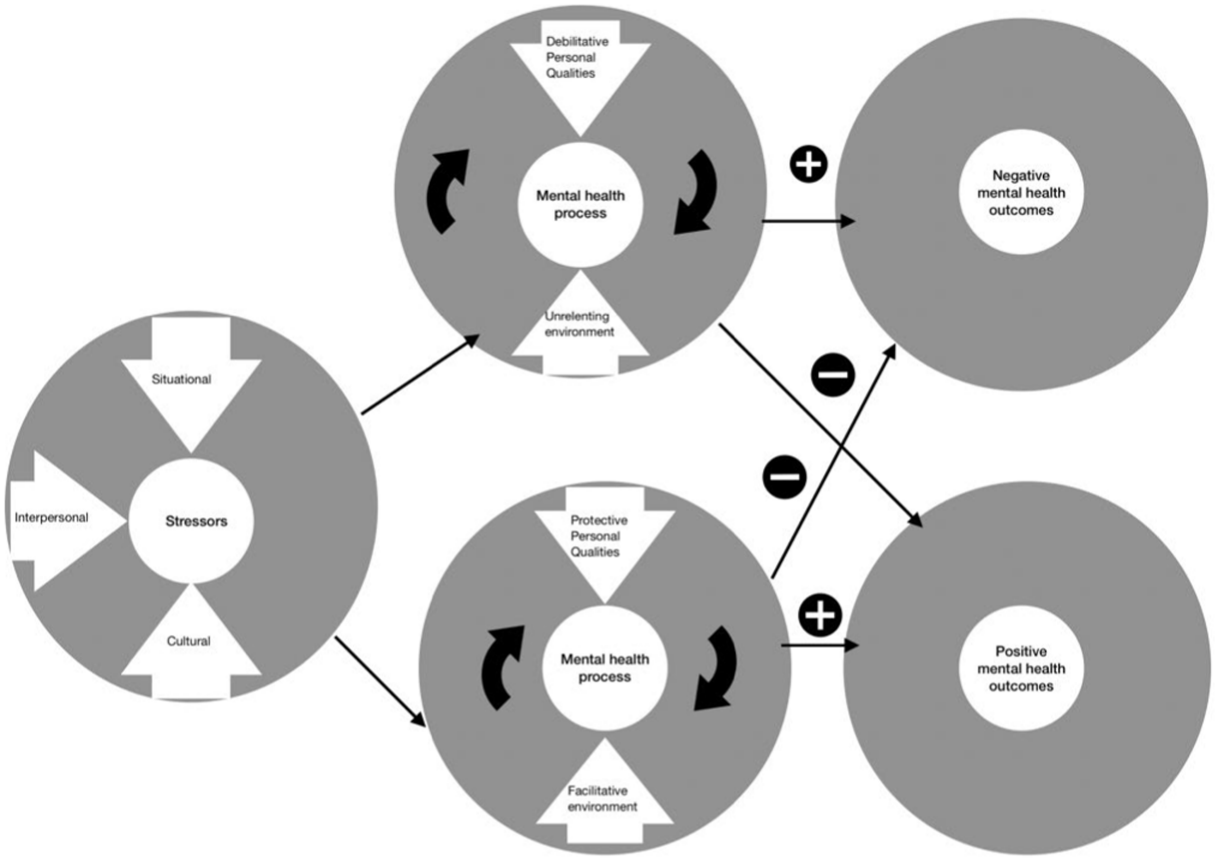

FIGURE 4
Overview over a mental health process.

Moreover, there are indications that ballet dancers are at a higher risk of developing eating disorders than contemporary dancers (Benn and Walters, 2001; Schluger, 2010; Nordin-Bates et al., 2011; Dantas et al., 2018). Also, perfectionism seems a common predictor variable for eating disorders, performance anxiety, and burnout in both male and female dancers (Nordin-Bates et al., 2011, 2014; Haraldsen et al., 2021a,b). However, while some studies compared dancers to other population (Adame et al., 1991; Archinard and Scherer, 1995; Slater and Tiggemann, 2002; Pollatou et al., 2010; Spadafora, 2010; Kosmidou et al., 2017; Walter and Yanko, 2018), not enough coherent evidence was identified to secure an overall prevalence in this review.

4. Discussion

In this section, we present an overall meta-reflection and discussion of the findings presented in the results section. We start by discussing the research designs, methodology, and quality, and continue with the thematic analysis of the main findings within the scope and its subcategories. We conclude with a discussion of limitations, and future research.

4.1. Research design and methodology

The first research question focused on what type of research design, methodology, and population could be detected in the included studies. Our analysis showed that quantitative methods were dominating in the current literature, specifically, descriptive observational survey studies based on self-reported questionnaire data. The qualitative studies, which also were primarily descriptive in nature, were mostly based on interview studies. Hence, the diversity and sophistication of research designs and methodology was low. This affected the type of research questions to be asked, likely conclusions that could be drawn and the impact on the overall quality of the research (Teddlie and Tashakkori, 2011). This is shown in, for example, by a lack of building on previous studies identifying stressors in the literature. Even though the studies have pointed to many and varied problems that affect dancers' mental health, central aspects in mental processes (e.g., moderator and mediator variables), such as appraisals, responses, or resilience, are not properly explored, identified, or investigated. Moreover, only a few of the studies were intervention studies that tested out the effect of strategies to reduce or encounter previously identified stressors. Yet, methodological research literature highlights the importance of intervention studies (Welsh et al., 2023, p. 18). Intervention studies especially might be beneficial to test theories and put them into practice. Further, there are shortcomings concerning the conceptualization of mental health. There are tendencies to explore mental health in a general manner, with no given definition of the conceptualization in the context of the given study. For example, the concept of well-being is often used as an expression of mental health, underpinned by a variety of measurement (i.e., vitality, positive affect, self-determination) but also by an array of labels and constructs (i.e., psychological well-being, mental well-being, thriving or flourishing; van Staden et al., 2009; Aujla and Farrer, 2015; van Winden et al., 2020). Except for eating disorders, specific in-depth investigations of mental issues such as depression, anxiety or emotional distress are not yet conducted. Hence, this review points to many potential future research topics within Western dance to be examined. One important starting point is that mental health and its dynamic nature needs to be defined and conceptualized in dance.

The analysis of the range of population showed a preoccupation with pre-professional dancers and higher education students from Western countries, with ballet being by far the most researched dance genre. This may be due to ballet and its characteristics presenting easily measurable variables, which further highlights that in-depth research into other dance genres and freelance dancers is long overdue. From a critical viewpoint one might claim that the evidence concerning dance and mental health represent a story of young Western ballet dance students, and not a representation of the broad field of artistic dance itself.

4.2. Thematic scope and trends

To address the last two research questions that identified stressors, influential factors and mental health outcomes in dance literature, we undertook a thematic analysis that identified three main themes: *stressors, mental processes and mental health outcomes.* Each of these is discussed in turn in the following sections.

4.2.1. Stressors

The results identified a range of stressors comprised of *situational*, *interpersonal*, and *cultural*. In the context of Western dance theatre, cultural stressors appear to be the most influential, followed by interpersonal stressors. The extent to which of these stressors manifested themselves varied among the dance genres dissected in the data. This became especially apparent when analyzing the reviews' *cultural stressors.* This revealed that genres such as jazz are more concerned about body image, gender identities, and commercialization of the body than contemporary and modern dance, which seem more progressive in the cultivation and reflection of positive body image (Heiland et al., 2008; Pollatou et al., 2010; Alexias and Dimitropoulou, 2011; Swami and Harris, 2012). *Interpersonal stressors* identified many aspects of pressures. It appeared, for example, that not only teachers but also peers exerted pressure on dancers' body image and perceived expectations (Dantas et al., 2018). Classical ballet especially seemed irrevocably connected to deep-running traditions and a fostering of *cultural and interpersonal stressors*, which various participants in several studies reported to be "part of the deal" and as an aspect that is tacitly expected, accepted, and cultivated (Benn and Walters, 2001; Risner, 2014; Cahalan et al., 2019; Haraldsen et al., 2019). Other challenges and factors, such as *situational stressors*, are underrepresented across the scoping review and could therefore not provide a much-needed understanding of factors such as dancers' financial means, support systems, and environments (Sanchez et al., 2013). Several studies describe injuries as a central stressor that jeopardizes dancers' mental health (Macchi and Crossman, 1996; Backlund and Wallén, 2016; Cahalan et al., 2019; Haraldsen et al., 2021a). Although injuries are characterized by physical challenges, the findings highlight the importance of interconnecting dancers' physical and mental needs when dealing with an injury. Furthermore, dancers in all dance genres generally appear to possess or receive little knowledge about how to attend to injuries, rest, deal with mental health issues, and build a life outside of the dance environment (Macchi and Crossman, 1996; Aujla et al., 2014; van Winden et al.,

2020). Overall, there is a need to further the understanding of the interaction between physical and mental health in dance and test out the effect of mental health education as part of dance education and dance teacher training.

4.2.2. Mental processes

Findings in the literature suggest that dancers' mental health is influenced by both *protective* and *debilitative* factors. However, tendencies in the identified studies seem to indicate, that dancers are either languishing *or* are showing signs of thriving and flourishing. This appearance of a little nuanced picture of dancers' mental health seem to be underpinned by several factors. First, that there is little rigorous conceptualization of mental health in dance; second, that there is a prevalence of quantitative studies in the field that might not capture the more complex, in-depth aspects and dynamic states of mental health; and third, that research on mental health is generally not practically applied in interventions or other experimental designs.

The evidence relating to *protective personal qualities* revealed that buffering attributes, such as confidence, were presented as suggestions for further research rather than practically applied and explored (Kveton-Bohnert, 2017; Blevins et al., 2020; Carattini, 2020; Kim et al., 2022). Therefore, *protective personal qualities* should be seen as useful suggestions and indications for further research, rather than established evidence in the dance context. *Facilitative environment,* on the other hand, are underpinned by more in-depth endeavors that uncover which elements are likely to contribute to dancers thriving in their environment. The majority of these investigations focus on motivational climates and imply that awareness of the three basic psychological needs from self-determination theory and motivational quality in general can make a positive difference in dancers' lives (Quested and Duda, 2009; Hancox et al., 2017; Haraldsen et al., 2020). However, while motivational quality and climates appear to be researched to some degree in dance, there is still limited knowledge about dancers' motivational states in different dance genres. Also, to date, other important aspects, such as psychological safety, have been little explored and require further investigation.

In general, there was a prevalence in studies describing debilitative aspects inherent in an *unrelenting environment* (such as performance pressure and ego-involving climate), that, in turn, were linked to certain debilitative personal factors such as perfectionism or obsessiveness. Even though research on perfectionism conceptualizes the term and examines it contextually (Nordin-Bates et al., 2011, 2014; Stornæs et al., 2019), both ego-orientation and obsessiveness lack conceptualizations and contextual approaches. We know, for example, little about the dimensions of obsessiveness and how aspects, such as compulsive striving, look like in different dance genres. So far, these *debilitative personal qualities* seem inextricably linked to an *unrelenting environment* that appears to enable peers and teachers to influence dancers' body image, eating attitudes, and overall ideals, which in turn hamper dancers' development and well-being (Critien and Ollis, 2006; Lacaille et al., 2007; Harper, 2012; Stanway et al., 2020; Haraldsen et al., 2021a). Several of the studies offer valuable advice how to address and change debilitative aspects of the particular cultural features of the dance environment (Bonbright, 1995; Mainwaring et al., 2001; Batur et al., 2003; van Staden et al., 2009; Schluger, 2010). However, to date almost none of these plans have been put into action and tested for viability and effect.

Overall, the findings in this scoping review indicate that we possess little knowledge about the mental processes in dance. For instance, no study, to date, has investigated concepts of resilience in dance. However, sport psychology studies have conducted investigations into coping strategies, stress and recovery as well as resilience processes. They highlight that gaining knowledge about whether an individual appraises a stressor as a threat or challenge is decisive in the process of how the stressor is perceived and dealt with (Fletcher and Sarkar, 2016). Future research needs to address and reflect whether different components such as appraisals and responses might further the understanding of mental health processes in dance. Furthermore, research should capture the dynamic nature of dancers' mental health processes. These should investigate whether, and in which way dancers' *protective* and *debilitative personal* qualities coexist and how they interact and adapt during different time periods.

4.2.3. Mental health outcomes

This review captured both *positive* and *negative mental health outcomes.* Findings identified the presence of mental health by means of increased life quality, positive emotional states, establishing a work/life balance, and using psychological skills to increase confidence, self and career management. (van Staden et al., 2009; Nordin-Bates et al., 2011; Kveton-Bohnert, 2017; Hopper et al., 2020; Kim et al., 2022). The most frequent indications for the absence of mental health were stress, distress and tiredness related to burnout. The presence of mental illness was indicated by negative outcomes such as anxiety and eating disorders. Of these, eating disorders and psychological trauma following injury occurrence especially, seem to be deeply influenced by dance environments' ingrained power culture and ballet aesthetics, as well as by factors of significance such as mirrors (Liederbach and Compagno, 2001; Kenny et al., 2019; van Winden et al., 2020; Pentith et al., 2021). Thus, the strong indications for both the absence of mental health and the presence of mental illness, point to a most warranted change in the dance world to address these issues.

Prevalence has been difficult to identify, but would be needed in order to gain a more precise overview of prevalence in mental health outcomes. Studies examining, for example, how dancers compare to the general public or other athletes, would aid the understanding of mental health and the debilitative impact of mental health issues in dance. Overall, positive and negative outcomes appear to exist side by side, despite endeavors to study them as separate entities. That means that dance research needs to look at the holistic picture, modeling and testing the sum of stressors, resources available in the process and the composition of the individual's health situation, in order to understand these outcomes (see Figure 4). However, to date dance research still lacks replication studies and more experimental designs that test and verify mental health components. It is important to consider how these could compose a more holistic picture of dancers' mental health.

4.3. Limitations

This scoping review has several limitations. First, the nature of a scoping review is to present trends and an overview of the scope of existing literature, and thus cannot present a detailed and in-depth analysis of the findings. This leaves research question 3 challenging to answer in concrete terms. Second, the inclusion of grey studies, such as master thesis, might be a limitation given the quality of such included studies. However, as dance research is a rather young research field, master theses have, so far, played an important part in contributing to the overall research evidence, and thus, excluding these

could have resulted in an incomplete picture of the existing literature. Third, the disperse evidence and the general lack of replication studies challenges the demonstration of prevalence in a variety of mental issues and disorders. Fourth, no structured and detailed quality assessment has been undertaken. This might be a general weakness of scoping reviews that could have strengthened the reader's assessment of the included studies. However, an assessment of the quality of the journals with the most included studies, gives a general overall quality assessment. Fifth, how these findings are presented, which definition of mental health has been chosen to underpin this endeavor, and what research gaps that are detected, are interlinked with the perceptions, opinions, and background of the researchers, despite their striving to avoid bias and practice reflexivity. This means that the authors also are reflected in the synthesis and meaning making of this review. Since few reviews of this kind exist in dance literature, it has been our endeavor to present a review that offers connection points from which readers can make sense of existing literature on mental health in dance. Therefore, the authors hope that this scoping review can, despite its limitations, be seen as a valuable puzzle piece to a much bigger jigsaw.

4.4. Concluding remarks

In this scoping review, we have tried to summarize and synthesize what appears to be dispersed studies on the matter of mental health and its determinants in dance. In general, dance students and dancers are exposed to a unique range of stressors that might potentially increase their vulnerability to the absence of mental health or mental illness. On the other hand, in the process towards their flourishing mental health state, both personal and environmental qualities seem to be important contributors in the total equation. As several studies in this review have shown, a deeper and applied understanding of the interaction between *stressors, mental health processes* and its *outcomes* are essential to gain insight into and grasp the dynamic nature of mental health. Hence, this scoping review suggests that mental health in dance should be conceptualized as a complete and dynamic state. However, the synthesized picture of mental health in dance is far from complete and seems still quite anecdotical in nature-revealing topics uncovered, populations left out, and too little diversity and rigor in the methodological approaches. Insofar, the current review has contributed to advance the scope of knowledge about mental health in dance and intends to initiate a more informed discussion about how we can better understand, conceptualize, measure, and support dancers' mental health.

Author's note

Research in dance psychology and mental health is rapidly growing. Yet, evidence in the field can seem dispersed due to few existing meta overviews that outline research in dance related to mental health and, especially, facilitative, or debilitative processes associated with mental health outcomes. Therefore, the aim of this scoping review is to present an overview of the state of the art and to strengthen future dance research by gathering and contextualizing existing findings on mental health in dance. This effort has revealed that factors such as personal qualities, stressors, appraisals, responses, and the impacts of the environment are useful indicators for understanding facilitative or debilitative mental health processes. In turn, these are associated with positive or negative mental health outcomes but also point to gaps that need to be filled. Thus, this scoping review both synthesizes disperse evidence in the field but is also aims to present a foundation for future research in mental health in dance.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Funding

This scoping review was funded by the Oslo National Academy of the Arts' Dance Department.

Acknowledgments

The authors would like to acknowledge the help and contribution of Einar Thor Jonsson and the library staff at the Oslo National Academy of the Arts.

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.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1090645/full#supplementary-material

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frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 23 February 2023
DOI 10.3389/fpsyg.2023.1032767

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

RECEIVED 05 September 2022
ACCEPTED 31 January 2023
PUBLISHED 23 February 2023

CITATION
Liu X, Yang G, Wang S, Wang X and Wang X (2023) Development and initial validation of the Partnership Scale-DanceSport Couples. *Front. Psychol.* 14:1032767. doi: 10.3389/fpsyg.2023.1032767

Development and initial validation of the Partnership Scale-DanceSport Couples

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Introduction: DanceSport is described as a dance involving a male–female partner. It is important to comprehend the partnership between dance couples so that their competitive performance can be effectively supported. However, only a few studies have verified the influence of partnership between DanceSport couples on competitive performance and explored its psychological mechanism to provide means to deal with the partnership. The reason was that there was a lack of appropriate assessment tools.

Aims: This multi-study outlines the development, content, and construct validity of a novel, mixed-method tool to assess DanceSport partnership.

Methods: The development of the Partnership Scale-DanceSport Couples (PS-DSC) included four studies and data from four samples of Chinese elite dancers (N = 914 total). In stage 1, outlined in study 1, PS-DSC items were generated and then refined using the feedback provided by academics, sports coaches, and elite dancers. In stage 2, outlined in studies 2 and 3, exploratory factor analysis and confirmatory factor analysis were used to examine the structure of the PS-DSC items. In stage 3, outlined in study 4, composite reliability, discriminant validity, and convergent validity were assessed. The result of this process was a 13-item three-factor instrument. Based on these initial findings, the PS-DSC provided the first valid and reliable way of measuring partnerships between DanceSport couples.

Conclusion: This study has taken the promising first step in developing a tool to comprehensively measure partnerships between DanceSport couples.

KEYWORDS

partnership, DanceSport, scale development, athlete, obligatory instrumental ties, expressive ties, interpersonal perception

1. Introduction

DanceSport (also called ballroom dance/competitive dance) is an extremely complex sports discipline (Vermey, 1994) that contains ten kinds of dances, namely, Cha, Samba, Rumba, Paso Doble, Jive, Waltz, Tango, Viennese Waltz, Slow Foxtrot, and Quickstep. Starting as one of the social graces expected of the European upper classes, DanceSport derives from the Latin word "balare" (to dance) and is now an umbrella term for a style of elite partner dancing (Ogilvie, 2017). This kind of partner dancing is danced both

competitively (Bulman, 2006; Bria et al., 2011) and socially (Marion, 2006), in which there is a phenomenon of "feeling your partner" (Fostiak, 1996).

DanceSport requires partners to follow the rhythm of the music and compete against other dance couples to display the beauty of the sport (Jae Sung and Yoo Bin, 2012). Therefore, partnering skills are one of the important judging components in World DanceSport Federation competitions (Remelč et al., 2019; Yoshida et al., 2020). The overwhelmingly dominant aesthetic of DanceSport is the pairing cooperation of the male and female (Marion, 2006; Budnik-Przybylska et al., 2015). The prerequisite for demonstrating the beauty of this duet is having a partner; however, it is not easy to establish, maintain, and develop a partnership as different dancers have various life backgrounds that shape diverse personalities and habits and hence the conflicts in the process of interaction are unavoidable. In addition, once a partnership is established, due to the need for competition and training, the dancers face a longer period of interaction with their partners and their lives. Training and competition are highly intertwined (Reynolds, 1998) that a relationship of overlapping instrumental ties and expressive ties will be formed between partners (Wang, 2018), the boundary between the instrumental ties (business-like partnerships) and expressive ties becomes more blurred, and it is easy to break the partnership because of love issues (Liu et al., 2022). Therefore, for the dancers, besides the great amount of practice (diligence and endurance) and a high level of technical expertise (for which a good trainer is important), their partners are vital, and good cooperation between partners is of decisive importance for effective competition (Peters, 1992; Majoross et al., 2008; Budnik-Przybylska et al., 2015). Some scholars even argued that partnership was the essential characteristic of DanceSport that distinguishes it from other sports (Marion, 2006; Ogilvie, 2017). Therefore, a number of coaching hours of DanceSport go into attempting to depict the performing "male/female relationship" between partners (Marion, 2006). However, what is the nature of the DanceSport partnership? How to examine the partnership between DanceSport couples? Few studies have been conducted to address these issues, which would have the consequence of failing to advance the practice and theory of DanceSport at the interpersonal level. In view of this, Majoross et al. (2008) suggested that a new method should be developed to obtain a more elaborate and precise picture of this special connection. Based on this, we hoped to address this issue with the Partnership Scale-DanceSport Couples (PS-DSC) developed in this study. In practice, coaches and elite dancers can use the scale to assess the quality of a partnership. The higher the scores on each dimension, the stronger the motivation to excel in competition and the stronger the partnership. In terms of theoretical research, researchers can use the scale to measure partnerships to advance research on the relationship between partnerships and other variables, which will help guide related practice.

1.1. The concept and framework of DanceSport partnership

The development of a DanceSport partnership scale is an effective way to obtain information about personal relationships between elite dancer couples. Through a literature search, it was found that there were a few articles by researchers from 16 countries (Spain, India, South Korea, Hungary, USA, Canada, UK, Romania, France, Germany, Slovenia, Switzerland, Lithuania, Poland, Israel, and China) focusing on DanceSport partnerships. Among them, only Korean scholars have extracted the partnership dimension and developed assessment tools (Myung et al., 2010; Kim et al., 2011). Myung et al. (2010) studied the DanceSport partnership on grounded theory, conceptualized the DanceSport partnership as "a bilateral relationship based on mutual trust, sharing interests and risks among dance couples and assuming equal responsibility for achievements" based on the survey of 389 Korean elite dancers, and determined the 5 dimensions of partnership, namely, *partner care, partner harmony, reciprocal endeavor, perfect rhythm, and economical environment*. *Partner care* refers to being patient and considerate of dance partners and trying not to feel uncomfortable when getting along. *Partner harmony* refers to understanding the personality of the partners, being good at communication, and connecting with their hearts. *reciprocal endeavor* requires a cooperative attitude to pay earnest efforts to train frequently. *Perfect rhythm* refers to an intense sense of music and technical tension. *Economical environment* refers to having certain economic conditions and affording training and competition because the achievements of dancers are based on inviting teachers to attend classes for a long time and expensive clothing, among others. Based on Myung et al. (2010), Kim et al. (2011) found that the DanceSport partnership was a cooperative relationship that has the characteristics of mutual understanding and cooperative spirit in four dimensions, namely, *trust, referee-audience feedback, physical harmony, and economic conditions.* Among them, *trust* is the basic requirement for a partnership; *referee-audience feedback* is the demand of partners' performance; *physical harmony* indicates that the dancers need to be harmonious in appearance, physique, body proportion, and body shape with the partners; and *economical environment* is considered the same as that mentioned in the study of Myung et al. (2010). In addition, Kim et al. (2011) also took 323 SportDancers registered with the Korean DanceSport Association for the survey, further verified the concepts and dimensions of the partnership, and developed the Korean DanceSport partnership scale, which contained 18 items utilized by other studies (Jae Sung and Yoo Bin, 2012; Yang, 2016).

Overall, the above four-dimensional theory and five-dimensional theory still have the following 3 limitations. (1) As a kind of interpersonal relationship, the psychological connection between DanceSport partners will be an important object of attention. However, *economical environment* and *physical harmony* are the influencing factors of the formation and maintenance of the partnership; *perfect rhythm* is the influencing factor of partner cooperation ability at the individual level, and *referee-audience feedback* is the influencing factor affected by the competitive performance of the partners. These are difficult to reflect the psychological connection between the partners and are difficult to regard as the dimensions of the partnership. (2) There are a few dimensions of partnership belonging to different disciplines or under different theoretical perspectives, such as sociology and musicology, which are not conducive to dialogue with relevant theories. As a special interpersonal relationship, it is the research concept of sports psychology. Although two representative studies have also found trust, partner care, partner harmony, and reciprocal endeavor from the perspective of sports psychology,

TABLE 1 Basic information of the interviewed elite dancers.

Discipline	Code	Sex	Age (year)	Training time (year)	Partner time (year)	Domestic best results	Length of interview (minute)	Interview recordings (words)
B	A	M	31	20	14	First (PRO)	65	11935
B	B	F	25	12	6	Third (PRO)	45	6297
B	C	M	26	16	4	Forth (PRO)	43	4376
B	D	M	23	13	3	Forth (PRO)	39	1863
B	E	F	29	21	3	Sixth (PRO)	27	4693
B	F	F	25	18	6	Sixth (PRO)	34	4862
B	G	F	32	20	5	Second (PRO-RS)	26	2717
B	H	M	26	20	7	Third (A-group)	67	9453
B	I	F	27	16	3	Third (A-group)	39	4018
B	J	M	20	15	8	Third (A-group)	36	4937
B	K	M	24	8	3	Forth [A(RS)-group]	21	2332
L	L	M	28	10	7	Second (PRO)	50	8699
L	M	F	25	15	3	Third (PRO)	50	8500
L	N	F	22	10	3	First [A(RS)-group]	53	11012
L	O	F	21	10	8	Third (A-group)	26	3399
L	P	F	22	13	4	Eighth (A-group)	30	4219
L	Q	F	19	10	3	Sixth [A(RS)-18 years-group]	32	3521
L	R	M	19	7	3	Sixth [A(RS)-18 years-group]	43	8026
L	S	F	21	8	3	First [A(RS)-group]	43	4468
L	T	F	21	15	3	First [A(RS)-group]	27	6532

*B, ballroom dance; L, Latin American Dance; PRO, professional; PRO-RS, professional rising star, A(RS)-group, A-rising star.

partner care, partner harmony, and mutual assistance overlap to a certain extent, and hence, independence between the dimensions is weak. (3) DanceSport is a discipline based on romantic fantasy, which openly expresses emotions (Harman, 2019), shows the body between men and women, and highlights the intimate relationship between them (Ericksen, 2011). Therefore, compared with other dyadic sport events, such as ping-pong mixed doubles, tennis mixed doubles, and synchronized diving, DanceSport partnership is significantly different (Myung et al., 2010; Jae Sung and Yoo Bin, 2012). However, in the existing research on the partnership between DanceSport couples, due attention has not been paid to its characteristics, such as short-term passion. (4) Interpersonal relationship has cultural characteristics (Hsu, 1953) and so does DanceSport partnership. For example, based on the Rasch model in item response theory (IRT), Yang (2015) found that "my partner and I will be full of vitality when dancing in front of the crowd" and "my partner and I have left a deep impression on the audience" (Kim et al., 2011) were considered to be prejudiced against the male group because South Korean men cannot be regarded as the object of appreciation. However, the scale developed under specific cultural backgrounds should not be used uncritically in different cultures (Duda and Hayashi, 1998). However, few studies have paid attention to the cultural characteristics of DanceSport partnership from the perspective of cultural psychology. For countries including China based on Confucius culture, the obligations between DanceSport couples are ruled by "*renqing*" which focuses on the partnership itself without always considering that the instrumental intentions have not been recognized.

1.2. DanceSport partnership in our study

DanceSport partnership encompasses behaviors, emotions, and thoughts between two people (Kelley et al., 1983). In addition, according to the epistemological strategy of cultural psychology, that is, "one mind, many meanings; disunity universalism" (Shweder et al., 1998: 871; Cheung et al., 2011; Hwang, 2018), as well as the existing research results of DanceSport partnership and dance partner interaction practice, DanceSport partnership has a cultural identity. Based on these perspectives, we propose that the partnership between Chinese DanceSport partners includes obligatory instrumental ties (behaviors), expressive ties (emotions), and interpersonal perception (thoughts).

Obligatory instrumental ties (OIT) refer to the reciprocal behavior tendency of elite dancer couples based on the principle of obligation ruled by "*renqing*" to maintain their partnership during the whole process of taking DanceSport competition as the goal. It includes the obligation and instrument factors (Liu et al., 2022). First, because the importance of effective talent development in sports is well established as a key aspect of achieving high-level performance (Taylor et al., 2022), the competitive victory in DanceSport is taken as the starting point

TABLE 2 Identification experts list (n = 10).

Code	Title	Specialty
1	Professor	Sport psychology
2	Professor	Social psychology
3	Professor	Psychometrics
4	Professor	Culture psychology
5	Professor	The teaching and training of DS
6	Doctor	The teaching and training of DS
7	Doctor	The teaching and training of DS
8	Doctor	The teaching and training of DS
9	Champion	Champion of Latin dance competition
10	Champion	Champion of ballroom dance competition

DS, DanceSport.

(Bednarzowa and Młodzikowska, 1983; Budnik-Przybylska et al., 2015). In addition, according to Chen et al. (2013), the analysis of the characteristics of Chinese "guanxi (interpersonal relationship) will always be considered as a capital," as it can be found that the DanceSport partnership is a tool to achieve goals. Therefore, partners often exhibit a high degree of reciprocity and interaction (Reisman, 1981; Marion, 2006), and partnership is always taken as an instrument to obtain benefits (Lai, 2014; Liu et al., 2022). When describing the qualities of the ideal dance partnership, an elite dancer suggested that a partner who can help them improve their dancing skills and obtain excellent competitive performance is perfect (Marion, 2006). Second, however, in Asia like China, there is a strong emphasis on obligation between DanceSport couples (Liu et al., 2022). The obligation is ruled by "*renqing (favor)* or *mianzi (face)*" based on Confucianism, which is based on personal feelings rather than commercial law to safeguard obligations. When people fail to comply with the rules, it will lead to public criticism. To avoid such criticism, Chinese people present a "public-self" to others to preserve their face or the face of others, while maintaining their true and selfish "private self" (Chang, 2012). Although Westerners are accustomed to the two concepts of losing and saving face, using and understanding these metaphors, the Chinese do it better; they are also very good at giving face, taking care of the face, and fighting for the face to maintain a harmonious relationship (Hwang, 1987; Peng, 1998; Seligman, 1999).

Expressive ties (ET) refer to the emotional bond containing instant intimacy produced by elite dancer couples during the full process of taking DanceSport competitions as the goal. Expressive ties involve both instant intimacy (Ericksen, 2011, pp. 20–21) and prolonged emotion (Brewińska and Poczwardowski, 2011; Yang, 2015). To be more specific, on the one hand, when dancers dance together for the pleasure of communication, an instant intimate relationship will be formed between them. For example, the dancers will demonstrate the romance and passion between the sexes in Rumba (known as the "soul of Latin dance" and the dance of love). Meneau (2020), a scholar at the University of Salzburg, Austria who specialized in gender and DanceSport research, even described the Rumba performance of the world's top competitors Gabriele Goffredo and Anna Matus in the 2014 Brno Open: "*He approaches her from behind until his chest touches her back, then thrusts his hands to her lower thighs and caresses her upwards. After grabbing her waist, he pushes her away and sharply pulls her back to him, provoking an impact of her back against his ribcage.*" On the other hand, a partnership between DanceSport couples contains factors such as care and appreciation. To continuously improve professional skills and obtain excellent competitive performance, dyadic couples not only need to spend a lot of time and energy in training but also need to travel to different cities and countries to participate in competitions. The daily life, learning, and training of the two are highly intertwined. Therefore, there is a shared interactive memory system (Transactive Memory System, TMS) between the dance partners to jointly

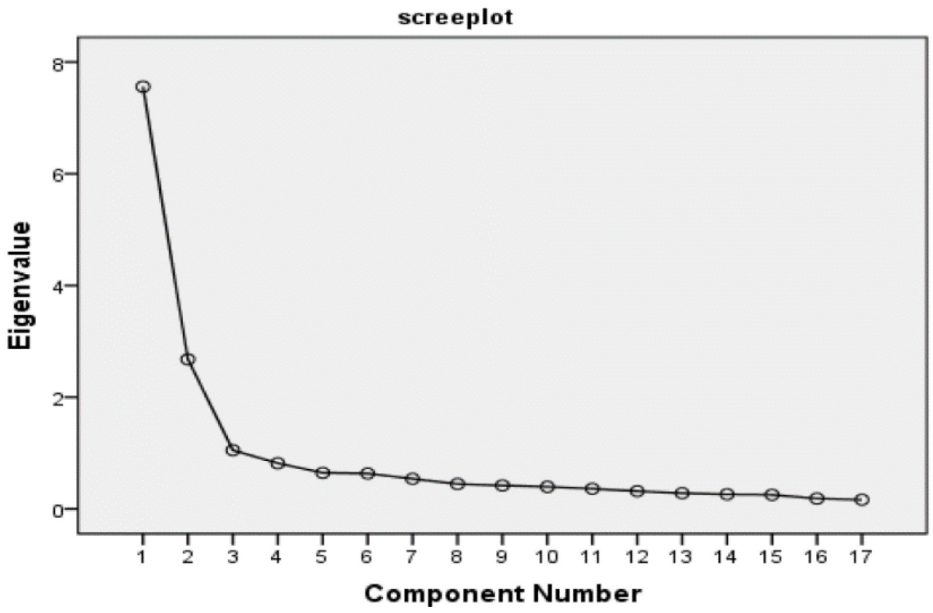

FIGURE 1
Scree plot of the DanceSport partnership.

TABLE 3 Summary of DanceSport partnership scale.

Item	Critical value	Item total correlation	Cronbach's Alpha after the item is deleted	Communality	Factor loading	Result
X1	10.286	0.634**	0.944	0.518	0.598	Retain
X2	12.554	0.709**	0.942	0.803	0.853	Retain
X3	10.698	0.631**	0.943	0.705	0.787	Retain
X4	14.236	0.790**	0.941	0.721	0.716	Retain
X5	15.396	0.804**	0.940	0.735	0.759	Retain
X6	9.346	0.619**	0.944	0.831	0.872	Retain
X7	12.953	0.682**	0.943	0.726	0.802	Retain
X8	11.801	0.658**	0.943	0.530	0.679	Retain
X9	12.718	0.753**	0.941	0.714	0.792	Retain
X10	10.852	0.670**	0.943	0.790	0.811	Retain
X11	13.021	0.719**	0.942	0.834	0.871	Retain
X12	12.95	0.731**	0.942	0.728	0.505	Retain
X13	10.141	0.660**	0.943	0.512	0.606	Retain
X14	12.747	0.725**	0.942	0.848	0.878	Retain
X15	8.916	0.490**	0.945	0.500	0.618	Delete
X16	14.584	0.806**	0.940	0.722	0.731	Retain
X17	14.813	0.807**	0.940	0.737	0.712	Retain
X18	15.593	0.792**	0.941	0.707	0.714	Retain
X19	12.857	0.724**	0.942	0.668	0.766	Retain
X20	9.522	0.563**	0.944	0.554	0.707	Retain

Cronbach's alpha of this scale is 0.945. **means $P < 0.01$.

encode, store, and retrieve information (Grysman et al., 2020). According to Wegner (1987), dance partners will have an intense sense of identity and emotional bonds during the process of cooperation. In the case of elite dancers, the interaction between them exists in both professional training and private life. Dance partners are not only best friends but also life partners (Brewińska and Poczwardowski, 2011). In fact, ballroom dance is about love and also about sex (Ericksen, 2011, p. xii), as Brewińska and Poczwardowski (2011, pp. 27) mentioned that rapport between dance partners was essential whether driven by romantic attraction to each other or simply by a shared passion for the dance. This is mainly because the technical acquisition of DanceSport requires long-term cooperation and training. During this period, the partners are always together, and the connection between the two is intimacy, passion, and immersion (Yang, 2015). They must exhibit passion and emotion during dancing. Very often, high-class dancing couples are also pairs in life (Majoross et al., 2008; Brewińska and Poczwardowski, 2011).

Interpersonal perception (IP) refers to the ability of elite dancer couples to share and expose each other during the whole process of taking competition as the goal so as to sensitively perceive the psychological and behavioral tendencies of dance partners, including revealing their hearts, sharing, and understanding each other. As depicted by Dan (2012), interpersonal abilities are the engine of artistic communication and the wish to dance comes from the wish to communicate and to feel a connection with the partners. Partners show themselves to each other, get to know each other, and create a heart-to-heart awareness of each other, which is so vital that Myung et al. (2010) defined the dimension of "*partner harmony*" in the partnership between partners after interviewing registered Korean elite dancers and set up the item "understand the personality of the partner" in the dance partnership questionnaire. However, in the Chinese context, it may be more important to understand the dance partner. More specifically, for the Chinese, intimacy is the result of the interaction between individuals as boundaries melt away, i.e., two people violate each other and then reach a state of "you and I are indistinguishable" (Jamieson, 1998; Friedman, 2005). The dance couples are more likely to raise the training issues into love issues, for the expressive ties between the partners will always break the regular operation mode of professional cooperation, which can lead to quarrels and conflicts. Therefore, the elite dancers need to understand their partner through communication, share their inner thoughts, and create a heart-to-heart connection, which can facilitate the resolution of arguments and differences brought about by the blurred role boundaries.

1.3. The aim of the present study

Although research on the athlete–athlete partnership framework is an important research direction, the research is still in its infancy. According to Poczwardowski et al. (2019), the most important work of researchers is to build a complete and ambitious system out of a large theoretical wasteland, focus on the screening and dimensional constructions of two-person interpersonal

TABLE 4 The summary of factor analysis of Partnership Scale-DanceSport Couples (PS-DSC) (*N* = 289).

Items	Factor loading			Communality
	Factor 1	Factor 2	Factor 3	
X14 cooperate with my partner will get closer to my goal	0.889			0.874
X11 cooperate with my partner will make me grow professionally	0.876			0.842
X2 cooperate with my partner will achieve my goal	0.866			0.820
X7 cooperate with my partner promote my personal ability	0.813			0.733
X3 my partnership is mutually beneficial and win-win	0.809			0.709
X20 I obligately follow the training plan agreed with my partner	0.680			0.503
X13 I and my partner should support each other	0.598			0.502
X9 In dance training or competition, my partner often gives me a fresh feeling		0.816		0.746
X19 I find my partner very attractive		0.780		0.685
X4 In dance training or competition, I and my partner are full of passion		0.769		0.732
X5 I and my partner understand each other		0.747		0.730
X16 I get along with my partner		0.730		0.726
X18 I and my partner appreciate each other		0.703		0.707
X17 I and my partner care about each other		0.695		0.736
X8 I feel relaxed and happy with my partner without pressure		0.663		0.522
X6 I feel I really know my partner			0.877	0.830
X10 I feel my partner really knows me			0.806	0.775
X12 I and my partner are tied together			0.707	0.774
X1 I am willing to share my true thoughts with my partner			0.655	0.561
eigenvalue (unrotated)	9.68	2.61	1.19	
variance explained (%)	27.44	26.61	16.89	
the amount of variance explained (%)	27.44	54.05	70.94	

relationships (i.e., analytical framework construction), and then incorporate it into a theoretical model of how two-person interpersonal relationships arise in relation to other variables (Poczwardowski et al., 2019). As the DanceSport partnership research is in its primary stage of theoretical research, literature on the partnership between DanceSport couples is sparse (Majoross et al., 2008; Liu et al., 2022). Therefore, the purpose of our study was to develop a scale to measure the partnership between DanceSport couples—Partnership Scale-DanceSport Couples (PS-DSC). The following four studies were conducted. The first study aimed to generate initial items and refine them. The second study was to examine the factor structure of the PS-DSC items identified in study 1 through exploratory factor analyses. The third study was to further examine the factor structure of the PS-DSC items using confirmatory analyses. The fourth study provided an assessment of composite reliability, discriminant validity, and convergent validity.

2. Study 1: Initial development of the scale

Study 1 was to generate items that captured the three partnership dimensions between DanceSport couples and to evaluate and refine the initial PS-DSC item pool.

2.1. Expert interviews to validate definitions

The operational definition and the three-dimensional structure (instrumental ties, expressive ties, interpersonal perception) of the partnership between the DanceSport couples were validated using expert interviews and were finally approved by one researcher from the Institute of Psychology, Chinese Academy of Social Sciences, one Associate Researcher from the Institute of Psychology, Chinese Academy of Sciences, three masters from the School of Psychology at Beijing Normal University, and 6 DanceSport experts from sports colleges and universities (The Beijing University of Physical Education, The Capital Institute of Physical Education, The Wuhan Institute of Physical Education, and The Xi'an Institute of Physical Education; by telephone and field visits).

2.2. Elite dancer interviews

The initial items were generated through 20 excellent Chinese DanceSport elite dancers (Table 1) who have a training period of more than 7–20 years, more than 3 years of working experience with a fixed partner, and exhibited superior performance in competitions. This sample was confirmed in advance with two competitors who had won championships and 4 DanceSport experts from Beijing Sports University and Xi'an Sports University.

TABLE 5 Descriptive statistical summary table of observed variables for the DanceSport partnership questionnaire (N = 288).

	Min	Max	M	S	Skewness	Kurtosis
X1 I am willing to share my true thoughts with my partner	1	5	3.86	1.006	−0.669	0.006
X2 cooperate with my partner will achieve my goal	1	5	4.04	0.923	−1.039	1.272
X3 my partnership is mutually beneficial and win-win	1	5	4.17	0.92	−1.319	1.863
X4 In dance training or competition, I and my partner are full of passion	1	5	3.62	0.922	−0.593	0.375
X5 I and my partner understand each other	1	5	3.60	0.979	−0.565	0.04
X6 I feel I really know my partner	1	5	3.17	1.073	−0.208	−0.279
X7 cooperate with my partner promote my personal ability	1	5	4.18	0.859	−1.112	1.504
X8 I feel relaxed and happy with my partner without pressure	1	5	3.56	1.017	−0.511	−0.038
X9 In dance training or competition, my partner often gives me a fresh feeling	1	5	3.3	0.952	−0.181	−0.188
X10 I feel my partner really knows me	1	5	2.99	1.088	−0.084	−0.347
X11 cooperate with my partner will make me grow professionally	1	5	4.27	0.815	−1.229	1.966
X12 I and my partner are tied together	1	5	3.31	1.087	−0.385	−0.223
X13 I and my partner should support each other	1	5	4.35	0.787	−1.444	2.865
X14 cooperate with my partner will get closer to my goal	1	5	4.16	0.867	−1.179	1.821
X16 I get along with my partner	1	5	3.7	0.938	−0.764	0.624
X17 I and my partner care about each other	1	5	3.56	1.051	−0.583	−0.022
X18 I and my partner appreciate each other	1	5	3.35	1.029	−0.482	−0.039
X19 I find my partner very attractive	1	5	3.31	1.091	−0.395	−0.37
X20 I obligately follow the training plan agreed with my partner	1	5	4.13	0.816	−1.1	1.997

TABLE 6 Initial model fitness result of DanceSport partnership.

	χ^2	df	χ^2/df	GFI	AGFI	NFI	CFI	PNFI	PGFI	RMSEA
Initial Model	568.686	149	3.817	0.818	0.768	0.868	0.899	0.757	0.641	0.099

The sample consisted of 8 men and 12 women. Their average age was 24.30 years (range = 19–31, SD = 3.80). On average, they have been dancing for 13.85 years (SD = 4.44) and experienced 4.95 years of partner time (SD = 2.82). The interviewees almost covered the excellent dancers of each group class that can represent the level of Chinese sports dancers. Therefore, the results obtained through the interviews were undoubtedly credible and representative of understanding and generalizing the items of PS-DSC.

The total length of the interviews was 796 min. The interview period spanned 45 days from 29 May 2019 to 12 July 2019. The reason for the long span was due to the intensive domestic and international events as most elite dancers participated in many competitions and it was hard to make appointments with them to get the interview. Finally, the transcription of the voice material into text material was 115,869 words.

2.3. Initial item generation and item refinement

By analyzing the results considering the Korean DanceSport partnership scale (Lee and Dawes, 2005; Myung et al., 2010; Kim et al., 2011) and the recommendations of DeVellis (2011), we generated 35 items using the definitions and key characteristics of each component. The following 20 items were chosen by 10 experts (Table 2) for their clarity, readability, relevance, similarity to other items generated, items in existing scales, and the degree to which they adhered to the specified criteria.

3. Study 2: Scale refinement and EFA

The results generated by study 1 awaited empirical support (or invalidation) regarding the partnership between DanceSport couples. In study 2, we explored the factor structure and the psychometric properties of the second revised pool of twenty items identified in study 1 through EFA, which was considered a useful method of data reduction when developing or refining a scale (Anderson and Gerbing, 1988) and to ensure the refinement of each subscale before proceeding to CFA analysis.

3.1. Participants

The sample reserved for study 2 consisted of 289 young elite dancers (134 men and 154 women). The average age of the elite

TABLE 7 Items deleted after revised.

Revise	Deleted items
1	X5 I and my partner understand each other
2	X10 I feel my partner really knows me
3	X13 I and my partner should support each other
4	X9 In dance training or competition, my partner often gives me a fresh feeling
5	X8 I feel relaxed and happy with my partner without pressure
6	X19 I find my partner very attractive
7	X7 cooperate with my partner promote my personal ability

dancers was 20.96 years (range = 14–33, SD = 3.40). On average, they had been dancing for 6.98 years (SD = 4.12), had dedicated 9.28 h (SD = 9.65) to training and competition per week, and had experienced 21.26 months of partner time (SD = 21.57).

3.2. Data analysis

The purpose of data analysis was to further optimize the items of the scale and assess the factor structure of the subscales. Before conducting the EFA, the following information was collated and used to decide which items to retain: (a) critical value, item-total correlation, Cronbach's alpha after the item is deleted, commonality, and factor loading and (b) the value of the KMO (Kaiser–Meyer–Olkin) and Bartlett tests, and an oblique rotation that was investigated to identify the factor structure (Anderson and Gerbing, 1988).

Then, EFA was calculated using IBM SPSS Statistics 22. We wanted an empirical summary of the dataset by principal components analysis (Tabachnick and Fidell, 2007) and decided that the number of factors were evident through an unrotated factor solution. Then, Kaiser's criterion (Kaiser, 1960) and the scree plot (Cattell, 1966) were adopted to determine the number of factors in each subscale.

3.3. Discussion

Preliminary tests before EFA revealed that all items met the criteria (critical value ≥3.50, item total correlation ≥0.40, Cronbach's alpha after the item was deleted did not get smaller, communality ≥0.200, and factor loading ≥0.45), except for the item "X15." The reason was that Cronbach's alpha of this scale remained 0.945 when it was deleted (see Table 3). In addition, the value of the KMO (Kaiser–Meyer–Olkin) and Bartlett tests was suitable for factor analysis (0.926, $p < 0.001$).

The outcome of the item analysis turned out to be the suitability of the data for EFA which aimed to recombine disordered variables and explore the potential structural relationship between the variables (Lai, 2014). This study conducted EFA on the remaining nineteen items. Using principal component analysis, three factors were obtained according to Kaiser's criterion, the eigenvalues of which were greater than 1. It can be seen from the scree plot that, after the third factor, the slope becomes gentle and the factor starting from the fourth factor presents a straight line (see Figure 1), indicating that the contribution of these factors to the original variables can be almost ignored. These two tests proved that it was appropriate to extract the three factors. In addition, an oblique rotation was performed to identify the factor structure (Anderson and Gerbing, 1988), and the results are shown in Table 4.

According to Table 4 and Figure 1, the results of the three factors were explained as follows:

The items "X14, X11, X2, X7, and X3" in factor 1 showed that dance partnership was regarded as a means to obtain competitiveness and performance, which was in line with the "economic man" hypothesis. The items "X20: I obligately follow the training plan agreed with my partner" and "X13: I and my partner should support each other" highlighted the sense of obligation to hide utilitarianism, which indicated that the couples need to undertake certain obligations to obtain excellent competitive performance. Chinese dance partners follow the law of "*renqing*" and "*mianzi*" which emphasized the role of the obligation of desalinating utilitarian purposes so as to avoid the embarrassment caused by even exchange, which was different from the contractual obligation corresponding to power in the West. To sum up, the stickiness between the utilitarian tendency and the sense of obligation was strong. Based on the above seven items, factor 1 was named the obligatory instrumental tie.

The items "X5, X16, X18, X17, and X8" in factor 2 revealed the long-term accumulated emotions between dance partners. This was in line with the requirements of the "social man" hypothesis, that is, the emotional needs were the basic needs of people. Competitive sports events, including DanceSport, require long-term training to acquire the skill (Reynolds, 1998). Some participants in our study were between the ages of 17 and 28 years. They have higher

TABLE 8 Results of the confirmatory factor analysis for DanceSport Partnership (N = 288).

	χ^2	df	χ^2/df	GFI	AGFI	NFI	CFI	PNFI	PGFI	RMSEA
1	483.418	132	3.662	0.841	0.794	0.877	0.907	0.757	0.649	0.096
2	385.642	116	3.324	0.861	0.817	0.890	0.920	0.759	0.653	0.090
3	317.014	101	3.139	0.875	0.832	0.904	0.932	0.761	0.650	0.086
4	237.892	87	2.734	0.898	0.860	0.921	0.948	0.763	0.651	0.078
5	169.581	74	2.292	0.923	0.891	0.940	0.965	0.764	0.651	0.067
6	141.954	62	2.290	0.930	0.898	0.945	0.968	0.751	0.634	0.067
7	119.592	51	2.145	0.938	0.905	0.957	0.975	0.739	0.613	0.068

Then, the second-order model test was conducted, and the results showed that $\chi^2/df = 2.319$, $RMSEA = 0.068$, $SRMR = 0.037$, $GFI = 0.938$, AGFI = 0.906, $NFI = 0.957$, $CFI = 0.975$, $PNFI = 0.740$, and $PGFI = 0.614$. This reveals that the fitting effect was good.

TABLE 9 Component reliability of latent variables and average variation extraction of Partnership Scale-DanceSport Couples (PS-DSC).

Latent variable Observable variable	Estimate	CR	AVE
Obligatory instrumental ties		0.93	0.72
X14 cooperate with my partner will get closer to my goal	0.883		
X11 cooperate with my partner will make me grow professionally	0.932		
X2 cooperate with my partner will achieve my goal	0.896		
X7 cooperate with my partner promote my personal ability	0.851		
X20 I obligately follow the training plan agreed with my partner	0.667		
Expressive ties		0.87	0.65
X4 In dance training or competition, I and my partner are full of passion	0.488		
X16 I get along with my partner	0.886		
X18 I and my partner appreciate each other	0.871		
X17 I and my partner care about each other	0.893		
Interpersonal perception		0.72	0.89
X6 I feel I really know my partner	0.854		
X12 I and my partner are tied together	0.832		
X1 I am willing to share my true thoughts with my partner	0.863		

emotional needs and greater emotional fluctuations. In addition, the three items "X9, X19, and X4" reflect a short-term emotional state full of desire formed by the contestant and his partner in the field. In addition, expressive tie was included in Chinese 'Guanxi' (Kipnis, 1997). Based on the above eight items, factor 2 was named expressive tie.

The items "X6 and X10" in factor 3 reflect the elite dancers' requirements for perceiving all aspects of their partners. Item "X12" reflected that the elite dancers wanted to express a tacit understanding with their partners in dance and life. Item "X1" reflected the elite dancers' need for self-disclosure, under the reciprocal effect of disclosure, and individual self-disclosure, which will lead to the disclosure of the others (Miller, 1990) and ensure full communication between dance partners in training and avoided conflicts as in the cooperative context (Tjosvold, 1981). These items described the desires of elite dancers to perceive the ideas and attitudes of their partners and to understand their views of themselves. As the dancers will have cognitive differences or even conflicts due to individual differences, they need to constantly strengthen their interaction and communication with the perceptual object, timely adjust their state based on their cognitive ability and attitude toward their partners, and ensure the development and maintenance of the partnership. In addition, the stability of interpersonal relationship depends on the formation of certain relationship perception (Baumeister and Leary, 1995). Combining the above four items, factor 3 was named interpersonal perception.

4. Study 3: Scale confirmation and CFA

The purpose of study 3 was to further examine the three-factor 20-item structure model that is identified in study 2 using confirmatory factor analysis (CFA) through SEM techniques.

4.1. Participants

The sample reserved for study 3 consisted of 288 elite dancers (115 men; 172 women). The average age of the elite dancers was 19.30 years (range = 14–31, SD = 3.30). On average, the elite dancers have been dancing for 7.70 years (SD = 4.40), dedicating 9.67 h (SD = 4.17) to training and competition per week and experiencing 18.65 months of partner time (SD = 23.19).

4.2. Data analysis

Confirmatory factor analysis examined whether the relationship between a factor and the corresponding measurement term conforms to the researchers' theoretical assumptions, we used SEM to verify the fitting degree of the proposed model to the actual observation data obtained from EFA. The SEM mode analysis adopted the estimation method of complete information technology, which was built on the bases of the normal theory. Therefore, the selection of the estimation method was affected by the nature of the sample distribution, and the data of this study needed to be conformed to the multivariate normal distribution. The normality test required that the absolute values of the skewness coefficient and kurtosis coefficient were less than 1.96. The results of this study showed that (as shown in **Table 5**) the skewness value of the observed variables of DanceSport partnership was between −1.444 and 0.084 and that the kurtosis value is between −0.022 and 2.865, and hence, the data of our study tend to be normally distributed.

We used CFA with maximum likelihood estimation to examine whether the hypothesized three-factor structure was supported by

the data. Multiple goodness-of-fit measures were used to indicate the model fit [$\chi^2/df < 3$ (Kline, 2005); GFI, AGFI, CFI, NFI ≥ 0.90; PNFI, PGFI < 0.8 (Kline, 1998)]. The value of RMSEA was between 0.05 and 0.08. When the value was below 0.05, it indicated that the model fitting degree was incredibly good (Browne and Cudeck, 1992). The results of this study (**Table 6**) showed that the model fitting index was not ideal. According to the standard of a minimum of 3 items in each dimension, this model still has a lot of room for correction, and hence, the model would be revised and retested.

In this study, the items were deleted according to the M.I. modification index, meaning that, between two items with higher M.I. indices, the item with the highest M.I. value than other items was first selected for deletion to eliminate the serious collinearity problem between items. In this study, a total of 7 model revisions were carried out and 7 items were deleted in turn as shown in **Table 7**. **Table 8** shows the model fitting indicators of the 7 revisions. The results showed that, after the 7th revision, the model fitting indicators of the model met the strict requirements of the psychometric test.

5. Study 4: Reliability and validity test

5.1. Participants

In this study, the event held by the Chinese DanceSport Federation (Beijing Station) was selected as the carrier to obtain the results of the A(RS)-group and A-(RS) group elite dancers (after experts' identification, the elite dancers in these two groups had a deep understanding of the partnership). The sample consisted of 242 young elite dancers, of which 122 were men and 120 were women. Of them, 91 have been dancing for 0–5 years, 107 for 5.1–10 years, 28 for 10.1–15 years, and 16 for over 15 years. A total of 151 elite dancers spend 0–12 months with their partners, 58 for 13–36 months, 22 for 37–60 months, and 11 for over 60 months.

5.1.1. Reliability analysis

A composite reliability of >0.6 was one of the criteria for judging the intrinsic quality of the model. The average variance of >0.50 indicated that the intrinsic quality of the model was ideal (Bagozzi and Youjae, 1988; Hair et al., 2009). Using SEM to calculate the reliability of the individual topics and potential variables, the results are shown in **Table 9**. The results showed that the internal structural fitness of the DanceSport partnership model developed in this study was in line with the ideal level and has good internal quality.

5.1.2. Validity test

5.1.2.1. Discriminant validity

Discriminant validity refers to the low correlation or significant difference between the dimensions and the potential traits represented by dimensions. This study used the correlation between the dimensions and the correlation between dimensions and total score to judge the differential validity of the scale. The Pearson correlation analysis showed that the correlation coefficients between each dimension of DanceSport partnership, namely, the subscale and the total score, were 0.838–0.869, which reached a significant level ($P < 0.05$). The correlation coefficient between dimensions is 0.555–0.631 and the scale has good differential validity.

5.1.2.2. Convergent validity

Convergent validity refers to the items that measuring the same potential traits will fall on the same factor dimension, and there was a high correlation between the items and the measured values between tests. Only when the factor load of each observed variable on its latent variable was not less than 0.45, the observed variable was sufficient to reflect its constructed potential variable (Bentler and Wu, 1993). In this study, the dimensional factor loads of obligatory instrumental ties, expressive ties, and interpersonal perception were all moderately and highly significant and exceed the threshold of 0.45. Therefore, PS-DSC has good convergent validity.

6. General discussion

This study aimed to develop a scale to measure partnership between DanceSport couples. The four studies outlined highlight the key stages in the initial development and validation of the PS-DSC. In stage 1, outlined in study 1, PS-DSC items were generated and refined through literature analysis, interviews with players with rich partner experience, and expert identification. In stage 2, outlined in studies 2 and 3, exploratory and confirmatory analyses were used to further examine the structure of PS-DSC items. In stage 3, outlined in study 4, composite reliability, discriminant validity, and convergent validity were assessed. The result of this process was a three-factor 13-item scale.

The development of the PS-DSC was underpinned and guided by some considerations. First, we considered the partnership between DanceSport couples to be composed of three distinct and interrelated components representing obligatory instrumental ties, expressive ties, and interpersonal perception. We found strong support for this hypothesized three-factor structure across measurement models and samples. Second, we found that the 3 dimensions did work on measuring the partnership between DanceSport couples using practical and theoretical analysis. For dancers, they can choose partners who share the same goals as them by scoring using the scale. For example, elite dancers who tend to have expressive ties can choose partners with higher scores in expressive ties and interpersonal perception. The coaches can also help the elite dancers match their partners by scoring on the scale. This enables the dance partners to stay together for a long time, cultivate more tacit skills of pairs, provide a good interpersonal environment for elite dancers to break through more excellent competitive performance, and make certain contributions to the world dance sport competition.

6.1. Obligatory instrumental ties

This dimension integrates both instrumental ties and obligatory ties (Liu et al., 2022). On the one hand, it is in line with the reciprocal endeavor dimensions of the partnership

between Korean DanceSport couples (Myung et al., 2010), the commitment dimension in the 5C theory of athlete–athlete partnership (Poczwardowski et al., 2019), and the 3C theory of the coach–athlete relationship (Jowett and Meek, 2000) in terms of instrumental elements that emphasized exchange and utilitarianism. Because DanceSport partners are a community sharing common goals and tasks (Vegt et al., 2010), highly interdependent dance dyads emphasize the exchange of "gain" and "give" results with the goal of obtaining competition rankings. Therefore, in our study, items "X7 cooperate with my partner promote my personal ability," "X11 cooperate with my partner will make me grow professionally," "X12 I and my partner are tied together," and "X14 cooperate with my partner will get closer to my goal" all showed good reliability and validity in statistics when tested.

However, for relationship in China was particularistic (Farh et al., 1998) on the other hand, we emphasized the sense of obligation between DanceSport couples. As Alan Fiske (1992) pointed out, obligations can only be discussed in different relationships, which meant that the sense of obligation has specific cultural characteristics. For example, in the items of the DanceSport partnership scale developed by Korean couples, the items: "my partner and I will be full of vitality when dancing in front of the crowd" and "my partner and I have left a deep impression on the audience" are considered to be prejudiced against Korean male groups (Yang, 2015). As Hwang (1987) states, the component of obligation in partnership between Chinese dance couples was a mixture of expressive and instrumental ties, following the "*renqing*" rule, as opposed to the "contractual obligations" that emphasized the role and obligation of weakening utilitarianism. Therefore, in our study, the item "X20 I obligately follow the training plan agreed with my partner" was indispensable for elite dancers. For example, one elite dancer [A(RS)-group] in China stressed that "I feel guilty to see my partner practicing dancing in the glass room." In addition, one professional elite dancer mentioned that "we are not a couple, we are fighting together for a common goal, but I still hope not to look too much utilitarian, we are all friends." Therefore, we believed that obligatory instrumental ties were an important and special dimension of DanceSport partnership in the Chinese context.

6.2. Expressive ties

This dimension contains intimacy caused by long-term contact and short-term passion. It is in line with the partner care dimension of partnership (Myung et al., 2010), the closeness dimension in the 5C theory of athlete–athlete partnership (Poczwardowski et al., 2019), and the 3C theory of the coach–athlete relationship (Jowett and Meek, 2000) in terms of long-term intimacy. Based on Robert Stemberg's ternary theory of love (Sternberg and Grajek, 1984), scholars believed that intimacy included the characteristics of mutual understanding, caring, and support, which was highly positively correlated with being understood and appreciated (Fitzsimons and Kay, 2004). As for DanceSport elite dancers, they needed to increase the frequency of interdependence in the process of long-term training and competition to establish close contact with their dance partners to learn the technique of double cooperation together (Ericksen, 2011). Therefore, romantic relationships, marriage relationships, or similar kinship relationships will be derived from the interaction of partners. For example, in the interview with this study, one elite dancer, the third (PRO) in China mentioned that "in the first 5 or 6 years when we left hometown and danced together in Shanghai, we only had each other and took care of each other. We were like family." Therefore, we proposed items "X16 I get along with my partner," "X17 I and my partner care about each other" and "X18 I and my partner appreciate each other," which can measure the intimacy and depth with their dance partner.

However, the short-term passion, which is very vital to competitive performance, was seldom proposed in studies of a partnership between elite dancers' dyads, for the athlete–athlete partnership in different sports presented distinctive characteristics (Poczwardowski et al., 2006). DanceSport is based on romantic fantasy (Harman, 2019) which openly expresses emotions, shows the body between dance partners, and highlights the intimate relationship between the two sexes (Ericksen, 2011). The intimate body movement makes the dancers sink into the love world full of male and female under the action of a mirror neural mechanism. Peters (1992), a Yale University teacher who has won American DanceSport competitions, wondered about the lust between dance partners. As she said, driven by passion, dancers' lives revolved around dancing, with enthusiasm and dedication, as they practiced complex tricks repeatedly. Whether on or off the dance floor, they were swallowed up by their own imagination of dance, such as practicing courtship rituals or erotic love in the tango so that people can see fascinating and attractive relationships immediately. She also wondered if they were still dance partners off the dance floor.

So, the results of this study showed that the item "X4 In dance training or competition, I and my partner are full of passion" has good statistical significance for the formation of the scale.

6.3. Interpersonal perception

Comparing the dimensions and scales of partnership between DanceSport couples (Myung et al., 2010; Kim et al., 2011), the interpersonal perception was a separate dimension in partnership between DanceSport couples in our study. Previous literature includes the components of interpersonal perception, such as "understand personality" (Myung et al., 2010). However, we believed that only one item cannot reflect the importance of interpersonal perception. The "Window theory" proposed by American psychologists Luft and Ingham (1955) stressed that with the development of interpersonal relations and the gradual establishment of intimacy, the " territory" of the open self, driven by the two interactive processes of self-disclosure and feedback from others, continued to expand outward along the two dimensions of depth and breadth so that the "territory" of the blind self, the hidden self, and the unknown self were constantly compressed and the individual's understanding of himself was more and more comprehensive and profound. Therefore, the more clearly one can disclose their internal thoughts, attitudes, emotions, likes and dislikes, and expertise, among others to others, the better others can understand and know themselves. DanceSport provides a

window for students to happily listen to and understand each other through body nonverbal communication (Ogilvie, 2017; Pisu et al., 2017).

Overall, the importance of interpersonal perception is reflected in its ability to better maintain and develop a partnership between DanceSport couples. Since, based on the field theory, the psychological connection between the DanceSport partners was a combination of instrumental ties and expressive ties influenced by different laws of operation, where the instrumental ties occur in the training competition arena, the expressive ties occur in daily life, and the dancers are likely to turn the cooperation issue into a love issue, making the intimate partnership between the dyads in practice break the conventional mode of operation of professional cooperation (Liu et al., 2022). In the absence of contractual constraints, the maintenance and development of partnerships will face challenges (Wang, 2018). In addition, based on the cultural psychology perspective, Markus and Kitayama (1991) put forward the self-concept analysis framework of "*independent self*" and "*interdependent self*" based on the characteristics of cultural differences, which emphasized that Asian people were more inclined to find themselves by relying on others. This was an inclusive individualistic interpersonal relationship, in which the individual's self-boundary was rheological and the establishment of expressive ties would accelerate the blurring of this boundary (Sampson, 1988). The expressive ties are the result of interaction after the boundary between individuals melts in China. The two people invade each other and then reach the state of "no distinction between you and me" (Jamieson, 1998; Friedman, 2005). Thus, elite dancers are likely to raise cooperation issues to love issues, to make the intimate relationship break the mode of professional cooperation in practice. In the case of only "*renqing*" without contractual constraints, the maintenance and development of partnerships will face challenges. Therefore, our study came up with three items- "X1 I am willing to share my true thoughts with my partner," "X6 I feel I really know my partner," and "X12 I and my partner are tied together" to measure whether couples can understand their partners' dance style, technical characteristics, and possible problems in dance (Pistole, 2003), without just caring about "understanding personality" between dance partners (Myung et al., 2010). This interactive function between partners makes dance movements be used as an intervention means to help participants interact with each other (Pisu et al., 2017).

7. Strength and limitations

The present study demonstrates some strengths. It provides a scale to evaluate the quality of the partnership between DanceSport couples and promote the development of DanceSport research in depth. Creating a scale of DanceSport partnerships will be beneficial for sports dancers and coaches. In addition, as a future study, we believe it will be good to recruit non-Chinese experiment participants and prove it. Another strength of the present study is that our study conforms to the development direction of sports psychology. Poczwardowski, Barott, and Jowett have stressed that research about partnerships among dyadic sports can be considered an important topic in 2006. After 12 years, in the theme (Sport-a path to peace between people)" under the 4th International Scientific and Practical Conference, Russian scholar Maximova (2018) reviewed the development of synchronized swimming in recent years with the opening of a dyadic sport, stressing once again that partnership has a tendency to develop into a new discipline in sport and raise expectations for the construction of equal and successful partnerships. In addition, a growing trend in the transformation of sports culture was to organize double event competitions, such as beach volleyball, figure skating, and ballroom dancing (Moskatova and Maltsev, 2018), and the peers seem to be important at all career stages (Kram and Isabella, 1985). Therefore, the study paid more attention to the partnership. The concept of partnership has appeared in the field of sports psychology but has not received much attention in DanceSport so far. Our research systematically discussed the partnership between DanceSport couples through qualitative and quantitative research.

This study has some limitations. Since we are using self-reported forms to obtain information, the results may be influenced by social expectations. In addition, we are not sure whether the results of this study can be extrapolated to other dyadic sports. The reason is that unique connotations to athlete–athlete partnership were influenced by the style of sports characteristics and hence there may be differences in athlete–athlete partnership components (Gaudreau et al., 2010; Poczwardowski et al., 2019). Therefore, future research should explore the analysis framework of the athlete–athlete partnership in different events to advance the theory of partnership in different sports and enrich the theory of competitive performance (Wickwire et al., 2004), which provides challenges and opportunities for discovering new concepts and theories in the partnership of different dyadic sports events.

8. Conclusion

Our research was to apply the construct of a partnership between DanceSport couples and develop the scale to measure it. Here, we have reported on key stages involved in the development and initial validation of this new scale. Based on these analyses, the PS-DSC shows evidence of good factorial validity and reliability.

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 present study was conducted in accordance with the Declaration of Helsinki and was also approved by the Ethics Committee of the Wuhan Sport University. Written informed consent was obtained from all subjects involved in this study, and they were all completely voluntary and anonymous throughout the entire study. Written informed consent to participants in this study was provided by all subjects. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

XL and XFW: conceptualization. XL and SW: methodology. XL, XFW, XLW, and SW: formal analysis. XL: investigation. XL and GY: data curation. XL: writing—original draft preparation. GY and XFW: writing—review and editing. XL and XLW: project administration. XFW and XLW: funding acquisition. All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

Funding

This research was funded by the "2021 Young and Middle-aged Scientific Research Team of Wuhan University of Sport (21KT15)".

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.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 05 November 2024
DOI 10.3389/fpsyg.2024.1465595

OPEN ACCESS

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RECEIVED 16 July 2024
ACCEPTED 21 October 2024
PUBLISHED 05 November 2024

CITATION
Whitehead PM, De Jaegher H, Santana I, Todd RM and Blain-Moraes S (2024) Capturing spontaneous interactivity: a multi-measure approach to analyzing the dynamics of interpersonal coordination in dance improvisation.
Front. Psychol. 15:1465595.
doi: 10.3389/fpsyg.2024.1465595

Capturing spontaneous interactivity: a multi-measure approach to analyzing the dynamics of interpersonal coordination in dance improvisation

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Introduction: Interpersonal coordination is widely acknowledged as critical to relating with, connecting to, and understanding others, but the underlying mechanisms of this phenomenon are poorly understood. Dance—particularly improvised dance—offers a valuable paradigm for investigating the dynamics of interpersonal coordination due to its inherent ability to connect us. However, conventional approaches to studying coordination often fail to capture the co-creative spontaneity that is intrinsic to such interactions.

Methods: This study combined multiple measures of interpersonal coordination to detect moments of high coordination between two freely improvising dancers. We applied maximum correlation vectors, normalized Symbolic Transfer Entropy (NSTE), and surveys to analyze the time-varying dynamics of similarity in movement speeds, directed influence, and subjective perception of dancers engaged in an improvisation task.

Results: This multi-measure approach offers a means of capturing the interplay between different dimensions of interpersonal coordination.

Discussion: This approach may be used to understand the underlying mechanisms of co-creative social interactions in improvised dance and other forms of spontaneous interactivity.

KEYWORDS

movement, symbolic transfer entropy, social interaction, interactional synchrony, coordination dynamics, video analysis, pose estimation

1 Introduction

As an art grounded in the kinesthetic, dance emerges from movement and enables humans to relate to each other through deeply embodied and creative attunement. This intrinsic quality positions dance as a natural laboratory to explore the complexities of social interactions. Central to this exploration is the role of coordination in interpersonal interactions. Through coordination, humans engage in co-regulation, where interaction partners collectively adjust their patterns of verbal and nonverbal activity to facilitate communication. The role of coordination in human interaction is supported by extensive literature that illustrates the relationship between

interpersonal coordination and various intra- and interpersonal markers of social bonding and prosocial behavior (for reviews see Hu et al., 2022; Mogan et al., 2017; Rennung and Göritz, 2016; Vicaria and Dickens, 2016). Several dance studies have further corroborated these findings, demonstrating that high levels of interpersonal coordination enhances empathetic ability and cooperation (Koehne et al., 2016; Reddish et al., 2013). In light of the unique relational power of embodied creative movement, dance offers a privileged medium for exploring the interactional process of coordination that underpins our socio-emotional experiences of relating to others.

Although all dance is inherently relational, some traditions of movement embrace greater degrees of spontaneous collaboration. In freely improvised group or partnered dance, the boundaries between moving and being moved are blurred, and the level of collective dynamics is especially rich as dancers creatively explore the relations of their movement quality, spatial organization, and temporal alignment. In free improvisation dance, the collective of movers are afforded and experience a state of collective agency, a state which is often accompanied by a profound feeling of togetherness (Himberg et al., 2018). In this way, Himberg et al. (2018) argue improvisation can be understood as fostering a particular quality of relation between individuals that shifts the attribution of agency from "I" toward "We." Many quotidian interactions unfold without an explicit direction or objective and evolve through a similar dynamic of co-creation and mutual adaptation. The dynamic of mutual adaptation and regulation through movement coordination renders dance improvisation a valuable paradigm for assessing co-creative social interactions that extend beyond this particular art form into the spontaneous interactivity that pervades daily life.

Techniques for capturing spontaneous interactivity and interactional coordination are notably scarce. The majority of previous studies on interpersonal coordination focus on non-dance activities (e.g., finger-tapping tasks) (see Repp, 2005; Repp and Yi-Huang, 2013). Among the studies that have explored interpersonal coordination within dance, many have employed observational methods such as microanalysis to evaluate coordination (Evola and Skubisz, 2019; Torrents et al., 2018) or have quantitatively assessed coordination in dance contexts that either involved choreography (Brown and Meulenbroek, 2016; Crone et al., 2021; Washburn et al., 2014) or relied on an external rhythm or tempo guide (Boker and Rotondo, 2002; Ellamil et al., 2016; Reddish et al., 2013; Solberg and Jensenius, 2019). As such, existing tools for quantitatively measuring movement coordination in interaction have predominantly focused on measuring alignment in oscillatory behavior, for example, amongst dancers at night clubs (Ellamil et al., 2016; Reddish et al., 2013), or tracking the body's overall quantity of movement (Boker and Rotondo, 2002; Himberg et al., 2018). These tools are often undergirded by a normative approach and assume that interactional movements will conform to certain expected dynamics. This approach is effective in capturing interaction guided by an external tempo or goal-oriented joint actions, such as choreography, because they allow interactors to anticipate something about the future of their interaction. However, freely improvised dance presents a distinct, and characteristically spontaneous, interactional paradigm that is not predicated on an external coordinating source. Consequently, many conventional tools for measuring interactional features of dance cannot capture the dynamics of mutual attunement that are essential to the spontaneous interactivity of free improvisation. Furthermore, it is important to capture *multiple* levels of interpersonal organization, including collective-level variables such as interpersonal coordination, individual-level dynamics that relate to mutual attunement, and the relationships between these levels. Thus, the objective of this study is to evaluate approaches to measuring moments of high coordination between two freely improvising dancers and demonstrate the value of this combination of measures as a framework for investigating interactions through multiple levels of description. Specifically, we aimed to investigate the following three research questions:

1. How accurately does measuring temporal alignment of motor behavior capture moments of high interpersonal coordination?
2. Can measuring the direction of interactivity between dancers inform our interpretation of interpersonal coordination by providing insight into the dynamics of mutual attunement?
3. What is the relationship between detected moments of high coordination and the relational dimensions of the dancers' experiences of moving together?

2 Methods

2.1 Participants

Dancers with at least 5 years of previous improvisation experience and who were at least 19 years of age were recruited for this study through local dance organizations, collectives, and companies. Ten individuals were included in the study and partnered into five unique dyads. Pairs were already acquainted with each other in four out of the five dyads. One of the participants in the unacquainted dyad was the first author, as the original participant had to cancel on short notice (PW met the eligibility criteria). All participants completed the full session and were remunerated accordingly. This study was approved by the University of British Columbia Behavioural Research Ethics Board and written consent was obtained from all participants prior to commencing the session.

2.2 Experimental design

This is an embedded mixed-methods study design (Creswell et al., 2003). We first identify moments of high and low coordination between dancers using a novel quantitative approach. We then embed qualitative descriptions of the directional relationships and the subjective experience of these moments to provide complementary levels of description of intersubjectivity. Experimental sessions were divided into the following three phases: (1) a dyadic improvisation task, (2) the participants' independent review and annotation of the recorded improvisation, and (3) a semi-guided group interview between participants and the first author (interview data not analyzed in this manuscript). The sessions took place in Vancouver, Canada at one of three dance studios.

2.3 Procedure

2.3.1 Setup

Sessions began with a brief warmup led by one of the researchers. The warmup was scripted to maintain consistency across sessions and guided the participants through a body scan with gentle joint

mobilizations. After the warmup, the participants were randomly assigned referents (i.e., they were told they were either dancer "A" or dancer "B") and were seated perpendicularly to one another at a table (table dimensions: 85 × 85 cm), positioned according to their referents in preparation for the improvisation task (Figure 1). Stickers were then placed on the tops of each wrist of each participant (see Figure 1) to facilitate the extraction of spatial coordinate data from the video recordings. A video camera (GoPro Hero 4 with a frame rate of 60 Hz and a resolution of 1920 by 1080) was mounted on a microphone stand that extended over the table to obtain an aerial view of the participants and table surface.

Participants were then read a statement outlining the parameters of the improvisation task. Participants were told that they must keep their hands in contact with the table surface, as if magnetized, for the duration of the improvisation. Importantly, participants were *not* instructed to try and coordinate with their partner. They were then allowed to ask any clarification questions. Once participants were clear on the task, each completed a two-minute calibration during which they improvised independently for 1 minute with their eyes closed and 1 minute with their eyes open. This calibration period allowed participants to get acquainted with the guidelines of the task and provided an opportunity to ensure that all equipment was functioning.

2.3.2 Improvisation task

The improvisation task consisted of a 15 minute seated improvisation between the two participants (Santana et al., 2021). The improvisation was divided into five 3-min blocks in which perceptual conditions were varied: we manipulated visual information available to participants to optimize our chances of eliciting wide variability in the levels of coordination between dancers (Koul et al., 2023a; Koul et al., 2023b; Miyata et al., 2017). In Block 1, both participants had eyes closed; Block 2, both participants had their eyes open; Block 3, participant A had eyes open, participant B had eyes closed; Block 4, participant A had eyes closed, participant B had eyes open; Block 5, both participants had eyes open (Figure 1). Instructions to participants to either open or close their eyes were given by a voice recording (e.g., "A close, B close"). Apart from these instructions, the improvisation was conducted in silence. Although the perceptual conditions varied, no instructions were provided to the dancers about coordination, nor the lead/follow roles that they should take should coordination emerge.

2.3.3 Segmentation and commentary

After the improvisation, participants reviewed the video footage and marked moments in which they felt there was a transition in the interaction with their partner (Chang, 2018) (e.g., a shift in their subjective feeling of connection, a shift in the dynamic of the movement). These identified moments marked the boundary of "segments." For each segment, participants (1) rated coordination on a 10-point scale; (2) made four binary selections about their perspective of the interaction; and (3) provided a free response commentary (see Figure 2).

2.4 Data extraction

To extract kinematic data from videos, we conducted body part tracking using DeepLabCut (version 2.2.3) (Mathis et al., 2018; Nath et al., 2019) (Figure 3). We tracked both participants' hands using the markers as a precise labeling point. Because videos were captured from an aerial perspective, spatial coordinates gave the location of each hand in two dimensions (x, y) for each video frame. Note that multiple body parts were labeled (as seen in Figure 3) to train a robust neural network, but only the hand data was used for analysis. Over-labeling is a practice recommended by DeepLabCut to improve the tracking performance of the neural network.

We labeled 360 frames taken from seven videos (95% used for training, 5% for testing). We used a ResNet101-based neural network with the system's default parameters for 100,000 training iterations,

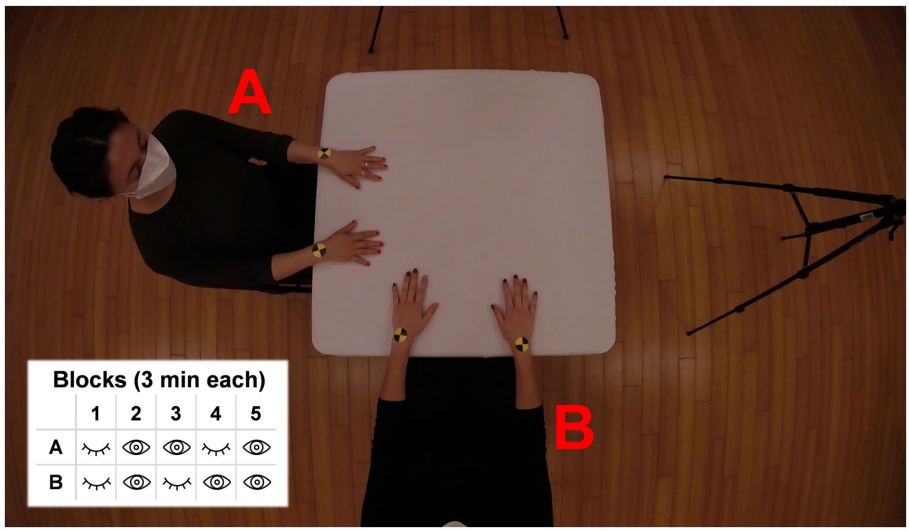

FIGURE 1
Experimental setup. The participants, labeled here with their respective referents **(A,B)** are seated perpendicular to one another at a square table. Markers (yellow and black stickers) are placed on their hands for post-experiment pose estimation using DeepLabCut (open-source pose estimation software). Improvisation task structure is included in bottom left.

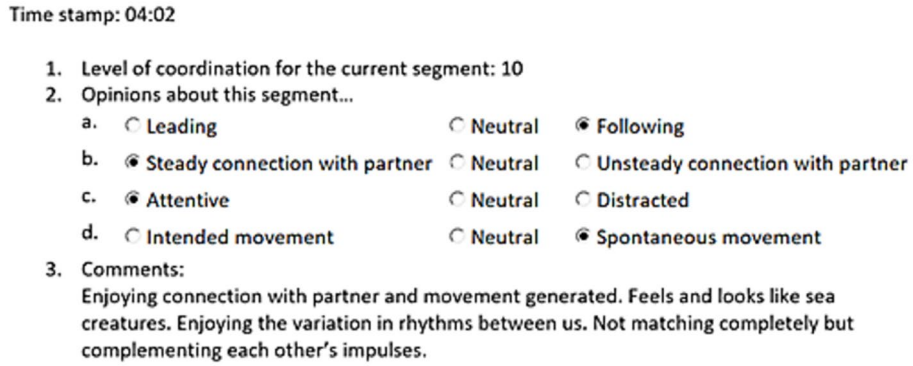

FIGURE 2
Illustration of the segmentation and commentary form structure and the data types collected from each segment.

FIGURE 3
Demonstration of DeepLabCut pose estimation of user-defined body parts. Note that multiple body parts were labeled (as seen in this figure) to train a robust neural network, but only the hand data was used for analysis.

with a resulting test error of 7.84 pixels (image size 1920 by 1080 pixels). The choice of ResNet101 was based on DeepLabCut's recommendation for complex human activities, such as "multiple humans dancing" (Model Training Tips and Tricks—DeepLabCut, 2024). Additionally, DeepLabCut's authors advise most users with basic proficiency in computational methods to use the default parameters, which we followed for model training. We then used a p-cutoff of 0.6 to condition the x and y coordinates for future analysis. This trained network was used to analyze and extract spatial coordinate data from video footage collected during each session. Spatial coordinate predictions for each session were filtered using DeepLabCut's built-in median filter.

2.5 Data analysis

2.5.1 Rating moments of high and low coordination

All recordings were coded by human raters to identify "moments" of high and low interpersonal coordination. Raters were blind to the data, including the conditions of the block. Raters were provided a definition of interpersonal coordination as the "temporal alignment of hand marker movement." The terminology "temporal alignment" was chosen to deter raters from interpreting "interpersonal coordination" as "doing the same movement" and instead call their attention to the similarity in speed dynamics of the dancers' movement. Notably, under this operational definition, instances of joint stillness are considered high coordination. High or low coordination needed to be sustained for at least 10 s to be considered a "moment." The first author independently reviewed and coded the recordings, and over 50% of the moments were subsequently coded by four other raters. The coding guide was reviewed and discussed amongst all raters, and revised through iterations until all raters applied it consistently, and the inter-rater reliability reached substantial agreement.

2.5.2 Movement analysis

The first research question of this study is: how accurately does measuring temporal alignment of motor behavior capture moments of high interpersonal coordination? To address this question, we developed an algorithm that calculated a novel metric of interpersonal coordination between the hands of the dancers and automatically classified the dynamic variation of this metric as a high or low coordination moment.

All movement analyses were conducted in MATLAB R2023b. Spatial coordinates (x, y) from DeepLabCut corresponding to the participants' hands (markers) were imported into MATLAB and used to compute speed time series as follows:

$$speed_{f-1} = \frac{\sqrt{\left(x_f - x_{f-1}\right)^2 + \left(y_f - y_{f-1}\right)^2}}{t}, f > 1$$

Where the numerator represents the distance traveled in 2D coordinate space since the previous frame (f-1), and the denominator represents the amount of time passed since the previous frame. This yielded a speed time series of length n-1 (where n is the total number of frames).

Speed time series were pre-processed in three steps. First, frames from any time series that was not exactly 54,000 frames (sampling rate of 60 frames/s × 15 min) were trimmed from the end of the series.

Second, outliers for each session were removed (percentage of data removed: $M = 1.43\%$, $SD = 0.37\%$) and replaced with interpolated values. Outliers were detected as values greater than three local standard deviations away from the local mean over a 1-s window. Outlying values were then linearly interpolated (1-D interpolation). Finally, the resulting time series were smoothed using a moving mean filter (window = 0.5 s).

We then calculated a metric of interpersonal coordination over time—the maximum correlation vector (MCV)—defined by the maximum correlation of between-participant hand pairings. This measure was chosen to assign equal importance to all forms of hand coordination (i.e., independent of the number of hands involved in the coordination). The similarity in speed between participants' movements (i.e., temporal alignment) was measured with rolling-window Spearman correlations (window = 5 s) on each between-participant time series pairing within a session (i.e., A left to B left; A left to B right; A right to B left; A right to B right). From this, four correlation vectors were produced for each session: $CV_{ALEFT \rightarrow BLEFT}(t)$; $CV_{ALEFT \rightarrow BRIGHT}(t)$; $CV_{ARIGHT \rightarrow BLEFT}(t)$; $CV_{ARIGHT \rightarrow BRIGHT}(t)$. The MCV was then calculated by selecting the maximum correlation coefficient across all hand pairings for each point in time.

$$MCV(t) = \max_{t} \begin{cases} CV_{ALEFT \rightarrow BLEFT}(t) \\ CV_{ALEFT \rightarrow BRIGHT}(t) \\ CV_{ARIGHT \rightarrow BLEFT}(t) \\ CV_{ARIGHT \rightarrow BRIGHT}(t) \end{cases}$$

To control for spurious correlations in the data, we conducted a permutation-like test based on data sliding to assess the significance of observed correlations within each moment (Moulder et al., 2018). This involved breaking the time-dependent structure of one participant's data, X, by selecting a random cut point and swapping the segments of data about the cut point (i.e., "sliding" the data) to create X^s. The shuffled time series X^s was then correlated with the other participant's unshuffled time series Y using rolling-window Spearman correlations. Data sliding was repeated 1,000 times within each moment and significance thresholds were obtained from the 95th percentiles of the shuffled correlation distributions. The significance threshold for each rated moment is represented visually along with the MCV to enable time-resolved comparisons of the significance of the hand coordination.

We then assessed the accuracy of MCV in detecting moments of high coordination. For each rated moment of high or low coordination, we calculated a weighted summation of the values of MCV above and below threshold y. Evidence for low coordination was assessed using the area under the curve between y and MCV for all values of MCV below y, and evidence for high coordination was assessed using the area under the curve between MCV and y for all values of MCV above y, where $y = 0.5$. Moments were classified as high or low coordination based on the metric with the larger evidence. The predictive accuracy of our binary classification algorithm was then assessed with a confusion matrix. Ground truth was human ratings of the videos, and predicted classifications were the labels assigned by the classification algorithm. From this matrix we computed standard descriptive performance evaluation measures such as overall accuracy, precision, and sensitivity.

2.5.3 Normalized symbolic transfer entropy

In our second research question, we ask if measuring the direction of interactivity between dancers can inform our interpretation of interpersonal coordination by providing insight into the dynamics of mutual attunement. To answer this, we used normalized Symbolic Transfer Entropy (NSTE) to estimate the direction and magnitude of information transfer between two kinematic source signals—in this case, the dancers' hands. Transfer entropy (TE) is a model-free, nonlinear extension of Granger causality. Like Granger causality, it quantifies the predictive power of the past of a source signal toward the future of a target signal, beyond the predictive power of the past of the target signal itself (Lee et al., 2015). In simpler terms, TE provides a way to assess the directed influence or causal relationship between two time series. Unlike Granger causality, TE does not presuppose any relationship between these signals. Symbolizing TE involves substituting the values in both the source and target signal vector components with ranked values (i.e., symbols), which eliminates some of the parameter selection inherent to TE, making the method more robust and computationally efficient (Staniek and Lehnertz, 2008). The normalization of STE removes bias introduced by signal characteristics of the source signal and autocorrelation within the target signal, making STE values comparable across different pairs of time series (Lee et al., 2015).

NSTE was computed between each dyad's kinematic source signals, where the combination of participant hands used for the input time series was identical to that used to calculate the MCV. This enabled us to directly compare the undirected correlation measure of coordination (i.e., MCV) with the directed, information theory-based metric (i.e., NSTE) to assess its added value to capturing spontaneous interactivity. We computed NSTE for all rated moments of high and low coordination, using an embedding dimension of $m = 3$, a window size of 2 s, a window step size of 0.5 s, and varying tau systematically to span a prediction range of 100 ms ($\tau = 6$) to 250 ms ($\tau = 15$). Parameter selection occurred by identifying three moments with clear lead-follow relationships through visual inspection of the video recordings and selecting the parameters that maximized NSTE values during the moments and minimized them outside the moments. We then calculated the asymmetry of NSTE values in each direction (i.e., $NSTE_{A \rightarrow B}$ and $NSTE_{B \rightarrow A}$) to assess the dominant direction of information flow for each time step, as follows:

$$Asymmetry_{A \rightarrow B} = \frac{NSTE_{A \rightarrow B} - NSTE_{B \rightarrow A}}{NSTE_{A \rightarrow B} + NSTE_{B \rightarrow A}} \varepsilon [-1,1]$$

Thus, if $asymmetry_{A \rightarrow B}$ has a positive value, the information flow from A to B is dominant, and vice versa for a negative value.

2.5.4 Subjective reports

In this study's third research question, we ask: what is the relationship between detected moments of high coordination and the relational dimensions of the dancers' experiences of moving together? To address this, we identified moments of rated high coordination that co-occurred (i.e., +/− 180 s total) with segments marked by the participants (see Section 2.3.3). From these segments, we extracted participants' perceptions of coordination, role, and connection with their partner as well as any commentary, and examined these subjective reports alongside measures of coordination for patterns. Participant reports about attention and movement intentionality (questions 2c and 2d) were not considered in the current analysis as

the goal of this analysis was to investigate the relational dimensions of moving together rather than each individual's cognitive processes.

3 Results

Human raters of the videotaped improvisations identified 37 moments of sustained high or low coordination across five unique dyads. Of these 37 moments, 24 were rated as high coordination, while 13 were rated as low, with substantial inter-rater reliability (Fleiss' kappa = 0.68). High coordination moments were more likely to occur when both participants had their eyes open (16/24). Moments of low coordination were more evenly distributed across the different perceptual conditions.

Figure 4 provides an overview of all measures of interpersonal coordination calculated in our analysis across a full improvisation task, with human-rated moments of high coordination (red) and low coordination (blue) overlayed.

3.1 Moments of interpersonal coordination can be accurately detected by maximum correlation vectors

The MCV classified moments of high and low coordination with an overall accuracy of 80.56%, a precision of 65.52%, and a sensitivity of 79.17%. The current algorithm is biased toward the classification of high coordination; considering the study's focus on moments of high coordination as potential indicators of social connection, a preference for over-detection is acceptable, as it reduces the likelihood of overlooking moments of connection that would otherwise go undetected.

We evaluate and describe a representative selection of four moments with respect to the dynamics observed during moments of high and low coordination (Figure 5). Moments 2 and 26 were human-rated as high coordination and show sustained high values of the MCV, which decreases within a few seconds at the boundaries of the moment. The hand movements of both dancers show comparable speeds during these moments. Both moments include brief periods where the MCV drops below the significance and classifier thresholds; references to the corresponding moments in the videos confirm that these periods coincide with observable decreases in hand coordination.

Moments 5 and 37 were human-rated as low coordination and show MCV values that remain predominantly below the significance and classifier thresholds. Additionally, the MCV exhibits high variability and is not significantly different at the boundaries of these moments in comparison to patterns within the moment. Moment 37 involved fast hand movements across both dancers, reflected in the higher frequency and variability of the MCV; in contrast, Moment 5 involved slower and smoother hand movements, reflected in the lower frequencies of the MCV.

3.2 NSTE complements correlation metrics by revealing the dynamics of directed influence during moments of interpersonal coordination

The magnitude and relative dominance of the causal relationship between dancers provide a complementary perspective on moments of high and low interpersonal coordination beyond correlational metrics alone. We present MCV and NSTE metrics across four representative moments of low and high coordination to illustrate the value added by considering directional measures (Figure 6).

Moment 1 was classified as a low coordination moment by both human raters and the MCV algorithm. NSTE analysis reveals

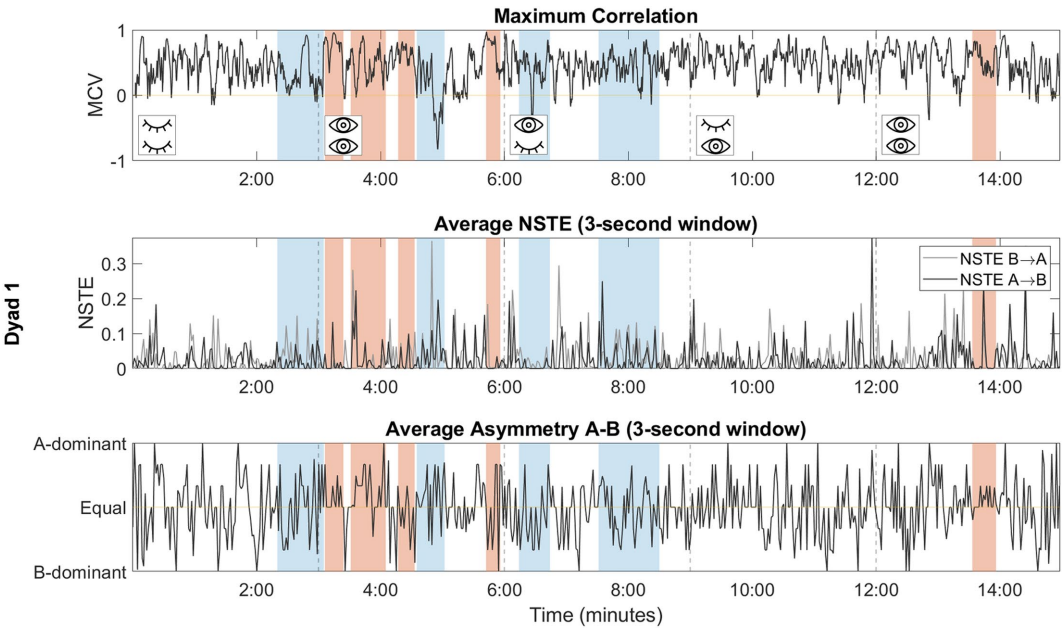

FIGURE 4
Overview of each coordination measure derived from a single session (dyad 1). Dotted lines delineate the boundaries of each perceptual condition. Moments of rated high coordination are denoted by red bars, while moments of rated low coordination are denoted by blue bars. To enhance signal clarity, the NSTE and asymmetry plots have been smoothed using non-overlapping 3-s windows.

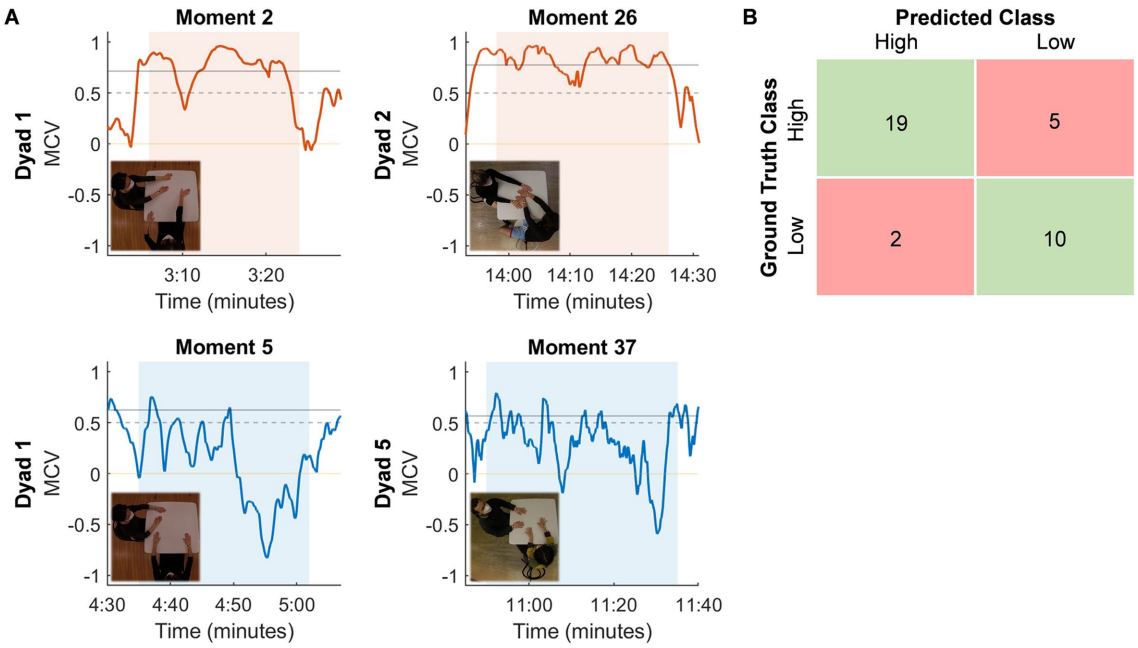

FIGURE 5
(A) Four representative moments illustrating true positive and true negative instances. For each moment, the maximum correlation vector is depicted alongside a vignette of the corresponding segment of interaction. High coordination moments are highlighted by orange panels and low coordination moments by blue panels. Solid grey lines denote the unique significance threshold for each moment while the dotted lines represent the classifier threshold $y = 0.5$. **(B)** Confusion matrix summarizing the results of classification.

multiple transient moments of casual influence between dancers, who alternate between leading and following. We visually validated several NSTE peaks with the video recording, confirming that they occurred during leader-follower interactions between the two dancers (e.g., dancer B pushing dancer A at 2:49, reflected in a high MCV and a peak in $NSTE_{B\rightarrow A}$). In this example, the NSTE magnitude during a transient MCV peak revealed the direction of influence between the dancers. Moment 16 was also classified as a low coordination moment. The MCV falls below zero at approximately 9:22; visual inspection of the corresponding video recording shows a call-response interaction between the dancers where dancer A briefly pauses followed by a similar pause from dancer B. At the beginning of this moment, dancer A leads B; at the end, the roles have reversed, reflected in the NSTE asymmetry.

Moment 17 and 23 were both classified as high coordination moments. Moment 17 consisted of subtle pushing between the dancers, corresponding to the back-and-forth dynamics in the NSTE asymmetry. In Moment 23, around 12:11, the dancers begin to move together in a circular motion, connected by a single fingertip. Although it is not clear from the video which dancer is leading, the NSTE metrics show dominant information flow from dancer A to dancer B, with a brief reversal of roles around 12:18.

3.3 Detected moments of high coordination reflect a one-to-many relationship with subjective experience

Participant comments on segments that overlapped with classified moments of high interpersonal coordination were associated with a range of experiences (Figure 7). The majority of participants reported a subjective experience of high coordination with their partner during these moments; subjective experiences of leading/following did not always correspond with the partner, nor with the NSTE metrics.

In Moment 9, dancer A perceived the moment as highly generative, coordinated, and connected, whereas dancer B viewed it as relatively dull, uncoordinated, and disconnected. The MCV during this moment fluctuated dynamically near the significance threshold, indicating inconsistency in the temporal alignment of their movements and generally lower levels of coordination, consistent with the experiences of dancer B. The NSTE metrics show near-zero causal influence between dancers for most of the moment, with the exception of several seconds when dancer A leads the movement of dancer B; this may be reflected in dancer A's subjective report of the experience of the moment.

There is strong coherence between the participants' reported experiences and coordination ratings in Moments 11 and 21. In Moment 11, the MCV is high across the duration of most of the moment, indicating heightened coordination between dancers. The NSTE metrics are very dynamic. Consistent with neither participant perceiving themselves as leading or following, the asymmetry between dancer A and B appears to be fairly balanced, with dancer A showing slightly more influence. Dancer A reported that the dyad was focusing on symmetry and creating shapes in this moment; the dynamic character of this moment likely reflects the many micro-adjustments from both participants needed to accomplish this. The MCV in Moment 21 is also high and particularly sustained, indicative of fluid coordination. The NSTE metrics show a sustained influence of dancer A on dancer B. Notably, this is in contrast to the dancers' subjective reports of the moment, where both participants reported that dancer A was following dancer B.

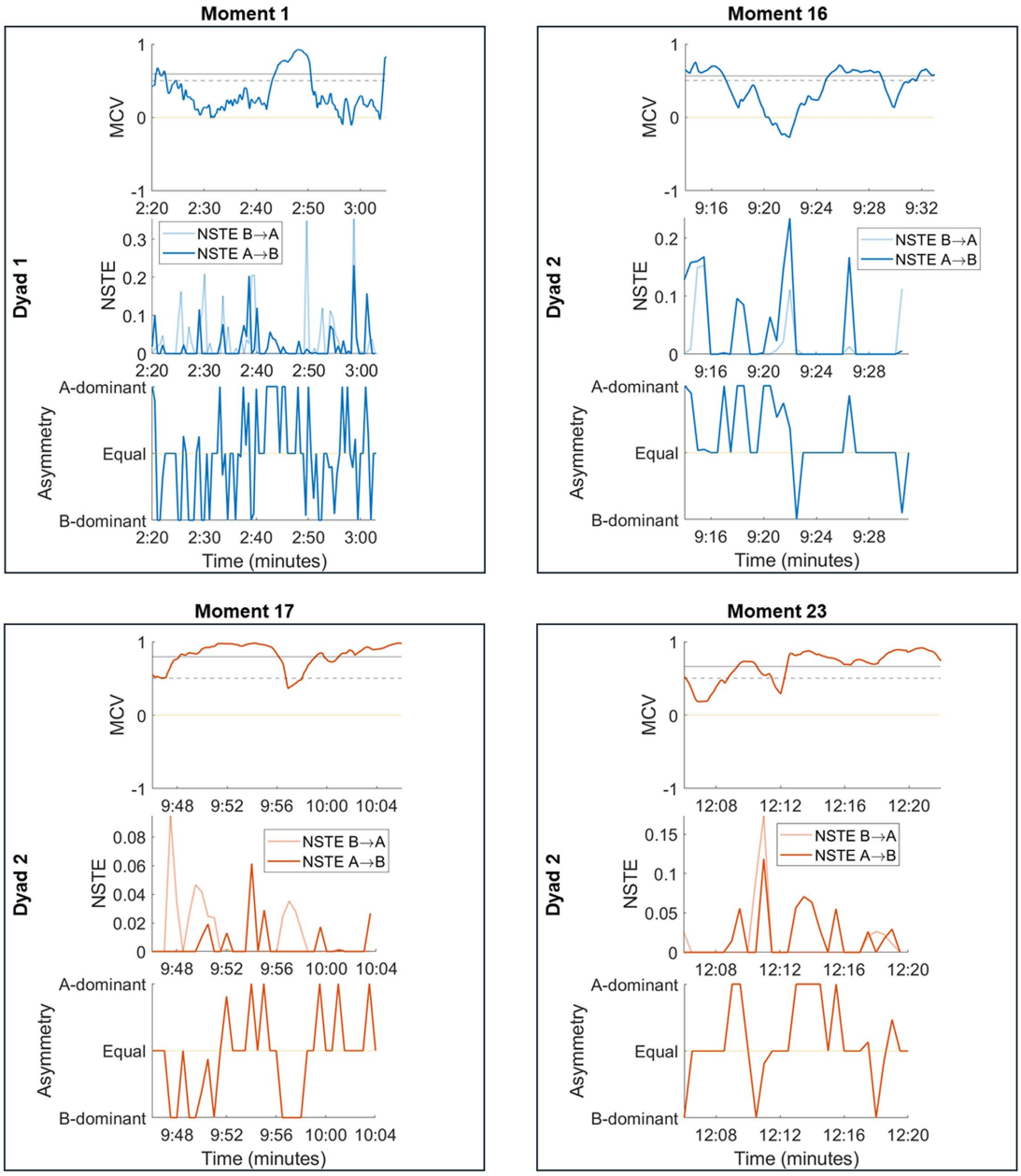

FIGURE 6
MCV, NSTE, and NSTE asymmetry from representative moments of high coordination (orange) and low coordination (blue). MCV significance threshold is indicated by the dotted line, while the classifier threshold is indicated by the solid line.

In Moment 32, participants reported high levels of coordination and a consistent connection with their partner. Dancer A perceived themselves as following their partner, while dancer B was neutral about their role within the moment. This was consistent with the results of the NSTE analysis, which showed dominant information flow from dancer B to A for the majority of the moment.

4 Discussion

This study presents a novel method for capturing spontaneous interactivity and characterizing the time-varying dynamics of coordination patterns within interpersonal interactions. We employ three metrics based on movement correlation, information theory, and subjective report to capture a cross-section of complementary perspectives on the emergence of high coordination moments between two freely improvising dancers. Our movement correlation metric—the maximum correlation vector (MCV)—classified moments of high and low coordination with an accuracy of 80%, illustrating the efficacy of automatically detecting these moments from video recordings using correlation-based measures. Our application of an information theory metric—normalized symbolic transfer entropy (NSTE)—to measure the direction of influence between dancers captured the causal influence between interacting partners. This is the first study to use NSTE on kinematic data and demonstrates the potential of this metric to reveal subtler dynamics of interpersonal

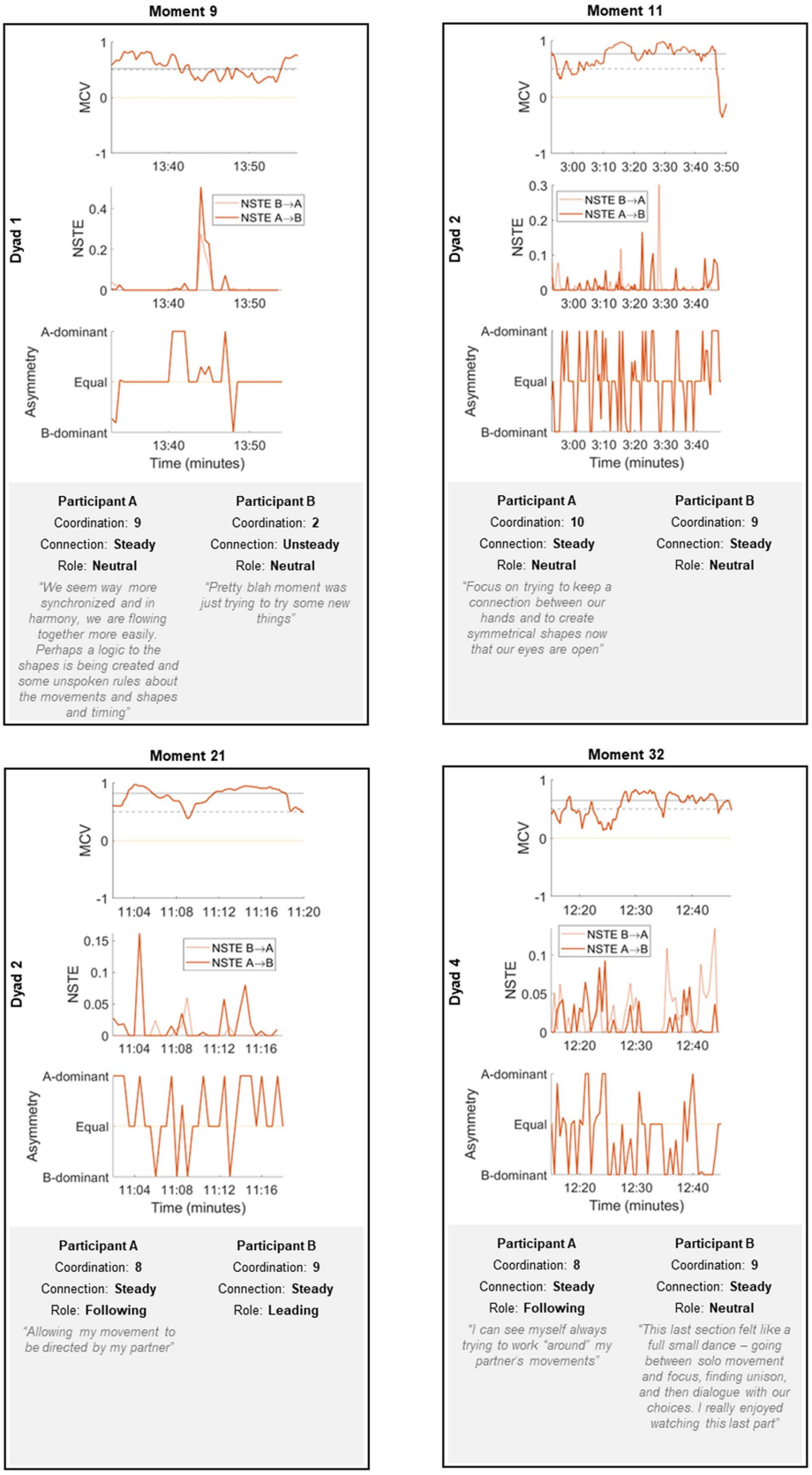

FIGURE 7
Cross-section of MCV, NSTE, and NSTE asymmetry from four moments of high coordination sufficiently overlapping with participants' segments, alongside commentary provided by participants.

interaction. Finally, we demonstrate a complex relationship between objective coordination measures and the relational dimensions of subjective experience, highlighting the need for principled approaches to the collection of first-person experiential data. Altogether, this study offers a novel framework for investigating the dynamics of interactions and the interpersonal domain, providing a strong platform for future research on the effects of moving together.

We define interpersonal coordination as the temporal alignment of motor behavior between two or more individuals. This includes instances where participants are temporally coupled while not necessarily rhythmically entrained or precisely matching each other's behavior. Interpersonal coordination is canonically described as "the degree to which the behaviors in an interaction are non-random, patterned or synchronized in both timing [and] form" (Bernieri and Rosenthal, 1991). In our study, interpersonal coordination has reduced dependence on form, and less emphasis is placed on the specific physical configurations and trajectories of movement (Smykovskyi et al., 2022; Koul et al., 2023a). Specifically, the MCV is calculated from speed rather than the velocity of the dancers' hands: this captures the temporal coherence of movement while accommodating diversity in movement form. Additionally, MCV is high during moments of joint stillness, as stillness does not necessarily imply a lack of coordination. The MCV is especially valuable in the context of freely improvised movement, where the lack of periodicity renders popular phase-based approaches (e.g., evaluating in-phase and anti-phase coordination) unsuitable (Marsh et al., 2009; Miles et al., 2017; Schmidt and Richardson, 2008). The high accuracy (~80%) of the MCV in detecting moments of high and low coordination demonstrates its alignment with both our conceptual understanding and visual perception of interpersonal coordination. This correlation-based metric has strong potential as the basis of an automatic system for assessing time-varying dynamics of coordination in the context of dance.

To date, much research on interpersonal coordination within dance has relied on phase-based measures to assess synchrony in oscillatory movements among individuals, with two notable exceptions. Boker and Rotondo studied non-expert movers who alternated between leading and following their partner in short free-form dance trials. Interpersonal coordination was measured using time-varying correlations between the total displacement of participants, which was calculated by averaging velocity signals from all tracked body parts across time (Boker and Rotondo, 2002). Brown and Meulenbroek explored interpersonal coordination in choreographed dance by correlating the acceleration of vertical hand movement among trained dancers (Brown and Meulenbroek, 2016). Our study improves upon these correlation-based measures in several important ways. First, Boker and Rotondo's approach of averaging velocity across all body parts obscures fine-grained information about the spatial similarity of movement; our study tracks coordinated moments between the same body part between dancers, preserving more nuance and detail. Second, Brown and Meulenbroek's method captures spatial and temporal alignment of the dancers, but it is only suitable for scenarios where participants perform identical actions. In contrast, our method is able to capture the complex dynamics of breaking and building symmetry that emerge in improvised versus choreographed dance. Furthermore, our study provides a metric that can be applied in the absence of all external cues for synchronization between dancers. Boker and Meulenbroek's study involved an external beat to which participants were dancing; their results are limited to rhythmically motivated movement coordination, rather than spontaneous intrinsically motivated coordination. Despite the movement being free-form, the coordination observed in their study cannot be solely attributed to the co-creation of participants. Brown and Meulenbroek's study involves choreography—a dance context with tasks designed to establish shared performance goals. This represents markedly different interaction dynamics compared to improvised dance settings. During choreography, the emerging interpersonal coordination may be more appropriately described as joint action—interpersonal behavior that is unified in a common desired outcome (Keller et al., 2014). Although joint action may be intricate, such as in ensemble dance, it represents a different kind of complexity when contrasted with the spontaneously co-created movement coordination observed in free improvisation. This approach taken in our study allows for the interpretation of high correlations as spontaneous coordination independent of external time-keeping cues, providing a clearer understanding of interpersonal coordination dynamics.

Our study is the first to apply NSTE to kinematic data. To date, NSTE has primarily been applied to intrapersonal physiological recordings. Previous studies have used it to measure the direction of information flow within the brain (Lee et al., 2013; Borjigin et al., 2013), and to investigate causal relationships amongst different types of intrapersonal physiological recordings, such as between brain and heart signals (Li et al., 2015). Some studies have used NSTE to examine directed coupling relationships between individuals to assess interpersonal physiological synchrony (Fu et al., 2021). Our study's application of NSTE to interpersonal kinematic data offers several advantages over other measures of directed influence, such as Granger causality (Granger, 1969), dynamical causal modeling (Friston et al., 2003), and (windowed) cross-lagged correlations. While Granger Causality has been used in studies of group coordination and leadership dynamics in musical ensembles (e.g., Hilt et al., 2019; Sabharwal et al., 2024), NSTE is particularly well-suited for contexts like free improvisation, where individuals' roles constantly shift. In contrast to the more structured dynamics of music performance, where leader-follower roles are often clearly defined, free improvisation involves spontaneous and flexible exchanges of influence. NSTE's ability to detect non-linear relationships and provide a model-free estimation of connectivity makes it ideal for capturing these dynamics (Lee et al., 2015). It is also computationally efficient and requires fewer *a priori* parameter selections than other methods. This measure is thus highly versatile and particularly well-suited for analyzing kinematic signals from naturalistic interactions, which are often non-stationary and non-linearly related.

In line with Varni et al. (2022), who examined the effect of leadership changes on entrainment in music ensembles, our work similarly aims to be able to describe how shifts in leader-follower roles affect coordination. Varni et al. (2022) concept of "soft entrainment"—where synchrony fluctuates rather than remains fixed—is consistent with our view of the flexible, adaptive nature of group coordination during free improvisation in dance. Furthermore, the work by Sabharwal et al. (2024) on the directionality of influence in musical performance complements our observations of leadership dynamics. Their findings suggest that greater directionality occurs when clear leader-follower roles are established, while co-creation, and thus improvisation in dance, lead to more mutual, less directional

interaction. This aligns with our results, where periods of spontaneous collaboration showed fluid exchanges of influence, supporting the notion of co-created movement.

A major strength of this study is its use of mixed methods, with complementary quantitative and qualitative levels of description of intersubjectivity, with each level providing different perspectives on the nature of interactions as complex systems. The first level treats the interaction as the unit of analysis, measuring interpersonal coordination through correlations in participant movement and quantifying the collective dynamics as an emergent property of the interaction system. The second level captures the interactions *between* components of the interaction system. The NSTE analysis quantifies the contribution and directionality of both components simultaneously. Thus, this measure is a proxy for how each interactor contributes to constructing the interaction at any given point in time, providing a richer description of the co-constructive nature of collective movement. The third level qualitatively captures our participants' subjective experience of moving together, focusing on the relational dimensions of this experience such as the sense of connectedness between participants. This multi-measure approach, which links multiple levels of description, offers distinct insights into the dynamics of the interaction and the ability of these levels to mutually inform each other. Mixed-method approaches to studying intersubjectivity have been advocated in multiple theoretical frameworks, such as *participatory sense-making* (De Jaegher and Di Paolo, 2007). Participatory sense-making is a theory of social cognition stemming from the enactive tradition of philosophy of mind that centers the *interaction process* in the query of intersubjectivity. It asserts that social understanding transcends mere individual mentalizing, emphasizing our mutual participation in meaning-making. Participatory sense-making underscores how interactions with the environment and others shape our understanding and aims to elucidate the role of interaction processes in sense-making experiences. By examining interaction dynamics across various levels of description without explanatory reduction from one level to the next, our approach respects the ontological status of the interaction process posited by influential philosophical literature on intersubjectivity. This approach allows a comprehensive exploration of the relationship between interaction dynamics, such as interpersonal coordination, and the relational dimensions of our social experiences. The methodological framework for investigating intersubjectivity used in this study can be used in future work to explore research questions related to participatory sense-making and as a tool for assessing specific outcomes of dance and their interactive underpinnings.

The results of this study need to be interpreted in light of several limitations. First, we do not explore moments of low interpersonal coordination or the transitions into and out of moments of high coordination. These transitions have been posited as crucial investigation points to better grasp the relationship between interpersonal coordination and subjective experience (Di Paolo and De Jaegher, 2012). To address this gap, future research should prioritize acquiring more nuanced first-person data, potentially through the use of phenomenological interviews, which aim to explicate the fine-grained details of subjective experiences (Olivares et al., 2015). Second, our approach misses spontaneously emerging interaction dynamics other than temporal coordination, such as call-and-response and mimicry. Such behaviours are fundamental features of dynamic interpersonal interactions and are often intuitively considered forms of coordination; the conceptual and operational definitions used in this study remain limited in scope.

5 Conclusion

In this study, we developed a novel approach to capturing interpersonal coordination within the context of dance improvisation. By integrating correlation-based measures of movement speed, novel applications of NSTE to kinematic data, and subjective experiential data, our approach offers a multi-dimensional lens to capture the intricate dynamics of co-creative interactions. Our findings underscore the effectiveness of correlation-based measures in detecting coordination patterns and highlight the utility of NSTE in revealing the directionality of influence between interactors. Furthermore, our definition of interpersonal coordination, emphasizing temporal similarity over spatial similarity, expands our understanding of coordination, particularly in the context of freely improvised dance. Our study advances the tools available for examining the intricate relationship between interpersonal coordination and subjective experiences in dance. Future research should aim to explore the transitions between moments of coordination, examine complementary interaction dynamics, and incorporate more comprehensive first-person experiential data. With dance's potential to enhance wellbeing and interpersonal connection, our methodological framework can pave the way for further investigations and applications in therapeutic and creative contexts.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://osf.io/6hz35/.

Ethics statement

The studies involving humans were approved by the Behavioural Research Ethics Board of the University of British Columbia (H22-00311). 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. The individual(s) provided their written informed consent for the publication of any identifiable images or data presented in this article.

Author contributions

PW: Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. HJ: Conceptualization, Funding acquisition, Writing – review & editing. IS: Conceptualization, Funding acquisition, Writing – review & editing. RT: Conceptualization, Funding acquisition, Investigation, Project administration, Resources, Supervision, Writing – review & editing. SB-M: Conceptualization, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research was supported by the Social Sciences and Humanities Research Council (SSHRC) of Canada Insight Development Grant (AWD-025602) and the Canada Research Chair in Consciousness and Personhood Technologies awarded to SBM.

Acknowledgments

The authors would like to express gratitude to Lochlan Walsh, Sharon Ho, Michael Duehmig, Anya Fineman, and Mayrina Sihombing for their invaluable help with this project. We also thank the members of the Motivated Cognition Lab and BIAPT Lab for their helpful comments and suggestions. Most importantly, we thank all the generous participants without whom this research would not be possible. This research was supported in part through the computational resources and services provided by Advanced Research Computing at the University of British Columbia.

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.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE Opinion
PUBLISHED 17 December 2024
DOI 10.3389/fpsyg.2024.1504559

OPEN ACCESS

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RECEIVED 30 September 2024
ACCEPTED 02 December 2024
PUBLISHED 17 December 2024

CITATION
Fontanesi C and Newman-Bluestein D (2024) Dancing through neurocognitive changes: dance/movement therapy supporting caregivers and people living with Alzheimer's and other dementias.
Front. Psychol. 15:1504559.
doi: 10.3389/fpsyg.2024.1504559

Dancing through neurocognitive changes: dance/movement therapy supporting caregivers and people living with Alzheimer's and other dementias

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KEYWORDS

major neurocognitive disorder, Alzheimer's, dementia, Dance/Movement Therapy (DMT), dance therapy, group therapy, caregiver

1 Introduction

A diagnosis of a progressive neurodegenerative disease implies a daily, personal loss that may be experienced by those directly affected by the condition and their caregivers. Dance/Movement Therapy (DMT) offers a complement to this perspective of what dementia is and what dementia does to people and personhood (Coaten and Newman-Bluestein, 2013; Newman-Bluestein, 2020).

Group and partnered dance sessions can support the emotional, relational, and physical needs of people living with major neurocognitive disorder[1] (MND) and of those caring for them, not only supporting families keeping their members at home or in the community but also offering respite and emotional release for caregivers (Ruiz-Muelle and López-Rodríguez, 2019). DMT is particularly well-suited to supporting people with Alzheimer's Disease (AD) or MND, as it engages multiple sensory modalities, thus neural pathways and networks, and respects each individual's unique way of communicating and reconnecting with identity and personal narratives (Goldstein-Levitas, 2016).

People who have AD/MND frequently deal with a detachment from their memories, sense of self, and societal functions, as noted by Goldstein-Levitas (2016). These losses cause them to become isolated, confused, and emotionally distressed, affecting not just the individuals with AD/MND but also those caring for them (World Health Organization, 2012). DMT offers a pathway to reintegrate those fragmented aspects of the self through embodied expression (Hill, 2009; Newman-Bluestein, 2017). The familiarity of a tune, shared movements, or even a simple gesture can bring back emotions and memories in ways that language cannot, as Newman-Bluestein (2017) pointed out. Dance and movement may bridge the experiences of individuals with AD/MND and the efforts of the care providers to connect. In this article, we contemplate how the interactions within group DMT could offer mental and physical health benefits to these people, their families, and their caregivers.

1 Dementia and major neurocognitive disorder (MND) are terms that describe a similar condition. However, we prefer to use the term MND instead of dementia, in line with the Diagnostic and Statistical Manual of Mental Disorders (DSM-5).

2 Dance/movement therapy framework

DMT frameworks for working with people living with AD/MND necessarily embrace reflections on connection and empathy (Hill and Newman-Bluestein, 2010), embodiment (Coaten and Newman-Bluestein, 2013), non-verbal communication and relationship (Newman-Bluestein and Chang, 2017), and even dance aesthetics (Newman-Bluestein, 2020).

The following four concepts—*welcoming*, *shifting*, *present moment*, and *vitality*—are drawn as examples from Donna Newman-Bluestein's training manual for caregivers of people with AD/MND (Newman-Bluestein and Chang, 2017). These concepts illustrate how DMT practice can support this population, emphasizing approaches centered on both the needs of individuals with AD/MND and their relationships with their caregivers.

Welcoming: The DMT invites individuals to participate in a therapeutic space rooted in safety, dignity, respect for choice, and empowerment. Members are invited by name to participate actively and contribute to the group's space through their language, cultural background, musical preferences, and original contributions.

Shifting: The therapist observes even the smallest changes in the range of motion and movement patterns, in the spatial relationships between participants, in the expressive qualities of movement, and in the shapes of gestures, recognizing that these shifts may reflect changes in motivation, emotional investment, and mood. The therapist supports the development of a creative group atmosphere, understanding that the therapy process involves working together.

Present moment: Artistic creation through movement enhances present-centered awareness, allowing individuals to access a state of presence. The therapist creates a space that encourages participants to accept their current state, facilitating a process in which their relationships with time and embodiment surface, revealing what is most meaningful to them in the moment.

Vitality: Vitality may be described as the sensation of inhabiting one's body, influenced by different cultural viewpoints on body awareness, breath, and movement. Through dance, individuals are reminded that their bodies are alive and dynamic, and the therapist promotes a sense of being that aligns with each person's values and lived experiences.

3 Personhood, I-Thou relationship, and here-and-now interactions

When working with people with AD/MND, we find it essential to recognize their uniqueness and the possibility for meaningful connections, even when cognitive impairment is severe (Kitwood and Bredin, 1992). In the past, when defining personhood, the tendency has been to prioritize autonomy and logical thinking over feelings and relational potential (Kitwood, 1997a). Even with severe cognitive impairment, an I-Thou form of meeting and relating is usually attainable (Kitwood, 1997b). Drawing from Ich and Du, published in 1922 by Martin Buber, Kitwood refers to two ways of experiencing a relationship. The I-It mode implies coolness, detachment, instrumentality, maintaining distance, and avoiding risk. Conversely, the I-Thou mode requires individuals to reach out, be spontaneous, and embark on a journey into a shared space (Kitwood, 1997b, p. 10). This connection goes beyond the confines of language and cognition, tapping into the essence of our shared humanity. It highlights every individual's inherent worth and dignity, regardless of their cognitive abilities. This notion resonates with our belief that building compassionate relationships lies at the core of DMT.

Further, Kitwood's ideas parallel Yalom (2009)'s concept of the importance of here-and-now interactions within a group. The group becomes a social microcosm where individuals can connect by de-centralizing the therapist's position and facilitating spontaneous expression (Yalom, 2009). Yalom emphasizes fostering honesty and spontaneity of expression within the group. These qualities are the lifeblood that nurtures an authentic and vibrant group experience. Encouraging individuals to express themselves in the present moment allows meaningful connections to form, transcending the conventional boundaries of therapist-led interactions (Yalom and Molyn, 2005).

In this approach, the therapist's role shifts from being the primary focus to becoming a facilitator who carefully listens and observes. As group members interact and connect, the therapist's task is to relate the spontaneous offerings and concerns of individuals to the overarching goals of the group (Yalom, 2009). This relational exchange mirrors the diverse meanings and perspectives within each member's unique internal world (Yalom, 2009).

4 Exploring the benefits of group and partnership dynamics

During early stages, regular dance participation can improve physical and cognitive function, alleviate anxiety, and help reduce feelings of depression associated with AD/MND, such as falls and physical decline (Ruiz-Muelle and López-Rodríguez, 2019). From a mental health perspective, dance fosters emotional expression, alleviates anxiety, and helps reduce feelings of depression for both caregivers and individuals with AD/MND.

DMT groups that include caregivers and individuals with AD/MND create opportunities for relationship-building and mutual support, strengthening emotional bonds, and fostering resilience (Coaten and Newman-Bluestein, 2013). In a group setting, caregivers often feel empowered by collective energy and empathy, while individuals with AD/MND feel less isolated (Beardall et al., 2014).

Caregivers can engage with others experiencing comparable difficulties through DMT groups. This experience has the potential to alleviate feelings of aloneness and offer essential emotional encouragement. Champagne (2024) emphasizes that DMT can serve as a resilience-building tool for caregivers, fostering a sense of flexibility, positive emotion, and shared experience through movement. Research by Petts and Urmston (2022) demonstrates that participation in dance activities can reaffirm the caregiver-care receiver relationship, helping caregivers find respite, reconnect with their loved ones, and rediscover a sense of identity that caregiving often subsumes. In this setting, caregivers shift from being

caretakers to partners, transforming their role into one of shared experience rather than solely obligation. This co-creation dynamic in DMT strengthens emotional bonds and allows participants to explore their relationships in a meaningful, non-verbal manner that fosters empathy, and closeness (Hill and Newman-Bluestein, 2010). In dance sessions, offering or following movements can create a shared experience that promotes emotional and social connectedness (Doe and Roe, 2023). This collective emotional space contributes to the participants' wellbeing, reducing stress and enhancing resilience in those with caregiving roles (Newman-Bluestein, 2017). For individuals with AD/MND, dance taps into neural pathways associated with memory, emotion, and movement. Familiar music and gestures can evoke thoughts, memories, and associations and bring moments of presence, even in those with severe cognitive impairments. However brief, these moments allow individuals and their caregivers to experience a deep sense of connection (Goldstein-Levitas, 2016).

5 Reflections on synchrony and syncopation in group and partnered DMT

Neuroscience increasingly supports the benefits of DMT, demonstrating that rhythmic movement can stimulate neural pathways involved in memory, emotion, and coordination, even in individuals with cognitive decline (Kshtriya et al., 2015). Studies indicate that synchronous movement enhances social bonding and influences neural and hormonal coupling, improving quality of life and wellbeing (Dieterich-Hartwell, 2024). Interpersonal synchrony (IS) fosters a unique relational experience, enabling participants to feel a sense of affiliation and closeness with others, which is especially beneficial for individuals with neurocognitive disorders and their caregivers.

Research on IS in children and adolescents highlights its impact on social bonding. For instance, Tunçgenç and Cohen (2016) suggested that synchronous movement may increase bonding and a sense of similarity among group members, even in groups with previous biases. Similarly, Prakash (2023) observed that synchronized movement in DMT can enhance social engagement, cooperation, and empathy. These findings support the idea that rhythmic synchrony may help bridge social divides and strengthen relational connections. In DMT, rhythm is a powerful mechanism for enhancing togetherness, group cohesion, and kinesthetic empathy. Prakash (2023) describes how rhythmic synchrony in group settings can create feelings of security and wellbeing as group members feed off each other's energy and rhythm.

Importantly, studies by Witek et al. (2014) and Matthews et al. (2019, 2020) reveal that syncopated rhythms and harmonic interplay activate brain regions associated with motor timing, reward, and the release of endorphins that foster social bonding. These results suggest that rhythmic complexity, rather than simple rhythmic synchrony, facilitates physical coordination and contributes to emotional engagement and joy, strengthening the bond between individuals in a group. Further, as Nelson et al. (2024) argued, relationships are not solely about precise synchrony. Moments of syncopation, or intentional rhythmic deviation, are critical in enhancing interactions' depth and relational richness. Unlike perfect synchrony, syncopation allows for "a relation between relations" rather than mere alignment, creating a dynamic space where differences and individuality emerge (Nelson et al., 2024). This "imperfect synchronization" can generate an aesthetic and therapeutic value, enriching the therapeutic process by allowing participants to experience empathy and connection without sacrificing their individuality. Syncopation thus enables participants to maintain personal expression while simultaneously engaging with others, allowing them to experience togetherness and difference.

In sum, synchrony and syncopation in DMT provide a multidimensional relational experience where rhythmic movement fosters emotional connection, empathy, and social bonding. By engaging in synchronous movement and navigating moments of syncopation, participants in DMT develop a sense of togetherness while preserving their identities. This nuanced dance of alignment and differentiation is central to the therapeutic impact of DMT, particularly for individuals with AD/MND and their caregivers, as it supports connection, personal expression, and mutual understanding in ways that transcend conventional therapeutic methods and language.

6 Conclusion

DMT offers a multidimensional approach to supporting individuals with AD/MND and their caregivers. It integrates elements of group support, meaningful relational dynamics, synchrony, and syncopation, fostering a shared sense of presence and connection. For individuals with AD/MND, these sessions create moments of coherence, helping them reclaim fragments of their identity and reconnect with their personal history and emotions. For caregivers, DMT provides a supportive space for shared experiences, transforming caregiving from an obligation into a meaningful partnership.

As virtual and in-person DMT frameworks evolve, the potential for broader access and positive impact on wellbeing expands. Future research should explore how collective meaning-making, synchrony and syncopation, and creative movement contribute to resilience, quality of life, and emotional expression in caregiving relationships, enriching the scope and application of DMT in neurocognitive care.

Author contributions

CF: Conceptualization, Writing – original draft, Writing – review & editing. DN-B: Conceptualization, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

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.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE Opinion
PUBLISHED 23 January 2025
DOI 10.3389/fpsyg.2025.1496146

OPEN ACCESS

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RECEIVED 13 September 2024
ACCEPTED 07 January 2025
PUBLISHED 23 January 2025

CITATION
Bek J, Jehu DA, Morris ME and Hackney ME (2025) Digital dance programs for Parkinson's disease: challenges and opportunities. *Front. Psychol.* 16:1496146. doi: 10.3389/fpsyg.2025.1496146

Digital dance programs for Parkinson's disease: challenges and opportunities

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KEYWORDS

Parkinson's disease, digital healthcare, neurorehabilitation, telemedicine, dance

Introduction

Dance provides therapeutic benefits for people with Parkinson's disease (PD) across motor and non-motor domains, including gait, mobility, mood, and cognition (McNeely et al., 2015; Shanahan, 2015; Bek et al., 2020; Carapellotti et al., 2020; Emmanouilidis et al., 2021). As a low-cost and widely accessible activity, dance can be a valuable adjunct to standard clinical treatment for PD. Digital provision of dance for PD has expanded significantly, accelerated by the COVID-19 pandemic (Bek et al., 2021a; Kelly and Leventhal, 2021; Morris et al., 2021, 2023). There is an ongoing need for accessible digital platforms for therapeutic activities like dance (Ellis and Earhart, 2021; Kelly and Leventhal, 2021) to provide for the growing PD population (Dorsey et al., 2018), including those in rural and remote communities without access to in-person programs. This article considers key challenges and potential solutions in digital dance for PD.

Current evidence on the feasibility and outcomes of digital dance programs for PD

Preliminary evidence indicates that online dance can be safe and feasible for individuals with mild to moderate PD, showing good rates of attendance and adherence and no adverse events (Morris et al., 2021, 2023; Walton et al., 2022; Pinto et al., 2023; Delabary et al., 2024a). Advantages of the digital format noted by people with PD include the convenience of not traveling and the ability to practice more frequently (Bek et al., 2021a; Ghanai et al., 2021). Participants report enjoyment of digital classes (Morris et al., 2021; Walton et al., 2022) and a desire to continue with online dance alongside in-person classes (Bek et al., 2021a; Delabary et al., 2024b), as also noted for exercise classes (Bennett et al., 2023) and singing therapy (Tamplin et al., 2024) for PD.

Live online dance participation has been associated with improvements in functional mobility, anxiety, and depression (Shanahan et al., 2017; Walton et al., 2022; Pinto et al., 2023), affect (Ghanai et al., 2021), and quality of life (Walton et al., 2022) in people with PD. Participants with PD engaging in live and/or recorded digital dance programs during the pandemic self-reported multiple motor (e.g., balance, posture) and non-motor (e.g., mood, confidence) benefits (Bek et al., 2021a).

Digital formats thus show promise as a feasible and effective approach to dance for PD. However, the literature is limited, including small samples and different modes of delivery. As practice and research in this field continue expanding, it is important to consider how the digital environment might impact therapeutic benefits of dance programs. Dance is a multidimensional activity (Dhami et al., 2015; Christensen et al., 2017; Bek et al., 2022a) incorporating physical, cognitive, social, affective, and creative components that contribute to outcomes for people with PD. The following section outlines therapeutic elements of dance that differ between in-person and digital contexts, with possible solutions to address limitations and optimize the experience and outcomes of digital dance programs. Table 1 summarizes the key challenges and solutions.

TABLE 1 Therapeutic elements of dance that may be impacted in the digital environment.

Elements of dance impacted by digital environment	Potential solutions
Social interaction: reduced opportunities for communication with peers and instructors	Live online classes; post-class social time; small classes with regular attendees; breakout rooms for larger classes; forums to communicate outside of class
Quality of instruction and feedback: loss of one-to-one feedback and personalized adaptations; absence of volunteers or assistants to support	Live online classes; clear instructions with repetition; one-to-one or small group teaching; individual support from volunteers/assistants; time for questions and suggestions after class; use of AI for individualized monitoring and feedback
Representation of movement and the body: altered body perception caused by restricted space, observing oneself on screen, and absence of visual and tactile feedback from others and the environment	Instructions to focus on observation of instructor/other dancers to support observational learning; use of kinesthetic imagery to increase sensations of movement
Music and rhythm: reduced enjoyment and rhythmic cues without live music; reduced audio quality	Ensure appropriate volume and audio quality of teaching materials and home devices to optimize therapeutic effects of music; facilitate personalized music choices to increase enjoyment and engagement
Aesthetics and creativity: reduced opportunities for creative expression and escapism	Participants to contribute to choreographic themes; encourage the use of props at home to promote creativity; use of analogy/metaphorical imagery to enhance the aesthetic experience of dance and guide movement quality; use of AI to support selection of culturally relevant themes and music

Therapeutic elements of dance that may be impacted in the digital environment

Social interaction

The extent and nature of social interaction is altered by the absence of a group or partner in the digital environment (Bek et al., 2021a; Ghanai et al., 2021; Walton et al., 2022). Qualitative reports indicate that participants value the peer support, social comparison (Walton et al., 2022; Senter et al., 2024), and physical contact (Rocha et al., 2017; Delabary et al., 2024b) provided by in-person classes. Although enjoyment from social interactions can be compromised in digital programs (Emmanouilidis et al., 2021), meaningful social engagement can still be achieved. For example, virtual coffee time after class provides opportunities for discussion, questions, and feedback (Delabary et al., 2024b). Smaller live online classes with regular participants could also create a sense of community (Bek et al., 2022b). Social interaction in large classes could be supported by using "breakout" groups to facilitate discussion after class or by providing an online forum to promote interaction outside of classes.

Quality of instruction and feedback

The effectiveness of instruction in the digital environment may be limited by factors including video/audio quality, viewing perspectives, and interaction with instructors (Bek et al., 2021a, 2022b; Delabary et al., 2024b; Tamplin et al., 2024). Feedback is important to ensure that movements are performed safely, to provide necessary adaptations, and to facilitate learning. A qualitative review of in-person dance for PD highlighted the value of the instructor-participant relationship (Senter et al., 2024). In contrast, reduced interaction with the instructor and the loss of one-to-one support were cited by participants with PD as disadvantages of digital classes (Bek et al., 2021a). These limitations may impact participants' motivation and confidence to engage as well as the potential for learning.

Quality instruction may be maintained in the digital environment through optimizing aspects of class design and production, such as slowing the teaching pace and repeating instructions (Delabary et al., 2024b). Live online classes are critical to enable participants to receive feedback. To facilitate high-quality feedback in digital programs, instructors could consider one-to-one or small group classes with volunteers or assistants to support participants during class. Participants should have opportunities to ask the instructor questions or make suggestions after class, which could be combined with social/coffee time (Bek et al., 2022a; Delabary et al., 2024b).

Representation of movement and the body

Dancers frequently observe, imitate, mirror, and coordinate with others' movements (Blasing et al., 2012; Bek et al., 2020). These processes engage the brain's motor system to facilitate movement and learning (Hardwick et al., 2018; Chye et al., 2022). Interventions based on action observation and motor imagery have shown positive effects in PD (Caligiore et al., 2017; Bek et al., 2021b; Mezzarobba et al., 2024), and qualitative data suggest that observation and imagery may be effectively implemented within dance for PD (Bek et al., 2022a). Additionally, awareness of the body is an important element of dance, and in-person dance training may enhance body awareness in PD (Hadley et al., 2020).

Body perception may be altered in the digital space (Delabary et al., 2024a), for example through seeing oneself on screen or having a more restricted area within which to move.

Self-report data indicates that many people with PD can engage in observational learning and use imagery to enhance the outcomes of digital dance participation (Bek et al., 2021a, 2022b). These processes could be supported in digital programs through specific instructions to increase attention to the movements of the instructor and other dancers and by encouraging participants to imagine the sensations of the demonstrated movements (i.e., kinesthetic imagery).

Music and rhythm

Music and rhythm are integral to most forms of dance and may contribute to beneficial effects for people with PD. Rhythmic cueing can support gait in people with PD (de Dreu et al., 2011; Nombela et al., 2013). Music promotes dopamine release in the basal ganglia (Salimpoor et al., 2011), and the beneficial effects of music in PD extend beyond rhythm to influence affect and motivation (Karageorghis et al., 2020; Tamplin et al., 2020, 2024). Music can also evoke motor imagery in people with PD (Poliakoff et al., 2023), and participants could potentially utilize the music from dance classes as an internalized cue to support movement in daily life (Bek et al., 2022a; Jola et al., 2022). People with PD enjoy the music accompanying dance classes and have expressed a preference for live music (Ghanai et al., 2021), which participants miss when dancing at home (Bek et al., 2021a).

In a recent study examining the feasibility of a one-on-one digital dance program for PD, participants worked with the instructor to select music for classes (Morris et al., 2021). Although it may be difficult to effectively tailor music to preferences in a group online class, different choices could be accommodated across a series of classes. Instructors should ensure appropriate music quality and volume (Delabary et al., 2024b), and participants could be supported to optimize the audio settings of their devices.

Aesthetics and creativity

The creative aspects of dance differentiate it from other forms of physical activity (Rocha et al., 2017; Fontanesi and DeSouza, 2021; Bek et al., 2022a). Dance programs for PD often feature communicative expressions and gestures, storytelling, and props. Qualitative data indicate that participants enjoy the creativity and escapism offered by dance (Bek et al., 2022a; Walton et al., 2022) and that artistic aspects of dance are diminished in the digital environment (Walton et al., 2022). Additionally, skin conductance measures have indicated that dance may increase physiological arousal compared to an exercise program of similar aerobic intensity (Fontanesi and DeSouza, 2021), suggesting an emotional response to the artistic experience of dance. To enhance the aesthetic and creative dimensions of digital dance programs, participants could be encouraged to contribute to choreographic themes and stories or use props during home practice. Instruction could also incorporate analogy and metaphorical imagery, which has been associated with positive outcomes of digital dance participation (Bek et al., 2021a).

Future directions for research and development

Further to the therapeutic elements of dance discussed above, there are important practical considerations in designing digital programs. Ensuring safety in the digital environment is critical, particularly considering gait and balance difficulties in PD, which can increase fall risk (Camicioli et al., 2023). People with PD who attend dance classes are at different stages of disease progression and can have different needs. They may also have different infrastructures at home to support online physical activity. It is important for health professionals and instructors to ensure that participants are safe to engage in home-based dance training, particularly those with greater disease severity who experience postural instability. Checklists have been devised to assist this process (see Morris et al., 2021, 2023). It is also advisable to use a checklist before each session to assess safety of the home environment and note procedures for dealing with adverse events.

Technical barriers relating to the hardware, software, or connectivity required for online classes must also be considered for both participants and instructors (Bek et al., 2021a, 2022b; Walton et al., 2022; Delabary et al., 2024b). To increase the accessibility of dance programs, alternative options could be offered to accommodate different abilities and preferences. While most participants may prefer live online classes that provide greater social interaction, others prefer recorded videos that offer flexibility and enable self-paced or repeated practice, or appreciate having both live and recorded options (Bek et al., 2021a). Pre-recorded DVDs or dance instruction by telephone[1] could provide valuable resources for individuals in rural communities without reliable internet access or a suitable electronic device, and these should also incorporate appropriate safety checks. A choice of different digital platforms for accessing classes could also increase participation by providing options that participants are familiar with (Delabary et al., 2024b). Participants could also be supported with training or guidance to use the required technology before joining a program.

Involving people with PD in the co-design and development of programs increases the relevance and could enhance outcomes of therapeutic activities like dance (Quinn et al., 2010; Morris et al., 2021; Bek et al., 2022a). Participant input is particularly valuable in digital programming to understand specific preferences, needs, and challenges. High levels of attendance and enjoyment of co-designed online dance classes have been reported (Morris et al., 2021), and patient input can enhance the accessibility and usability of digital technology platforms for home-based training (Bek et al., 2021b).

Finally, future research and development should capitalize on the opportunities offered by artificial intelligence (AI) to enhance and personalize digital therapies (Amjad et al., 2023), including the possibility to provide participants, dance instructors, and healthcare professionals with performance data and feedback. For example, computer vision and machine learning techniques

1 These options are already offered by Dance for PD® https://danceforparkinsons.org/.

could be used to measure changes or improvements in movement and adjust programs to align with individuals' ability levels. Participants could also receive individualized encouragement and guidance. AI could also allow instructors to tailor classes to different languages, cultures, and geographical locations, for example through translating instructions or suggesting culturally relevant music and themes.

Conclusions

Current evidence indicates that digital dance is feasible and enjoyable for many people with PD, and preliminary findings suggest that positive outcomes can be achieved in the online environment. Digital platforms can increase the reach of dance programs, although barriers to access remain. However, the evidence so far is limited to small-scale studies and self-report data, and the outcomes of digital and in-person programs have not been directly compared. Further research is needed to understand the impact of digital dance across domains and at different disease stages, including longer-term outcomes. In the meantime, this article outlines possible solutions to help maintain therapeutic benefits of dance in the digital environment.

Author contributions

JB: Conceptualization, Data curation, Funding acquisition, Investigation, Writing – original draft, Writing – review & editing. DJ: Conceptualization, Writing – review & editing. MM: Writing – review & editing. MH: Conceptualization, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. JB was supported by funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 101034345.

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.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE Opinion
PUBLISHED 30 January 2025
DOI 10.3389/fpsyg.2025.1500688

OPEN ACCESS

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RECEIVED 23 September 2024
ACCEPTED 16 January 2025
PUBLISHED 30 January 2025

CITATION
Jehu DA, Bek J, Bennett C and Hackney ME (2025) Group and partnered dance for people living with dementia: an overview of intervention design and measurement considerations. *Front. Psychol.* 16:1500688. doi: 10.3389/fpsyg.2025.1500688

Group and partnered dance for people living with dementia: an overview of intervention design and measurement considerations

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KEYWORDS

dementia, dance, intervention, exercise, cognitive decline, mild cognitive impairment, physical activity

Introduction

Dementia is a growing global public health priority, with 55 million people living with dementia (PLWD) worldwide (WHO, 2023). Approximately 45%−60% of dementia cases are preventable through modifiable risk factors (Calandri et al., 2024; Livingston et al., 2024). Much of the research on dementia focuses on prevention through lifestyle interventions, such as exercise (Kivipelto et al., 2020). Considerably less research has addressed treating dementia symptoms through lifestyle interventions, as PLWD are often excluded from intervention studies due to ineligibility criteria. Interventions must be tailored for PLWD because of their risk for recurrent falls (Jehu et al., 2021b) and distinct needs, such as forgetfulness (Jehu et al., 2024b), planning difficulties (Hauer et al., 2006), and apathy (Clarke et al., 2008). PLWD also commonly experience social isolation (Shen et al., 2022), poorer physical function (Jehu et al., 2024a), worsened behavioral and psychological symptoms (Cerejeira et al., 2012), poorer quality of life (Cerejeira et al., 2012), and reduced access to healthcare (Mitchell et al., 2016) compared to older adults without dementia. Designing efficacious interventions to improve health outcomes among PLWD is a frontline priority (Corriveau et al., 2017).

Potential benefits of dance interventions for PLWD

Dance can be particularly beneficial as a lifestyle intervention for PLWD through promoting social networking and enjoyment while boosting physical activity (Kshtriya et al., 2015). The aesthetic and creative aspects of dance may promote greater physiological arousal than aerobic exercise at a similar intensity (Fontanesi and DeSouza, 2020), but this should be confirmed by further studies with larger samples. Music and dance also encourage spontaneous rhythmic coupling between sensory and motor systems (Krotinger and Loui, 2021), and facilitate self-expression and the rediscovery of skills such as moving and singing as means of communicating (Hamill et al., 2012; Kshtriya et al., 2015).

Dementia is a progressive neurological disease that affects activities of daily living, while mild cognitive impairment is defined as cognitive decline greater than that expected for a person's age and education level, without significant functional impairment

(Gauthier et al., 2006). Although dance has potential as a therapeutic intervention for PLWD, research on this population is scarce. A systematic review of dance interventions for PLWD (Karkou et al., 2023) found only one randomized controlled trial, which also included those with mild cognitive impairment (Ho et al., 2020), possibly masking between-group differences in responsiveness. This study found that dance improved loneliness, mood, physical functioning, and stress relative to a wait-list control group (Ho et al., 2020). Another randomized controlled trial comparing 2 months of Latin dance with a wait-list control found no differences in physical activity, fitness, or sedentary behavior, possibly due to the small sample size of $n = 21$ PLWD (Aguiñaga and Marquez, 2019). Other non-randomized controlled trials have indicated that dance is feasible in residential care facilities, but found no changes post-intervention, possibly due to small sample sizes ($n < 30$) (Hokkanen et al., 2008, 2003). One case study showed improved physical function following a 12-week salsa dance intervention in an individual with Alzheimer's disease (Abreu and Hartley, 2013). A quasi-experimental study comparing a 10-week dual-task intervention with an Iranian dance intervention found improvements in gait parameters among n=38 female PLWD (Ghadiri et al., 2022). Qualitative and non-randomized research has observed positive emotional reactions during dance among PLWD (Palo-Bengtsson and Ekman, 2002; Hamill et al., 2012; Guzmán-García et al., 2013; Bumanis and Yoder, 1988). Other research has indicated that PLWD exhibit procedural learning of the dance movements throughout the intervention (Rösler et al., 2002). Despite promising findings, there is a need to extend beyond feasibility studies and investigate dance interventions with adequate power and an active comparison group. General recommendations for exercise dosing exist for PLWD (Bushman, 2021), but further work should establish precise evidence-based exercise guidelines to improve outcomes in PLWD. No evidence-based dance guidelines exist to improve outcomes in PLWD. This opinion paper focuses on tailoring dance interventions for PLWD to increase uptake and improve treatment design.

Key considerations for dance for PLWD

Accessibility of dance

Researchers and dance instructors should make dance accessible, emphasizing participation over performance, to foster creativity and awareness of the body rather than accuracy (Hamill et al., 2012). PLWD may find dance easier in a partnered than group format because the former involves person-to-person interaction and connection (Abraham et al., 2024). Partnered dance involves leader and follower roles. The "leader" role, a proxy for internally generated movements, conveys direction, timing, and amplitude of steps with tactile cues, while the "follower" role, a proxy for externally generated movements, detects and responds to the leader's tactile cues (Abraham et al., 2024). The leader role is more cognitively demanding, requiring participants to remember specific movement sequences and choose appropriate next steps, while the follower role receives and responds to ongoing non-verbal cues. It may therefore be more beneficial to have PLWD in the less cognitively demanding follower role. Instructors should provide opportunities to engage in person-to-person contact and move together as a unit; such opportunities promote re-attachment and connection by overcoming communication difficulties, thereby building a socially cohesive environment (Hamill et al., 2012). Depending on dementia symptoms, such as agitation, PLWD may prefer non-partnered dance. Regardless of the dance type, participants should be encouraged to express themselves freely and spontaneously (Hamill et al., 2012). Instructors should wear name tags and simulate social interactions with group members while dancing (Hamill et al., 2012). We recommend regular reassurance, especially in times of confusion (Izquierdo et al., 2021). To foster meaningful progress in PLWD, we also recommend short and simple exercise instructions and mirroring techniques (i.e., performing dance moves with the PLWD enabling them to copy movements) (Izquierdo et al., 2021).

Individual adaptations

Adaptations to changing functional capacity levels should be considered throughout the intervention, to account for physical and functional limitations and secondary medical complications (Cipriani et al., 2020). Dementia is a non-linear progressive neurological disease that varies across individuals (Sachdev et al., 2014); thus, simpler instructions may be needed for PLWD as cognitive decline progresses. Cognitive, physical, and functional impairments may impact engagement and adherence levels; consequently, instructors should tailor dance programs to individuals' abilities. Conversely, PLWD may experience cognitive, physical, and functional improvements during interventions (Bracco et al., 2023); thus, complexity should be adjusted such that dance programs remain adequately challenging. Ongoing consultation with the PLWD's healthcare team (e.g., neuropsychologist), who are aware of the level of functional impairment, is important for appropriate dance prescription throughout the intervention (ACSM, 2021).

Caregiver support

Dance interventions seem to decrease caregiver burden (Wharton et al., 2021), and caregiver support is needed for PLWD to successfully engage in interventions. Reminders to attend classes can benefit PLWD who may lack an advocate and forget to attend (Portacolone et al., 2023), or may be aware of their own cognitive decline and avoid social activities due to embarrassment and stigmatization (Ho et al., 2021; Zhu et al., 2023). Partnered dance may be more beneficial for PLWD because a caregiver or instructor could act as a partner to cue for dance moves, help with spotting to reduce fall risk, and increase supervision for those who wander. However, partnered dance would likely increase intervention costs relative to group dance as each PLWD would need a cognitively intact partner (e.g., instructor/assistant).

Stakeholder input

Interventions should be designed with key stakeholders (e.g., caregivers, residential care facility staff, patients, and community advisory board) to ensure adequate training, resources, and

TABLE 1 Summary of recommendations for dance intervention design and measurement outcomes.

General recommendations for structuring interventions for dementia	
✓ Simple instructions ✓ Slow music tempo ✓ Mirroring technique ✓ Repetitive choreography ✓ Partnered dance for spotting ✓ Familiar music to enhance mood and enjoyment, and support reminiscence ✓ Reminders to attend dance class (e.g., on their door on the exercise day) ✓ Appropriate trainer-to-participant ratio	✓ Name tags on instructors and participants ✓ Schedule dance interventions in the morning to avoid sundowning ✓ Schedule around meals and other events at the residential care facilities to increase adherence ✓ Have a champion to support adherence ✓ Design the intervention based on feedback from key stakeholders ✓ Communicate with PLWD and their caregivers with empathy, listen to their concerns, and validate their feelings
Considerations for choosing the type of dance intervention in dementia	
✓ Select the dance style depending on the therapeutic target ✓ Select feasible, valid, reliable, and responsive outcome measures in PLWD	✓ More research is needed to determine the optimal dose of dance in PLWD for all outcomes

support for PLWD in the community and residential care (Jehu et al., 2023b). Residential care facility staff have been hesitant to implement physical activity programs among PLWD due to therapeutic pessimism (Knaak et al., 2017), perceived risk, low belief in their utility, insufficient training and support, workload concerns, and high staff turnover (Wylie et al., 2022). Among PLWD, barriers to physical activity may be attitudinal or physical and include disliking physical activity, lacking experience of being physically active, pre-existing chronic conditions, sickness, holidays, and caregiver factors such as unavailability and health concerns (Suttanon et al., 2012). While residential care facility routines and negative attitudes about physical activity have reduced physical activity promotion in many facilities (Wylie et al., 2022), behavior change is possible among facility staff, caregivers, and PLWD (Low et al., 2015). For community-dwelling PLWD, it is important to support caregivers in delivering dance interventions to reduce burnout, such as providing educational resources, training, and regular phone calls (Jehu et al., 2023a). Several organizational factors should be considered when designing interventions, including ensuring that support (e.g., escorting PLWD to exercise, scheduling) and resources (e.g., staff) are available from the organization, as well as training researchers and dance instructors on the importance of dance interventions for PLWD, dance and dementia communication techniques, and safety (e.g., training for Cardiopulmonary Resuscitation and spotting) (Demers et al., 2015). Including PLWD and a community advisory board as members of the team can enable facilitators, avoid barriers, and promote generalizability to the larger population.

Considerations for choice of dance style and interventional targets

Selecting appropriate outcomes depending on individual needs, the type of dance, and dementia subtypes should be considered in the intervention design (Jehu et al., 2023a). For example, if the therapeutic target is to improve cardiovascular health, the current guidelines for prescribing exercise intensity should be followed (Riebe et al., 2015), and heart rate should be monitored throughout the intervention. Additional research is needed to identify optimal exercise intensities for improving health outcomes in specific populations, such as those with vascular dementia (Barnes and Corkery, 2018). If the therapeutic target is improving cognitive health, dance types involving visual-spatial cognition, memory, and planning, such as Argentinian Tango, may be appropriate, especially for people with Alzheimer's disease (Wharton et al., 2021). The dance style should be carefully selected for the target population, as even low-intensity dance could be challenging for deconditioned PLWD. The complexity of dance moves should be considered depending on dementia severity, as dance movements are generally more complicated than other types of exercise. To date, no studies have compared the effects of different doses of dance among PLWD for any outcome (Rice et al., 2024). Such research would provide insight into the frequency, intensity, and duration of dance required to achieve optimal benefits for PLWD.

It is important to standardize person-centered valid and reliable outcome measures that are sensitive to change in dementia to increase comparability across studies. In a recent scoping review of more than 40 different types of dance intervention, over 50 cognitive measures and 30 mobility measures were identified, highlighting the lack of consistency in the standardization of outcomes (Rice et al., 2024). The outcome measures should also be feasible for PLWD. For example, previous work has documented substantial missing data due to poor adherence to wrist-worn activity monitors (Jehu et al., 2024b). Minor protocol changes (e.g., placing activity monitors on the lower back rather than the wrist) may increase adherence. A recent systematic review and consensus statement recommends a specific set of outcome measures for PLWD across cognition, activities of daily living, biological markers, neuropsychiatric symptoms, quality of life, and global domains (Webster et al., 2017). Dance researchers may want to provide similar recommendations in a consensus statement and add important measures such as balance, gait, falls, and social determinants of health (Jehu and Skelton, 2024, 2023; Jehu et al., 2021a). Researchers may also consider additional outcome measures depending on their research question, such as caregiver burden. Table 1 outlines a summary of our recommendations.

Future research directions

Preliminary research indicates potential cognitive, motor, and psychological benefits of dance interventions for PLWD (Balbim et al., 2022; Cezar et al., 2021). More rigorous research with larger sample sizes is needed. Involving PLWD, their caregivers, and clinicians in designing tailored and accessible dance interventions, as well as selecting appropriate outcomes, may increase relevance for this population. Dance intervention design should be tailored

to neuropsychological and behavioral symptoms associated with specific dementia subtypes, such as addressing wandering for those with Alzheimer's disease or providing external cues for those with Parkinson's-related dementias. Our recommendations are more specifically for PLWD who are still able to follow instructions; further research is needed to involve those with more severe dementia. A better understanding of the impact of dance interventions on cognitive, motor, and psychological outcomes may inform targeted treatment and monitoring strategies in PLWD.

Author contributions

DJ: Conceptualization, Writing – original draft. JB: Writing – review & editing. CB: Writing – review & editing. MH: Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. JB was supported by funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 101034345.

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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frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 24 March 2025
DOI 10.3389/fpsyg.2025.1469066

OPEN ACCESS

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RECEIVED 24 July 2024
ACCEPTED 20 February 2025
PUBLISHED 24 March 2025

CITATION
Kawase S and Eguchi K (2025) Impact of group dancing during Japanese festivals on people's sense of community.
Front. Psychol. 16:1469066.
doi: 10.3389/fpsyg.2025.1469066

Impact of group dancing during Japanese festivals on people's sense of community

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Moving together or attending festivals has been reported to foster social bonding. However, whether festivals with and without dancing affect individuals' social bonds and sense of community remains unclear. The existing research does not demonstrate whether lasting effects exist over time, even when community festivals are held only a limited number of times a year. To address this issue, this study examines the impact of dancing at local festivals on individuals' sense of community. This study hypothesized that if dancing with others enhances social bonding, individuals' participation in festivals may enhance sense of community since dancing is a part of many festivals. Accordingly, an online survey was conducted a few months after a community festival, and participants responded to three scales: the Brief Sense of Community Scale, Community Consciousness Scale, and UCLA Loneliness Scale. The results found (1) that the participants who attended and danced at a festival with dancing showed a higher sense of community and lower loneliness level than those who did not dance or those who attended a festival without dancing. (2) Previous festival attendance habits did not influence these tendencies. (3) Furthermore, these tendencies were not related to the individual's willingness to attend festivals. Therefore, dancing at festivals may promote a greater sense of community than attending festivals without dance.

KEYWORDS

dance, music, festival, embodiment, social bonding, sense of community, isolation, loneliness

1 Introduction

Moving the body in response to music is considered an enjoyable experience worldwide (Fitch, 2015; Stevens, 2012). A typical example of people moving their bodies in accordance with music occurs during festivals. Various types of traditional dances are performed at festivals around the world (Frederiksen and Chang, 2023). As shown in the UNESCO List of Cultural Heritage, dance is performed at ceremonies and festivals all over the world (United Nations Educational, Scientific and Cultural Organization, 2024). For example, Hula in Hawaii, Bon Odori (Bon dance) in Japan, Irish Stepdance in Ireland, Ghoomar in India, Maypole Dance in the United Kingdom, and Samba in Brazil. These dances reflect the cultural heritage and traditions of their respective regions, often performed during festivals or special occasions. Argan et al. (2021) showed that a Turkish dance festival could offer benefits, serving as an important experiential space that could improve the physical and social confidence of participants and strengthen intergenerational solidarity. Argan et al. (2021) also demonstrated that participants at the Turkish dance festival demonstrated a significant relationship between the motivation to gain dance experience and the quality of the experience; furthermore, this quality significantly impacted satisfaction. This finding suggests that the intention to participate in the festival may affect the participants' sense of community. Furthermore,

community-based festivals and community dances have been associated with a sense of community (Kino, 2016; Shinonaga et al., 2020).

Regarding the benefits of dancing and group dancing, many studies have shown that dance is a beneficial activity that promotes physical, psychological, and social health in various age groups (Fong Yan et al., 2024; McCrary et al., 2021). In a review article, McCrary et al. (2021) demonstrated the physiological, cognitive, and psychological benefits of dance. They indicated that dance functions as an aerobic exercise that improves cardiorespiratory endurance, increases muscle strength and flexibility, and improves balance and physical coordination. Furthermore, they also pointed out that learning and remembering choreography helps to maintain and improve cognitive function. As for psychological effects, dance promotes the secretion of endorphins, reduces stress and anxiety, and enhances mood. As a social benefit, group dance activities can strengthen social ties, promote social interaction, reduce feelings of isolation, and contribute to a sense of community (McCrary et al., 2021). Dancing together can also promote the secretion of oxytocin and strengthen social bonds (Vander Elst et al., 2023). The benefits of dance have also spread to dance movement therapy (DMT) and dance interventions in medical institutions. DMT is said to be effective for reducing depression and anxiety, improving quality of life, and improving interpersonal, cognitive, and motor skills (Koch et al., 2014). Dance is also regarded as a promising treatment and rehabilitation method for neurodegenerative diseases such as Parkinson's disease and Alzheimer's disease (Vander Elst et al., 2023).

In many traditional dances, music is essential. Music and its accompanying physical movements are cultural behaviors, and they are activities that people have long been familiar with (Trehub et al., 2015). Indeed, in concerts, people can be seen swaying their bodies (Keller and Rieger, 2009). In sports activities, audience members sing while jumping up and down to cheer athletes or teams (Knijnik, 2018). Furthermore, both music and dance are associated with festivals (Frederiksen and Chang, 2023). Extensive scientific research has investigated the physiological, cognitive, developmental, evolutionary, and social aspects of moving the body to music and its effects on relationships with others (Cirelli et al., 2014; Kirschner and Tomasello, 2010; Savage et al., 2020; Tarr et al., 2016). In recent years, the urge to move one's body in response to music has been termed "groove" (as reviewed in Etani et al., 2024). The urge to move to music is probably a universal sensation because words describing the relationship between music and physical movements exist in many cultures (Etani et al., 2024; Kawase, 2024; Kawase and Eguchi, 2010). Regarding groove, groovy music can be the optimal music for anticipation mechanisms and activate the reward system. Anticipation and reward system are related to social connections (Fiveash et al., 2023). These studies highlight the significance of the link between rhythmic factors in music and physical movements. In addition, the fact that rhythmic physical movements are observed early during a person's developmental stages indicates that moving (or dancing) to music is a primitive characteristic of human beings (Trehub et al., 2015).

In response to the question of why people move to music, its evolutionary and adaptive significance is often highlighted. In this respect, its role in fostering social bonds deserves special mention (Dunbar, 2011). Indeed, moving together to music promotes prosocial behavior (Tarr et al., 2016) and social bonding (Savage et al., 2020). This is true for both infants and adults and is considered a fundamental human trait (Cirelli et al., 2014; Kawase et al., 2018; Kirschner and Tomasello, 2010). According to Cirelli et al. (2014), 14-month-old infants recorded a higher level of spontaneous helping behavior toward adults who moved together to music compared with those who did not move together. In an experiment conducted by Kirschner and Tomasello (2010) on 4-year-old children, two people who played instruments together with the children who moved while playing a musical instrument together showed more willingness to help the other child in trouble compared to those who simply walked together. Further, in an experiment on high school students, dancing together was found to release endorphins, which foster social hand-bonding (Tarr et al., 2016). These studies show that the formation of social bonds through movement in synchronization with music is a universal phenomenon observed across the lifespan from infancy to adulthood. This ubiquity suggests that the link between synchronized movement, music, and social bonding may have evolutionary roots, implying that this behavior has been selectively advantageous throughout human history. According to Kawase et al. (2007), when two people who drummed freely engaged in communication, a shared rhythm was correlated with good interpersonal impressions. The effects of movement synchronization have also been explained by brain mechanisms, which may enhance social bonding because of increased neural synchrony and enhanced interpersonal coordination (as reviewed in Basso et al., 2020).

Simply moving together is known to influence a person's prosocial behavior, as well; this is because synchronization promotes prosocial behavior (Carpenter et al., 2013; Keller et al., 2014), cooperative skills (Valdesolo et al., 2010), compassion and altruistic behavior (Valdesolo and DeSteno, 2011), empathy (Behrends et al., 2012), interpersonal likeability (Hove and Risen, 2009), rapport (Lakens and Stel, 2011), trust (Launay et al., 2013), and social closeness (Tarr et al., 2016). These effects are applicable to young children, as well. For instance, Carpenter et al. (2013) showed that 18-month-old infants were more helpful to adults who imitated the infants' behavior than to those who did not. Nevertheless, Stupacher et al. (2017) pointed out the importance of the social bonds generated by moving to matching music over those occurring from simply matching movements or monotonous stimuli, such as a metronome.

One of the most common examples of dancing to music occurs during festivals. Indeed, festivals help maintain the sustainability and stability of communities (Dunbar, 2011). Indeed, festivals and rituals involving dancing to music are prevalent in various communities worldwide (Stevens, 2012; Trehub et al., 2015); therefore, festivals highlighting music and dance are important targets to examine the cultural and evolutionary behavior of human communities. Furthermore, earlier studies indicate that participation in festivals enhances social capital (Arcodia and Whitford, 2006; Jaeger and Mykletun, 2013). Festivals have been shown to promote a sense of community (Hassanli et al., 2021), enhance community building (Mair and Duffy, 2020), and ensure community maintenance (Black, 2016) as part of improving social sustainability. Accordingly, festivals are predicted to affect community awareness and social connectedness.

This study examines whether dancing, which is an inherent part of many festivals, is associated with individuals' sense of community. Studies indicate that individuals' prosocial behavior and sociability increase after dancing and playing music with others (e.g., Dunbar, 2011; Kawase et al., 2018; Keller et al., 2014; Tarr et al., 2016). Many experimental studies clarify that an individual exhibits prosocial

behavior immediately after moving to music (e.g., Cirelli et al., 2014; Kirschner and Tomasello, 2010). If dancing with others enhances social bonding, individuals' participation in festivals may enhance social bonding since dancing is a part of many festivals.

However, it is unclear whether such effects persist over time since festivals and rituals, such as community festivals and ceremonies, are held only a limited number of times (usually once) a year. In the aforementioned research, individuals' promotion of prosocial behavior by moving to music was often measured immediately after the movement. In other words, the long-term effects of dancing associated with festivals, which occur very infrequently, remain unverified. This may be due to the infrequency of local festivals; moreover, since all the participants were not from the same area, collecting a large amount of data was difficult. Although earlier studies indicate that participation in festivals enhances individuals' sense of community, they do not clarify whether the presence of dancing in festivals makes any difference in social bonds and the sense of community.

The current study addressed the aforementioned research gap as follows: A large-scale online survey assessed by three scales regarding sense of community and loneliness was conducted; further, the study examined whether the people who participate in local festivals involving dancing have a higher sense of community than those participating in festivals without dancing regardless of participation history or intention. This condition can clarify whether those who had participated in festivals and danced had a greater sense of community than those in other conditions. Research on whether festivals that involve individuals moving to music make an ongoing contribution to community maintenance, as well as enhancing individual social bonds, helps reassess the effects of dance from a long-term perspective and clarifies why festivals involving dance are held iteratively. This also serves as a link between the aforementioned experimental studies and real-world practices.

This study explored the psychological impact of the presence or absence of dancing at Japanese festivals. Approximately 600,000 festivals may be held in a year in Japan, of which around 300,000 are traditional festivals (Nikkei, Inc, 2015, August 23). Many of these are held in relatively small local communities. In many cases, they are held once a year or every few years. It has also been pointed out that many festivals are held in summer (Tanaka, 2024).

Specifically, Bon dance is one of the most popular dances in festivals in Japan (Gilhooly, 2009). Bon dance is an outdoor activity enjoyed by individuals of all ages and genders during the Obon season, which typically occurs between July and August. Originally emerging as a folk tradition tied to the Obon festival—a time when the spirits of the deceased are believed to return to this world to be honored—the dance has undergone a shift in meaning over time. Its religious connotations have diminished in recent years, and it has largely evolved into a community-oriented form of entertainment that welcomes participation from everyone. Furyu odori, the traditional Japanese dances in festivals including Bon dance have been registered as UNESCO Intangible Cultural Heritage. The Japanese Agency for Cultural Affairs has introduced them in a leaflet with photos of the dances (The Agency for Cultural Affairs, n.d.). Bon dance festivals are organized throughout Japan and have become widely recognized as casual events that people can enjoy in their regular clothing, even in urban areas. These festivals may also serve an important function in fostering a sense of community and bringing people closer together and a sense of sharing the same rhythm during dancing together that will provide a relief that we are living in harmony with each other (Oishi, 2020).

Accordingly, this study addresses the following hypotheses that (1) the participants of festivals involving dancing possess a higher sense of community than those who do not dance or who participate in festivals without dancing, (2) individuals' high sense of community is not influenced by their previous festival participation habits, and (3) individuals' high sense of community is not influenced by the intensity of their willingness to participate in festivals.

2 Methods

2.1 Participants

This study considered 1,768 participants (1,164 men, 603 women, and one other) with a mean age of 53.2 years (standard deviation, SD = 13.0). At the time of the study, the participants had been living in their current area of residence for at least 8 years, that is, residing in the same area for at least 5 years, excluding the COVID-19 period (during which many festivals were not conducted in Japan). Prior to conducting analyses, the participants who provided the same response (straight-line response) on more than one scale were excluded from the study. The correlation coefficient between the population of Japan's 47 prefectures in 2023 and the number of participants in each prefecture in this study was 0.98 ($p < 0.01$). In other words, it can be said that the participants in this study are evenly distributed throughout Japan based on demographic data, without any regional bias.

2.2 Materials

Participants' sense of community was assessed by incorporating the following three scales in the survey:

1 The Japanese version of the Brief Sense of Community Scale (BSCS; Yu et al., 2022) was used to measure the sense of community. This eight-item instrument comprises the following four factors: need fulfillment (the perception that members' needs will be met by the community), membership (a sense of belonging or interpersonal relatedness), influence (the feeling that one is important, or able to make a difference, in a community and that the community is important to its members), and emotional connection (a sense of attachment or bonding based on the members' shared history, place, or experience).
2 The short version of the Community Consciousness Scale (CCS; Ishimori et al., 2013) is a 12-item scale having the following four factors: solidarity (contribution to and active involvement in the community), self-determination (a sense of playing an active role in community improvement), attachment (attachment to and pride in the community), and dependency (letting others solve local problems).
3 The Japanese version of the UCLA Loneliness Scale Version 3 (UCLA-LS3-J; Arimoto and Tadaka, 2019) is a 10-item scale comprising a single factor. This scale was used to measure connectedness to others, unlike the two aforementioned scales.

2.3 Procedures

The survey was conducted with the help of a research company (GMO Research, Inc., Tokyo, Japan). Participants were presented with a description of the study and an informed consent form, and those who agreed to participate in the study proceeded to attend the survey. To minimize potential biases, the survey was conducted in December, outside the primary festival season in Japan, which usually takes place during summer and autumn, with a concentration of events like Bon dance in August.

The informed consent form stated that the survey would be analyzed anonymously, survey participation was not compulsory, the participants would not be disadvantaged in discontinuing or withdrawing from the survey, and their data would not be used for anything other than the study purpose. Only those who agreed to these conditions participated in the survey. This study was conducted in accordance with the Code of Ethics of the Japanese Psychological Association.

Initially, participants responded to a brief face sheet detailing their personal demographics. To eliminate differences among the participants based on their participation in the most recent local festival, the survey targeted those for whom the nearest festival was canceled from 2020 to 2022 because many festivals were canceled during this period to prevent the pandemic's spread in Japan.

Subsequently, participants responded to the characteristics of local festivals (with or without dances with others) and their participation (whether or not they participated in 2023 and danced). The participants who attended more than one local festival a year were instructed to respond to the festival they were most familiar with. Participants also indicated their participation in festivals before COVID-19. Therefore, there are no duplicate participants when comparing averages in a single analysis below. For example, one participant will not be incorporated into the averages for both festivals with and without dancing. Statistical analysis was performed using IBM SPSS Statistics 24. ANOVA was performed on Type III SS.

3 Results

3.1 Months in which festivals are held

August was the most common month in which festivals were held (49.9%); it was followed by July (16.9%) and October (13.6%). Details on the festival schedule are visualized in Figure 1. Hence, study results reflect this cultural aspect. The survey was conducted in December. Hence, many participants indicated in their survey responses that several months had passed since their last festival attendance.

3.2 Differences in sense of community based on types of festivals attended

To examine the relationship between how people participate in festivals and the level of their sense of community, scale scores were compared among three groups using analysis of variance (ANOVA): the participants who participated in festivals involving group dancing, those who participated in festivals involving dancing but did not dance themselves, and those who participated in festivals without dancing (Table 1).

For each BSCS factor, the scores of the respondents who participated in a festival with group dancing were significantly higher than those of the respondents who did not dance or who participated in a festival without dancing. Further, for each CCS factor, except dependency on others factor, those who danced scored significantly higher than those who participated in a festival without dancing. Finally, for UCLA-LS3-J, those who danced scored significantly lower than those who did not dance at the festival. These results indicate that the sense of community among the participants who attended and danced at festivals was higher than that among the ones who attended festivals without dancing or who attended festivals with dancing but did not dance.

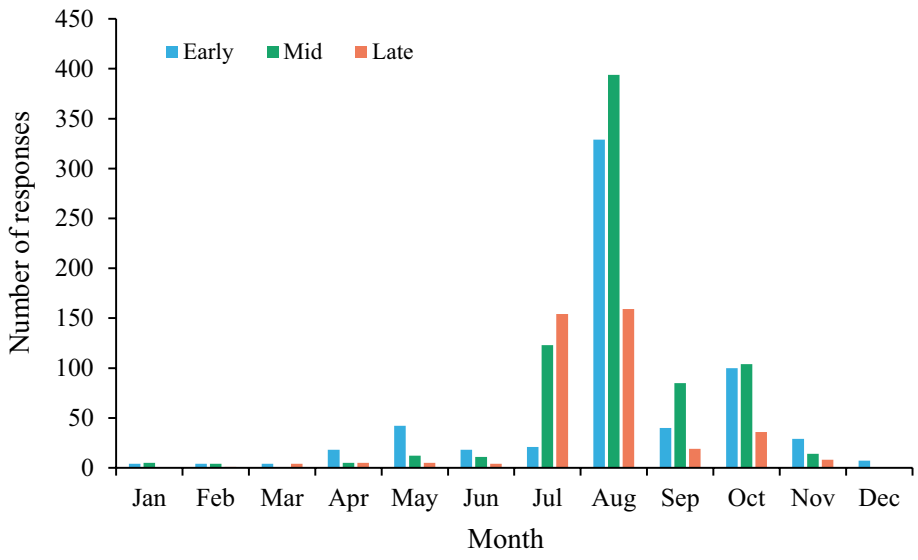

FIGURE 1
Month in which the festival was held for which responses were given.

TABLE 1 Mean ratings of scales and ANOVA results for participants' sense of community by festival type.

Types of participation in festivals	Festivals involving dance		w/oD	*F*	*df*	*p*	η_p^2	Multiple comparisons (Bonferroni)
	D	nD						
BSCS								
Need fulfillment	7.0	6.4	6.5	9.5	2, 700	0.000	0.026	D > nD**, D > w/oD**
Membership	7.3	6.5	6.9	9.9	2, 700	0.000	0.028	D > nD**, D > w/oD*
Influence	6.3	5.2	5.6	18.9	2, 700	0.000	0.051	D > nD**, D > w/oD**
Emotional connection	7.1	6.1	6.5	17.1	2, 700	0.000	0.047	D > nD**, D > w/oD**
CCS								
Solidarity	10.5	9.0	9.3	23.0	2, 700	0.000	0.062	D > nD**, D > w/oD**
Self-determination	11.1	11.1	10.5	3.2	2, 700	0.041	0.009	D > w/oD*
Attachment	10.3	9.8	9.6	6.1	2, 700	0.002	0.017	D > w/oD**
Dependency on others	8.6	9.1	9.1	4.3	2, 700	0.014	0.012	
UCLA loneliness scale	21.0	22.8	22.1	5.0	2, 700	0.007	0.014	D < nD*

D; Dancing, nD; not dancing, w/oD; without dancing. BSCS, Brief Sense of Community Scale; CCS, Community Consciousness Scale. **$p < 0.01$, *$p < 0.05$.

TABLE 2 Mean ratings and ANOVA results for participants' sense of community who attended festivals annually.

Types of participation in festivals	Festivals involving dance		w/oD	*F*	*df*	*p*	η_p^2	Multiple comparisons (Bonferroni)
	D	nD						
BSCS								
Need fulfillment	7.3	7.0	6.6	3.4	2, 335	0.035	0.020	D > w/oD*
Membership	7.7	7.1	7.3	2.6	2, 335	0.075	0.015	
Influence	6.7	5.8	5.7	9.7	2, 335	0.000	0.055	D > nD*, D > w/oD**
Emotional connection	7.4	6.6	6.7	5.8	2, 335	0.003	0.034	D > nD*, D > w/oD*
CCS								
Solidarity	11.0	9.6	9.7	7.6	2, 335	0.001	0.043	D > nD*, D > w/oD**
Self-determination	11.3	11.4	10.8	1.4	2, 335	0.256	0.008	
Attachment	10.7	10.4	9.8	3.5	2, 335	0.030	0.021	D > w/oD*
Dependency on others	8.1	9.0	8.7	2.3	2, 335	0.098	0.014	
UCLA loneliness scale	20.1	21.5	22.5	4.2	2, 335	0.016	0.024	D < w/oD*

D; Dancing, nD; not dancing, w/oD; without dancing. BSCS, Brief Sense of Community Scale; CCS, Community Consciousness Scale. **$p < 0.01$, *$p < 0.05$.

3.3 Sense of community when controlling for past participation

To control the effect of festival participation habits in the aforementioned results, we compared sense of community and loneliness only among participants who had attended the festival annually before COVID-19. Thus, an ANOVA was performed with festival type as the independent variable and sense of community scores as the dependent variable (Table 2). Results revealed that on the three BSCS subscales and two CCS subscales, the sense of community of those attending festivals with dancing was higher than that of those attending festivals without dancing. Loneliness was lower among the individuals who attended festivals with dancing than among those who participated in festivals without dancing. In other words, those who danced showed a higher sense of community, even among the participants having similar festival attendance habits, than those who did not.

3.4 Festival participation intent and sense of community

The sense of community of the respondents who participated in a festival was compared with that of the individuals who did not. In the analysis, the ones who did not participate were divided into two groups: those who wanted but were unable to participate and those who never intended to participate in the first place. This division helped identify the differences between respondents' intention to attend and participation.

Results indicated that, for festivals with dancing, the ones who participated and danced scored the highest on all BSCS subscales (Table 3). The same trend was observed for CCS, with those who participated and danced having the highest sense of community. Further, loneliness was found to be the lowest among those who participated and danced. However, those who intended to but could not participate showed that either BSCS or CCS had similar results to those who participated but did not dance: no difference regarding loneliness was found among these two subcategories.

Similar tendencies were found for festivals without and those with dance; however, the number of pairs with significant differences between groups was fewer than that for festivals involving dance (Table 4). In particular, no significant differences were found between the participants who intended to attend but were unable to attend and those who did not intend to attend.

Therefore, those who did not attend festivals, despite intending to attend, had a lower sense of community than those who did. This tendency was particularly prominent among festivals involving dance.

4 Discussion

This study investigated how dancing at local festivals affects individuals' sense of community. A survey that was conducted a few months after a community festival revealed the following findings: (1) The participants who attended a festival involving dancing and

TABLE 3 Mean ratings and ANOVA results for respondents who participated in dancing festivals, wanted but could not participate, and had no intention to participate.

	AD	AnD	Unattended		*F*	*df*	*p*	η_p^2	Multiple comparisons (Bonferroni)
			UI	UnI					
BSCS									
Need fulfillment	7.0	6.4	6.5	5.8	31.5	3, 1,042	0.000	0.083	AD>AnD, UnI**, AD>UI*, AnD > UnI*, UI > UnI**
Membership	7.3	6.5	6.7	5.8	41.7	3, 1,042	0.000	0.107	AD>AnD, UI, UnI**, AnD > UnI**, UI > UnI**
Influence	6.3	5.2	5.3	4.5	67.3	3, 1,042	0.000	0.162	AD>AnD, UI, UnI**, AnD > UnI**, UI > UnI**
Emotional connection	7.1	6.1	6.4	5.4	53.2	3, 1,042	0.000	0.133	AD>AnD, UI, UnI**, AnD > UnI*, UI > UnI**
CCS									
Solidarity	10.5	9.0	9.4	7.9	69.8	3, 1,042	0.000	0.167	AD>AnD, UI, UnI**, AnD > UnI**, UI > UnI**
Self-determination	11.1	11.1	10.9	10.4	5.8	3, 1,042	0.001	0.016	AD>UnI**, AnD > UnI*
Attachment	10.2	9.8	10.1	9.1	19.8	3, 1,042	0.000	0.054	AD>UnI**, AnD > UnI*, UI > UnI**
Dependency on others	8.5	9.1	8.7	9.5	10.7	3, 1,042	0.000	0.030	AD<UnI**, UI < UnI**
UCLA loneliness scale	21.0	22.8	21.7	24.4	23.3	3, 1,042	0.000	0.063	AD<AnD*, AD<UnI**, UI < UnI**

AD; Attended and Dancing, AnD; Attended, but not dancing, UI; Unattended, intended to participate, UnI; Unattended, no intention to participate, BSCS, Brief Sense of Community Scale; CCS, Community Consciousness Scale. $^{**}p < 0.01$, $^{*}p < 0.05$.

TABLE 4 Mean ratings and ANOVA for respondents in non-dancing festivals, those unable to participate, and those unwilling to participate.

	A	Unattended		*F*	*df*	*p*	η_p^2	Multiple comparisons (Bonferroni)
		UI	UnI					
BSCS								
Need fulfillment	6.5	6.0	5.6	9.9	2, 495	0.000	0.039	A > UnI**
Membership	6.9	6.0	5.7	16.6	2, 495	0.000	0.063	A > UI**, A > UnI**
Influence	5.6	5.0	4.5	21.6	2, 495	0.000	0.080	A > UI**, A > UnI**, UI > UnI*
Emotional connection	6.5	5.6	5.2	19.7	2, 495	0.000	0.074	A > UI**, A > UnI**
CCS								
Solidarity	9.3	9.0	7.8	20.7	2, 495	0.000	0.077	A > UnI**, UI > UnI**
Self-determination	10.5	10.3	10.0	2.9	2, 495	0.058	0.011	
Attachment	9.6	9.3	8.8	5.9	2, 495	0.003	0.023	A > UnI**
Dependency on others	9.1	9.2	9.3	0.3	2, 495	0.743	0.001	
UCLA loneliness scale	22.1	23.7	24.0	5.2	2, 495	0.006	0.021	A < UnI**

A; Attended, UI; Unattended, intended to participate, UnI; Unattended, no intention to participate, BSCS, Brief Sense of Community Scale; CCS, Community Consciousness Scale. $^{**}p < 0.01$, $^{*}p < 0.05$.

actually physically participated in dancing had a higher sense of community and lower loneliness than those who did not dance or who attended the festival without dancing. (2) These tendencies were not influenced by previous festival attendance habits. (3) These tendencies were not related to individuals' willingness to attend festivals. Accordingly, these results suggest that dancing at festivals can promote a sense of community since it is not significantly influenced by individuals' habits or willingness to participate.

4.1 Relationship between dance at festivals and their sense of community

The participants who attended festivals with dancing and danced had a higher sense of community and lower level of loneliness than those who did not dance or those who participated in festivals without dancing. Prior qualitative research has shown that participating in local festivals and dancing with others at local events are associated with a sense of community (Kino, 2016) and intergenerational solidarity (Argan et al., 2021). On the other hand, it has not been quantitatively clarified to what extent there is actually a difference in sense of community and loneliness between dancing and not dancing in those festivals. This study found that dancing with others at daily festivals in real-life settings is associated with increased sense of community and decreased loneliness. These results extend the findings of earlier studies in laboratory settings because it focuses on the social function of dancing at real-world festivals, which has been practiced since ancient times, and highlights the significance of dance. Further, the results add a new perspective to the findings of a series of studies that indicate how dance deepens social bonds (Dunbar, 2011; Savage et al., 2020; Trehub et al., 2015) by examining the presence or absence of dance. Furthermore, the connection between dance and a sense of community in the real world sheds light on the social meaning of the fact that the urge to move one's body to music is observed across cultures (Etani et al., 2024; Kawase, 2024; Kawase and Eguchi, 2010).

Additionally, the current results are consistent with the findings of experimental research on social bonding with those who move synchronously with others to music (Dunbar, 2011; Fitch, 2015; Savage et al., 2020; Tarr et al., 2016) and on prosocial behaviors that are exhibited by individuals (from 14-month-olds to high school students) immediately after they move to music (Cirelli et al., 2014; Tarr et al., 2015). Many of these studies regard experimental synchronous movement as a controlled, cooperative dance, and focus on the role of dance in the formation of society in human evolution. Furthermore, the present results are supported by the earlier findings that moving together in accordance with music, or simply moving together with other people promotes sociability (Cirelli et al., 2014; Kawase et al., 2018; Kirschner and Tomasello, 2010) and social bonding (Stupacher et al., 2017) prosocial behavior (Carpenter et al., 2013; Keller et al., 2014), altruistic behavior (Valdesolo and DeSteno, 2011), interpersonal likeability (Hove and Risen, 2009), rapport (Lakens and Stel, 2011), trust (Launay et al., 2013), and bonding with others (Tarr et al., 2016). The triggers for such prosocial aspects were reportedly the effects of transient physiological responses, such as the release of endorphins (e.g., Tarr et al., 2016). Brain mechanisms could also explain these social bonding effects through increased neural synchrony and enhanced interpersonal coordination (Basso et al., 2020).

Contrastingly, the current results indicate the long-lasting effects of dancing to music because this study was conducted several months after a festival that involved dancing. Community festivals and ceremonies occur only a limited number of times (usually once) a year. Although it does not clarify whether moving together to music can generate lasting social bonds, this study suggests that moving to music at a festival but only a limited number of times contributes to not only the enhancement of individual social bonds but also the ongoing maintenance of the community. Further, the results clarify that the inclusion of synchronous dancing in festivals is associated with a high sense of community. A large body of literature indicates that participation in festivals increases individuals' sense of community (Arcodia and Whitford, 2006), and accordingly, festivals promote community awareness (Hassanli et al., 2021), building (Mair and Duffy, 2020), and maintenance (Black, 2016) and enhance social sustainability. The current results, which are characterized by a high sense of community and a low level of loneliness, are consistent with the aforementioned findings.

However, the results suggest that the sense of community and level of loneliness differ according to the festival type, that is, the presence or absence of group dancing. Given that group dancing or moving together enhanced prosociality of participants toward those who did not dance with them (Reddish et al., 2016; Tarr et al., 2015), dancing together can affect prosociality not only towards those who danced together but also toward a broader range of members of the surrounding community. Therefore, it is possible that dancing and moving together at festivals increased closeness not only toward those who were present but also toward people in the community, even though they were not dancing together, and strengthened sense of community of festivals attendees who danced together. Further investigation into dancing at festivals should explore this possibility.

Furthermore, this study indicated that dancing may enable the formation and maintenance of social bonds, even in large community groups. Weinstein et al. (2016) showed that, in choral singing, even large groups that are less familiar with each other generate social bonds during collective singing to the same extent as in intimate small groups. Thus, social bonds are generated even in festivals where large numbers of community members participate. As for synchronous group dancing, and in line with the current results, it is suggested that social bonding can be appropriately extended to match the increase in group size, which makes dancing an effective method to connect with many people simultaneously.

The present results also suggest that the sense of community and feelings of loneliness are also influenced by the benefits of the dance itself. Dance exerts many positive effects on the mind and body (Fong Yan et al., 2024; Koch et al., 2014; McCrary et al., 2021; Vander Elst et al., 2023) in terms of improving physical function, cognitive function, and rehabilitation of neurological disorders and reduction of mental stress, depression, and anxiety. Furthermore, group dance activities promote social interaction and contribute toward reducing feelings of isolation (McCrary et al., 2021). Given these benefits of dance, festivals that involve dance could help to improve mental and physical stability and build social bonds while enhancing a sense of community.

4.2 Relationships among individuals' festival attendance habits, intention to attend festivals, and sense of community

The observation of the tendency for those who attend and dance in festivals to have a higher sense of community and a lower loneliness level, but being unrelated to their past festival attendance habits, can perhaps be interpreted by that those who dance possess a higher sense of community than others. However, in this study, those with a high frequency of past (pre-COVID-19) festival participation and those with high intentions to participate in festivals did not possess a higher sense of community than those who danced during the present year of observation. In other words, even if individuals intend to attend a festival, their sense of community does not become high if they do not dance at the festival. A link was observed between motivation, the quality of the experience, and satisfaction with participation in the Turkish dance festival (Argan et al., 2021). On the other hand, the results of this study show that, even if people had the intention to participate, those who did not participate in the festival showed a lower sense of community, indicating the importance of participating, dancing, and motivation. Furthermore, dancing at festivals may also provide participants with satisfaction. This virtuous cycle may increase their motivation to participate in the following year. Nonetheless, given the existence of very few studies on the impact of dance on festivals, the current study provided additional significant support for the impact of dance on festivals from a social perspective. Accordingly, it is important to move and share places and times to receive the benefits of festivals involving group dancing.

Interestingly, the effects of festival participation may not last for years. The sense of community of those who participated in the festival every year before COVID-19 but did not participate thereafter was not higher than that of the ones who danced after the pandemic. In other words, the effects of dancing at festivals may fade after a few years. This study was conducted toward the end of the COVID-19 pandemic, at a time when the restrictions that had been in place for approximately 3 years were relaxed and festivals resumed. Therefore, even if people had been attending festivals and dancing before COVID-19, the effect of attendance on their sense of community and loneliness would have diminished if they had been interrupted for some time. This means that the effect of festival participation can be considered to continue on a monthly, not yearly, basis. Consequently, one reason why some individuals continue participating in festivals may be the ongoing enhancement of their sense of community.

5 Limitations and future research

This study did not specify the long-term effects of festivals lasting multiple years. Hence, further investigation into the effects of participation in festivals with dancing is necessary. In general, festivals are held once a year or every few years. Therefore, it is necessary to focus on the sustainability of maintaining or attenuating the effects of participation in festivals. In addition, a method for randomly selecting participants is necessary. By randomly assigning festival participants to different conditions, the festival's effects on communal awareness can be measured under controlled conditions. Long-term follow-up surveys may also be effective. The simplest and most ideal method would be to randomly assign local participants to either "dance" or "not dance" and then continuously measure their sense of community. Furthermore, it is useful to understand the impact of differences in festival dance type and participation style on sense of community. For example, investigations into ethnic dances worldwide and casual brief participation in festival dances could provide valuable insights.

Experiences related to individual dance should be considered in future studies, since this study has not collected data regarding individual dance experience, for instance, dance lessons. To shed more light on the topic, international and cultural comparisons must be performed. In Japan, many different festivals are held; however, the forms of festivals and the attitudes of participants differ across cultures.

6 Conclusion

This study clarified that those who attended and danced with others at festivals involving dancing had a greater sense of community and lower loneliness than those who did not dance or those who attended festivals without dancing. These tendencies were unrelated to past participation habits or a high level of willingness to participate, indicating the importance of continuously participating in and dancing at festivals. Results provided new insights into the beneficial effects of moving the body in tune with music, which is a universally observed behavior, and its social significance. The famous Japanese saying *Odoranya son* (It's a loss if you do not dance) indicates that dancing can foster social bonds and alleviate loneliness while in present communities, reduced social bonds and intense feelings of loneliness are significant social problems (Toepoel, 2013). Since ancient times, local festivals have helped foster bonds between community members. This study can help reevaluate the roles of dance in festivals and shed light on the reasons for different human cultural practices.

For practical applications, this study highlights a simple solution to strengthen individuals' sense of community. By simply participating in local festivals involving dances, for example, Bon dance, individuals can increase their sense of belonging and social bonding. Sharing dance and music at festivals may help people experiencing verbal communication difficulties to socially bond with others since dance, in general, requires no words. Furthermore, a quantitative view of social bonding can help reassess the social value of local festivals.

Data availability statement

The raw data supporting the conclusions of this article can be available from the corresponding author on reasonable request.

Ethics statement

This study was conducted in accordance with the Code of Ethics of the Japanese Psychological Association. Ethical approval was not required for the study. 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

SK: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. KE: Investigation, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was supported by JSPS KAKENHI (grant numbers 23H00974 and 23K25671).

Acknowledgments

Special thanks goes to Dr. Judith Bek. Furthermore, we are grateful for the valuable comments from the reviewers.

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.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 25 April 2025
DOI 10.3389/fpsyg.2025.1491743

OPEN ACCESS

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RECEIVED 05 September 2024
ACCEPTED 07 April 2025
PUBLISHED 25 April 2025

CITATION
Li X, Yang Q, Zhou Z, Zeng M, Lu C and Dong W (2025) Effects of a 12-week dance intervention on left-behind children with co-occurring social anxiety and low self-concept. *Front. Psychol.* 16:1491743. doi: 10.3389/fpsyg.2025.1491743

Effects of a 12-week dance intervention on left-behind children with co-occurring social anxiety and low self-concept

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Objective: This study aimed to investigate the effects of a 12-week dance intervention on left-behind children (LBC) suffering from social anxiety and low self-concept, and to explore the relationship between social anxiety and self-concept.

Methods: Sixty LBC who met the criteria were selected from a school in Shaoyang City, Hunan Province, and were randomly divided into an Interventional group ($n = 30$) and a Control group ($n = 30$). The Interventional group received a 45-min dance intervention five times a week for 12 weeks, while the Control group maintained their original lifestyle. Social anxiety and self-concept were measured three times using the Social Anxiety Scale for Children and the Piers-Harris Child Self-concept Scale: at baseline (T0), post-intervention (12 weeks, T1), and follow-up (14 weeks after baseline, T2).

Results: (i) After the dance intervention, social anxiety and self-concept were significantly improved ($p < 0.05$). (ii) There was a significant negative correlation between the change scores (T1 minus T0) of social anxiety and self-concept ($p < 0.05$).

Conclusion: Dance intervention is an acceptable, practical and effective intervention that we can incorporate into a health programme to improve social anxiety and low self-concept in LBC.

KEYWORDS

left-behind children (LBC), dance intervention, social anxiety, self-concept, randomized controlled trial

1 Introduction

As China's urbanization accelerates and economic transformation continues, a large number of rural laborers are migrating to cities seeking better employment opportunities and higher incomes. However, due to the limitations of the household registration system and disposable incomes, these laborers cannot bring their children to reside in urban arears (Zhang and Zheng, 2022). These minors, under the age of 16, who are left at home by their parents and cared for by other family members, are commonly referred to as left-behind children (LBC). According to the latest data, as of August 2023, the number of LBC at the compulsory education stage in China is 15.5 million, accounting for about 15% of all children in the country (Ministry of Education of the People's Republic of china, 2023). Previous research on LBC in China has found that although they benefit financially from the remittances sent home by their parents,

they need to readjust to changes in the family dependency structure due to the lack of parental companionship over the years (Fellmeth et al., 2018). Over time, this prolonged separation fails to meet their emotional and psychological needs, making them more likely to develop various degrees of mental health problems compared to non-LBC (Tan et al., 2018; To et al., 2019). Among them, high social anxiety and low self-concept are the most prominent mental health problems observed in LBC (To et al., 2019).

It is noteworthy that social anxiety is the third most common mental health disorder after depression and substance abuse, with lifetime prevalence rates between 4 and 12% (Asnaani et al., 2010; Leigh and Clark, 2018; Stein, 2015). Age-of-onset data indicate that social anxiety typically occurs in late childhood and early adolescence, a period when individuals transition from familial dependence to peer interaction, shaping lifelong social skills (Bas-Hoogendam et al., 2018; Kilford et al., 2016). The development of specific neurocognitive abilities underpins this social reorientation (Kilford et al., 2016). One such ability is self-concept. As an important indicator of mental health, self-concept is significantly influenced by family environmental factors in its formation and development (Busch et al., 2021; Davis and Franzoi, 1986). Researchers have confirmed that specific groups of adolescents may be more susceptible to lower levels of self-concept than the general population (Ke et al., 2020). Additionally, some researchers have proposed a multidimensional model of self-concept from a developmental perspective, arguing that childhood is a critical period for its development (Larson and Richards, 1991).

Furthermore, research has found a link between social anxiety and self-concept (Kley et al., 2012; Nikolić et al., 2020). A pilot study of children with epilepsy by Jones et al. (2014) showed that when social anxiety symptoms were reduced in children with epilepsy, their levels of self-concept increased. Busch et al. (2021) demonstrated that self-concept was a significant predictor of anxiety symptom levels, with stronger inversed associations in adolescents. These findings provide evidential support for the relationship between social anxiety and self-concept in children, prompting us to explore whether the same association exists in LBC.

Currently, various non-pharmacological interventions targeting the underlying mechanisms to improve social anxiety and self-concept are showing positive results (Bennett et al., 2021; García-Martínez et al., 2012; Jazaieri et al., 2012). Among these, exercise intervention is one of the most commonly used and effective practical options, as it affects various physiological pathways related to social anxiety and self-concept, including improving angiogenesis and the balance of neurotransmitter concentrations, thus strengthening temporal cortices (LeBouthillier and Asmundson, 2017; Wassenaar et al., 2021). However, most studies on the beneficial effects of exercise interventions require specific equipment, venues, and aerobic or resistance training programs (LeBouthillier and Asmundson, 2017). These limitations hinder the accessibility and sustainability of exercise interventions. Additionally, these interventions are usually performed in isolation and lack interpersonal interaction, affecting participants' adherence to the intervention and psychosocial outcomes (He et al., 2022).

Given the potential benefits of exercise, a unique form of physical activity, dance intervention, was chosen to alleviate social anxiety and enhance self-concept in LBC. Dance was selected because it combines physical movement with social and musical elements (Yan et al., 2024). Unlike traditional exercise interventions, dance interventions include rhythmic movement coordination, balance, memory, social interaction, sound stimulation, and musical experience, which can improve compliance and psychosocial outcomes (Zhou et al., 2021). Moreover, the benefits of dance interventions being group activities, less site-demanding, easy to apply in various settings, and relatively inexpensive make them a potentially powerful intervention method (Huang et al., 2023; Liu et al., 2023). Previous studies have demonstrated that dance interventions improve physical and mental health indicators to a greater extent than other types of sport (Fong Yan et al., 2018).

However, although studies have explored the effects of dance interventions on the mental health of different populations, there are still limited intervention studies for LBC, and most of them focus on short-term effects. Therefore, this study is the first to use dance intervention, a novel approach, to track and analyze its effects on LBC's social anxiety and self-concept over a long period of time, and proposes the following hypotheses: (i) Dance intervention can effectively alleviate social anxiety in LBC; (ii) Dance intervention can effectively enhance self-concept in LBC; (iii) There is a correlation between the amount of change in social anxiety and self-concept.

2 Methods

2.1 Study design and procedure

The study was a randomized controlled trial (RCT) and was assessed at three time points: baseline (T0), post-intervention (12 weeks, T1), and follow-up (14 weeks after baseline, T2). The trial protocol adhered to the principles of the Declaration of Helsinki and was approved by the Medical Research Ethics Committee of Hunan Normal University (Registered under No. 2022039). Parents or legal guardians of all participants provided informed consent after the details of the study were fully explained. The CONSORT flow diagram of this study is shown in Figure 1.

2.2 Participants

Participants were recruited from a school specializing in the education of LBC in Shaoyang City, Hunan Province. A total of 402 students (from year three to year seven) were initially considered. The eligibility criteria were as follows: (i) inclusion criteria: presence of low to mild social anxiety indicated by a score ≥ 8; presence of low self-concept score within the 30th percentile (equivalent to a score of 46). (ii) exclusion criteria: children from single-parent families or orphans; children with physical disorders or neurological diseases. Ultimately, 60 eligible LBC were randomly

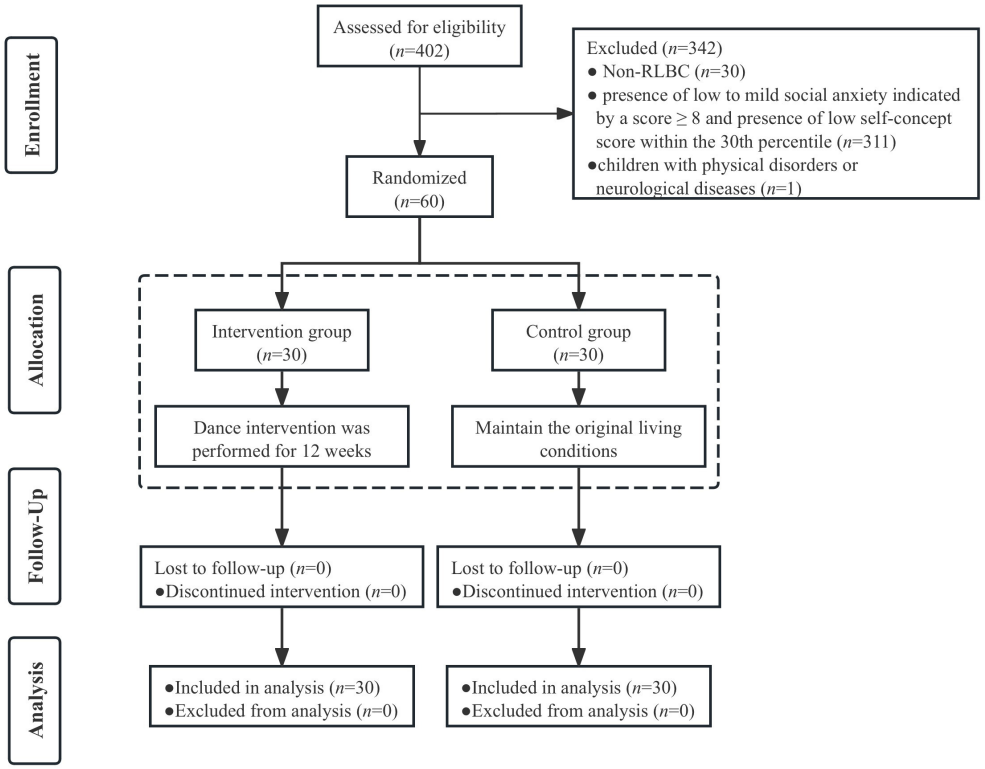

FIGURE 1
CONSORT flow diagram.

assigned to either the Intervention group ($n = 30$) or the Control group ($n = 30$).

2.3 Dance intervention

The intervention group participated in dance training four times a week, each session lasting 45 minutes (from 14:10 to 14:55 p.m., Monday to Friday). Each training session consisted of three parts: warm-up (5 min), dance training (35 min), and relaxation (5 min). The warm-up activities included exercises for the head, neck, shoulder, waist, hip, leg, wrist, and ankle. The dance training was based on the Cha Cha Cha style of Latin dance and was divided into three phases. The first phase focused on basic Cha Cha Cha movements, the second phase involved solo Cha Cha Cha combinations, and the third phase concentrated on partner Cha Cha Cha combinations. The relaxation exercises included stretches for the shoulders, neck, arm, back, and legs, as well as breathing and relaxation techniques. Details of the intervention programme can be found in Supplementary material. Two dance teachers with more than 5 years of experience in dance intervention conducted the dance sessions. The intensity of the exercise was maintained between 60 and 80% of the participants' maximum heart rate. A heart rate monitor (Polar H9; Polar Electro Oy Inc; Fi) was used to monitor the participants' heart rate intensity. The control group maintained their original lifestyle throughout the study period.

2.4 Measures

2.4.1 Basic information questionnaire

At baseline, the children completed a questionnaire that gathered information about their age, grade, gender, parent-children separation form, parent-children separation duration, guardianship type, and frequency of contact with the absent parent. This information helped us to develop and implement the intervention program. For example, the Cha Cha Cha dance was selected as the most appropriate dance for the age of the participants, and partner dances and group dances requiring duets were implemented in the third phase of the intervention according to the gender of the participants (He et al., 2022).

2.4.2 Social anxiety scale for children (SASC)

The Social Anxiety Scale for Children (SASC) was used to assess the social anxiety of LBC (La Greca, 1988). This scale is suitable for children and adolescents aged 7–16 years. It contains 10 items, including two factors: Fear of Negative Evaluation (FNE), and Social Avoidance and Distress (SAD). Each item uses a 3-point scoring system: 0 for never, 1 for sometimes, and 2 for often, with a total score of 20. According to the original scale, a score ≥ 8 indicates social anxiety, with higher scores representing more severe anxiety. The SASC has been translated into Chinese, and its psychometric properties have been validated in a large Chinese sample, demonstrating high reliability and validity (Mo and Bai,

2023; Wang et al., 2011). Therefore, this study used the Chinese version of the SASC to assess social anxiety in Chinese children. The Cronbach's α coefficient of the scale was 0.721, and the KMO value was 0.813.

2.4.3 Piers-harris child self-concept scale (PHCSS)

The Piers-Harris Child Self-concept Scale (PHCSS) was used to assess the self-concept of LBC (Pier, 1964). This 80-item self-report measure evaluates self-concept in children and adolescents aged 7–18 years. Each question has a standard "yes" or "no" answer. The scale is divided into six factors: Behavior Adjustment (BEH), Intellectual and School Status (INT), Physical Appearance and Attributes (PHY), Freedom and Anxiety (FRE), Popularity (POP), and Happiness and Satisfaction (HAP). According to the original scale, scores below the 30th percentile indicate a low level of self-concept. The Chinese version of the PHCSS is reported to be a reliable and valid measure among Chinese children (Huang et al., 2021). Therefore, this study used the Chinese version of the PHCSS to assess the self-concept of Chinese children. The Cronbach's α coefficient of the scale was 0.889 and the KMO value was 0.825.

2.5 Statistical analyzes

All statistical analyzes were conducted using SPSS Statistics software (release 29.0; IBM Corp., Armonk, NY, USA). The normal distribution of the outcome measures was confirmed using the Shapiro–Wilk normality test. Chi-square and independent *t*-test were used to determine baseline differences between the individuals randomly assigned to the Intervention group and the Control group. A repeated measures analysis of covariance (ANCOVA) was performed to examine the intervention effects of dance therapy on social anxiety and self-concept in LBC, with age included as a covariate in the analytical model. Pearson correlations were used to analyze the association between social anxiety and self-concept change scores (T1 minus T0). *P*-values less than 0.05 were considered statistically significant.

3 Results

3.1 Baseline characteristics

Out of the 402 LBC surveyed, 60 were identified as suffering from both social anxiety and low self-concept, accounting for 15 percent of all children. At baseline, no significant differences were observed in sociodemographic variables, social anxiety, and self-concept among these 60 LBC ($p > 0.05$). Participants' characteristics are presented in Table 1.

3.2 Effects of intervention

3.2.1 Changes of social anxiety in LBC

The results of the repeated measures ANOVA indicated a significant interaction effect for the SASC [$F_{(2,56)} = 17.131$, $\eta_p^2 = 0.380$, $p < 0.001$], FNE [$F_{(2,56)} = 7.851$, $\eta_p^2 = 0.219$, $p < 0.001$], and SAD [$F_{(2,56)} = 7.851$, $\eta_p^2 = 0.219$, $p < 0.001$]. Therefore, further simple effects analyzes were conducted.

The results showed a significant difference in SASC, FNE, and SAD (all $p < 0.001$) between the intervention and control groups at T1; At T2, there was a significant difference in SASC ($p = 0.023$), FNE ($p = 0.032$), but no significant difference in SAD ($p = 0.144$) between the intervention and control groups.

Within the intervention group, significant differences were observed from T0 to T1 for SASC, FNE, and SAD (all $p < 0.001$). However, no significant differences were found from T1 to T2 for SASC ($p = 0.925$), FNE ($p = 0.878$), and SAD ($p = 0.812$). Significant differences were again noted from T0 to T2 for SASC ($p < 0.001$), FNE ($p = 0.002$), and SAD ($p < 0.001$). Conversely, in the control group, there were no significant differences between any of the three time points for SASC, FNE, and SAD (all $p = 1.00$). Table 2 and Figure 2 presents a trend plot of the total social anxiety score and the factor scores.

3.2.2 Changes of self-concept in LBC

The results of repeated measures ANOVA indicated a significant interaction effect for POP [$F_{(2,56)} = 3.627$, $\eta_p^2 = 0.060$, $p = 0.032$] and HAP [$F_{(2,56)} = 4.750$, $\eta_p^2 = 0.077$, $p = 0.011$]. Therefore, further simple effects analyzes were conducted.

The results showed a significant difference in POP ($p = 0.021$) and HAP ($p = 0.014$) between the intervention and control groups at T2. Additionally, within the intervention group, HAP showed significant differences from T0 to T2 ($p = 0.006$). Table 3 and Figure 3 presents a trend plot of the total self-concept score and the factor scores.

3.3 Correlations between social anxiety and self-concept change scores

Table 4 presents the change scores for each group, indicating significant reductions in social anxiety scores (SASC, FNE, SAD) in the intervention and combined groups, but not in the control group. Moreover, self-concept showed significant improvement in the intervention and combined groups (PHCSS, BEH, INT, PHY, FRE, POP, HAP), while no significant effects were detected for the four factors (INT, PHY, POP, HAP) in the control group.

In order to verify the relationship between social anxiety and self-concept, the change scores of the post-test data (T0) minus the pre-test data (T1) were analyzed. The correlation results indicated a significant negative correlation between FNE and PHY ($p = 0.037$), POP ($p = 0.030$) in the intervention group as can be seen in Table 5 and Figure 4, however the control group did not show any significant correlations.

Additionally, for both control and intervention groups combined, there was a significant negative correlation between SASC and PHY ($p = 0.015$), and a significant negative correlation between FNE and PHY ($p = 0.015$), and FNE and POP ($p = 0.017$).

10.3389/fpsyg.2025.1491743

TABLE 1 Basic characteristics of participants at baseline.

Variables	Category	Intervention group ($n = 30$) [n (%)/M ± SD]	Control group ($n = 30$) [n (%)/M ± SD]	x^2/t	P
Gender	Male	15 (50.0%)	18 (60.0%)	0.606	0.436
	Female	15 (50.0%)	12 (40.0%)		
Grade	3	7 (23.3%)	3 (10.0%)	2.532	0.639
	4	2 (6.7%)	1 (3.3%)		
	5	4 (13.3%)	5 (16.7%)		
	6	5 (16.7%)	7 (23.3%)		
	7	12 (40.0%)	14 (46.7%)		
Parent-children separation form	Father	4 (13.3%)	8 (26.7%)	2.933	0.231
	Mother	7 (23.3%)	3 (10.0%)		
	Parents	19 (63.3%)	19 (63.3%)		
Parent-children separation duration (month)	6–12	14 (46.7%)	14 (46.7%)	1.714	0.634
	13–24	5 (16.7%)	2 (6.7%)		
	25–36	9 (30.0%)	12 (40.0%)		
	> 36	2 (6.7%)	2 (6.7%)		
Guardianship type	Father	3 (10.0%)	1 (3.3%)	2.239	0.524
	Mother	6 (20.0%)	5 (16.7%)		
	Grandfather/ Grandmother	11 (36.7%)	16 (53.3%)		
	Others	10 (33.3%)	8 (26.7%)		
Frequency of contact with the absent parent (time/month)	< 1	17 (56.7%)	14 (46.7%)	1.322	0.724
	1–3	7 (23.3%)	11 (36.7%)		
	4–14	4 (13.3%)	3 (10.0%)		
	≥ 15	2 (6.7%)	2 (6.7%)		
Age		10.73 ± 1.99	11.20 ± 1.24	−1.086	0.283
SASC		11.30 ± 3.25	10.30 ± 2.54	1.329	0.189
FNE		6.70 ± 2.38	6.13 ± 2.06	0.985	0.329
SAD		4.60 ± 1.45	4.17 ± 1.42	1.170	0.247
PHCSS		37.70 ± 7.26	38.00 ± 7.00	−0.163	0.871
BEH		10.03 ± 2.51	9.30 ± 2.98	1.030	0.307
INT		6.23 ± 3.12	6.40 ± 2.66	−0.223	0.824
PHY		3.33 ± 2.29	4.33 ± 2.22	−1.716	0.091
FRE		5.73 ± 2.79	6.10 ± 2.52	−0.534	0.596
POP		6.60 ± 2.55	7.10 ± 1.92	−0.857	0.395
HAP		5.03 ± 1.90	5.47 ± 1.74	−0.921	0.361

M, Mean; SD, Standard Deviation; SASC, Social Anxiety Scale for Children; FNE, Fear of Negative Evaluation; SAD, Social Avoidance and Distress; PHCSS, Piers-Harris Child Self-concept Scale; BEH, Behavior Adjustment; INT, Intellectual and School Status; PHY, Physical Appearance and Attributes; FRE, Freedom and Anxiety; POP, Popularity; HAP, Happiness and Satisfaction.

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TABLE 2 Effects of dance intervention on social anxiety.

Variables	Groups	T0 (M ± SD)	T1 (M ± SD)	T2 (M ± SD)	Time	Group	Time*Group
SASC	Intervention group	11.30 ± 3.25	7.33 ± 2.41	7.40 ± 2.13	$F = 0.452$ $P = 0.638$ $\eta_p^2 = 0.076$	$F = 5.583$ $P = 0.022$ $\eta_p^2 = 0.089$	$F = 17.131$ $P < 0.001$ $\eta_p^2 = 0.380$
	Control group	10.30 ± 2.54	10.53 ± 2.10	9.90 ± 2.27			
FNE	Intervention group	6.70 ± 2.38	4.70 ± 1.71	4.37 ± 1.99	$F = 0.183$ $P = 0.833$ $\eta_p^2 = 0.067$	$F = 3.535$ $P = 0.065$ $\eta_p^2 = 0.068$	$F = 7.851$ $P < 0.001$ $\eta_p^2 = 0.219$
	Control group	6.13 ± 2.06	6.37 ± 1.90	6.07 ± 1.21			
SAD	Intervention group	4.60 ± 1.45	2.63 ± 1.63	3.30 ± 1.81	$F = 0.183$ $P = 0.833$ $\eta_p^2 = 0.087$	$F = 3.535$ $P = 0.065$ $\eta_p^2 = 0.068$	$F = 7.851$ $P < 0.001$ $\eta_p^2 = 0.219$
	Control group	4.17 ± 1.42	4.17 ± 1.78	3.83 ± 1.38			

M, mean; SD, standard deviation; SASC, social anxiety scale for children; FNE, fear of negative evaluation; SAD, social avoidance and distress.

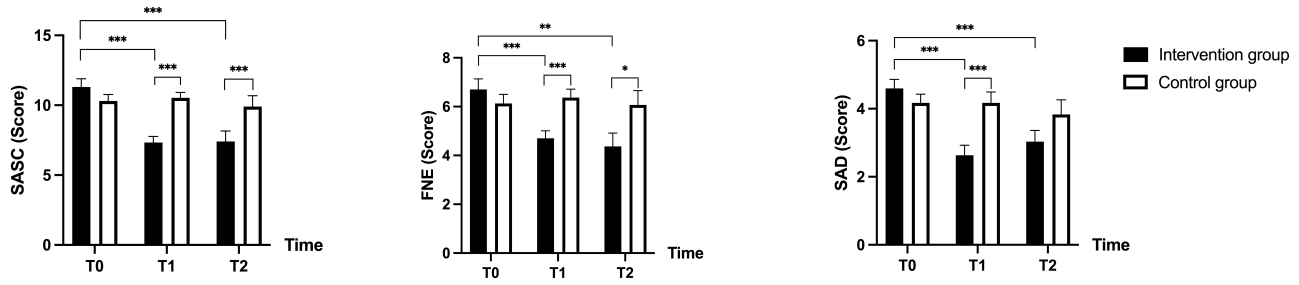

FIGURE 2
Trends in social anxiety in both groups before and after the intervention. SASC, Social Anxiety Scale for Children; FNE, Fear of Negative Evaluation; SAD, Social Avoidance and Distress. T0, at baseline; T1, post-intervention (12 weeks); T2, follow-up (14 weeks after baseline). *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.

Table 5 and Figure 5 describe in detail the changes for the combined group.

4 Discussion

The study results indicate that the dance intervention effectively alleviated social anxiety and enhanced self-concept among LBC. Furthermore, a significant correlation was observed between improvements in social anxiety and self-concept from baseline to post- intervention, supporting our initial hypothesis.

After 12 weeks of dance intervention, total SASC scores (including FNE and SAD subscales) decreased significantly and remained stable at the 14-week follow-up. These findings align with prior research. For instance, Liu et al. (2023) demonstrated that Latin dance fosters social connections and reduces anxiety, while Bennett et al. (2021) concluded dance interventions effectively mitigate anxiety symptoms across populations. The efficacy of dance in alleviating social anxiety symptoms in LBC can be attributed to several factors. Dance is a social activity rooted in human culture, which helps individuals improve their social skills and reduce social isolation by engaging in group activities with shared interests and goals (Liu et al., 2021). In our intervention, the inclusion of paired dancing in Phase 3 increased interaction opportunities among LBC, promoting socialization and peer interaction, which likely alleviated social anxiety. Additionally, dance as an aerobic exercise promotes the release of endorphins and dopamine, contributing to reduced social anxiety (Feenstra et al., 2022). Dance also combines physical activity with music, providing a sense of pleasure and relaxation (Särkämö et al., 2013). Neuroimaging studies have shown that music activates various brain areas, including the amygdala and mesolimbic reward system, which can profoundly affect emotions like anxiety and depression (de Witte et al., 2022).

The 12-week intervention significantly increased PHCSS total scores, particularly in POP and HAP. Although there are limited studies on dance interventions for self-concept, some research has shown positive outcomes. For instance, Ren et al. (2021) found that dance improved self-concept and emotional expression in individuals with chronic diseases. A meta-analysis by Koch et al. (2019) also reported positive effects of dance on various self-concept indicators. The mechanisms by which dance improves self-concept include promoting neuroplasticity in brain regions responsible for motor control, emotional regulation, and cognitive

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TABLE 3 Effects of dance intervention on self-concept.

Variables	Groups	T0 (M ± SD)	T1 (M ± SD)	T2 (M ± SD)	Time	Group	Time*Group
PHCSS	Intervention group	37.70 ± 7.26	40.87 ± 11.09	39.50 ± 10.87	$F = 0.710$ $P = 0.496$ $\eta_p^2 = 0.025$	$F = 0.131$ $P = 0.718$ $\eta_p^2 = 0.071$	$F = 0.884$ $P = 0.419$ $\eta_p^2 = 0.061$
	Control group	38.00 ± 7.00	38.27 ± 7.48	37.57 ± 14.76			
BEH	Intervention group	10.03 ± 2.51	10.27 ± 3.74	11.17 ± 3.42	$F = 0.451$ $P = 0.623$ $\eta_p^2 = 0.058$	$F = 3.303$ $P = 0.074$ $\eta_p^2 = 0.055$	$F = 1.567$ $P = 0.213$ $\eta_p^2 = 0.077$
	Control group	9.30 ± 2.98	9.50 ± 2.54	8.93 ± 4.14			
INT	Intervention group	6.23 ± 3.12	7.40 ± 3.69	7.60 ± 3.03	$F = 0.283$ $P = 0.749$ $\eta_p^2 = 0.035$	$F = 0.485$ $P = 0.489$ $\eta_p^2 = 0.068$	$F = 1.443$ $P = 0.241$ $\eta_p^2 = 0.025$
	Control group	6.40 ± 2.66	6.33 ± 3.20	6.60 ± 3.76			
PHY	Intervention group	3.33 ± 2.29	5.10 ± 3.56	4.57 ± 3.06	$F = 1.043$ $P = 0.354$ $\eta_p^2 = 0.018$	$F = 0.679$ $P = 0.413$ $\eta_p^2 = 0.012$	$F = 2.936$ $P = 0.059$ $\eta_p^2 = 0.049$
	Control group	4.33 ± 2.22	4.30 ± 2.25	5.10 ± 3.17			
FRE	Intervention group	5.73 ± 2.79	5.83 ± 3.45	5.73 ± 3.29	$F = 1.361$ $P = 0.265$ $\eta_p^2 = 0.046$	$F = 0.329$ $P = 0.569$ $\eta_p^2 = 0.046$	$F = 0.444$ $P = 0.644$ $\eta_p^2 = 0.016$
	Control group	6.10 ± 2.52	6.67 ± 2.82	5.40 ± 3.19			
POP	Intervention group	6.60 ± 2.55	6.97 ± 2.68	7.47 ± 2.11	$F = 0.294$ $P = 0.733$ $\eta_p^2 = 0.045$	$F = 0.497$ $P = 0.484$ $\eta_p^2 = 0.029$	$F = 3.627$ $P = 0.032$ $\eta_p^2 = 0.660$
	Control group	7.10 ± 1.92	6.87 ± 1.80	5.93 ± 3.11			
HAP	Intervention group	5.03 ± 1.90	5.77 ± 2.61	6.47 ± 2.39	$F = 0.251$ $P = 0.776$ $\eta_p^2 = 0.034$	$F = 1.032$ $P = 0.314$ $\eta_p^2 = 0.018$	$F = 4.750$ $P = 0.011$ $\eta_p^2 = 0.077$
	Control group	5.47 ± 1.74	5.23 ± 1.83	4.97 ± 2.40			

M, mean; SD, standard deviation; PHCSS, piers-harris child self-concept scale; BEH, behavior adjustment; INT, intellectual and school status; PHY, physical appearance and attributes; FRE, freedom and anxiety; POP, popularity; HAP, happiness and satisfaction.

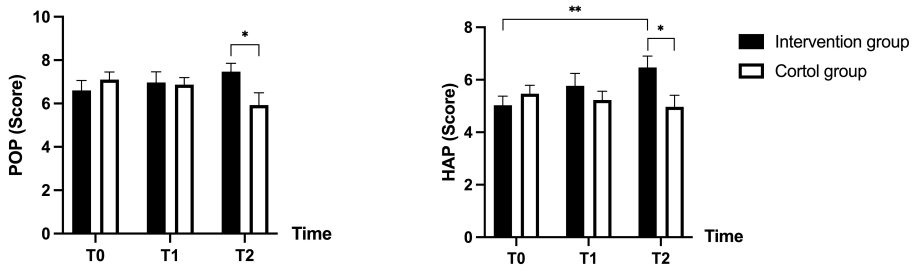

FIGURE 3
Trends in self-concept scores in both groups before and after the intervention. POP, Popularity; HAP, Happiness and Satisfaction. T0, at baseline; T1, post-intervention (12 weeks); T2, follow-up (14 weeks after baseline). *, $p < 0.05$; **, $p < 0.01$.

functions through repeated practice and challenges (Shim et al., 2019; Van der Aar et al., 2022).Additionally, the deep breathing and rhythmic movements in dance activate the vagus nerve, promoting parasympathetic activity and physiological relaxation, aiding in self-reflection and introspection (Christensen et al., 2021). Dance also integrates multiple sensory inputs, enhancing the brain's ability to process information and improving self-concept (Kronsted, 2020). However, it is particularly worth highlighting that in the self-concept intervention, the POP and HOP factors showed delayed improvement only 2 weeks after the intervention. Given that improvement occurred after 2 weeks rather than immediately after the intervention, the time lag seems to imply that there may be

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TABLE 4 Change in social anxiety and self-concept scores before and after the intervention.

Variables	Intervention group ($n = 30$) [M ± SD]	Control group ($n = 30$) [M ± SD]	Both groups ($n = 60$) [M ± SD]
SASC	−3.97 ± 3.49	0.23 ± 1.74	−1.87 ± 3.44
FNE	−2.00 ± 2.64	0.23 ± 1.65	−0.88 ± 2.46
SAD	−1.97 ± 1.79	0.45 ± 1.26	−0.98 ± 1.83
PHCSS	3.17 ± 9.84	0.27 ± 5.61	1.72 ± 8.05
BEH	0.23 ± 3.27	0.20 ± 2.57	0.22 ± 2.91
INT	1.17 ± 3.24	−0.07 ± 3.34	0.55 ± 3.32
PHY	1.77 ± 2.94	−0.03 ± 2.46	0.87 ± 2.84
FRE	0.10 ± 3.13	0.57 ± 2.32	0.33 ± 2.74
POP	0.37 ± 3.33	−0.23 ± 1.92	0.07 ± 2.71
HAP	0.73 ± 2.60	−0.23 ± 1.78	0.25 ± 2.60

Note: SASC, Social Anxiety Scale for Children; FNE, Fear of Negative Evaluation; SAD, Social Avoidance and Distress; PHCSS, Piers-Harris Child Self-concept Scale; BEH, Behavior Adjustment; INT, Intellectual and School Status; PHY, Physical Appearance and Attributes; FRE, Freedom and Anxiety; POP, Popularity; HAP, Happiness and Satisfaction.

TABLE 5 Correlations between social anxiety and self-concept.

Groups	Variables	PHCSS	BEH	INT	PHY	FRE	POP	HAP
Intervention group ($n = 30$)	SASC	−0.068	0.255	−0.185	−0.304	−0.808	−0.223	−0.252
	FNE	−0.207	0.120	−0.222	−0.382*	−0.138	−0.397*	−0.211
	SAD	0.174	0.258	−0.031	−0.025	0.049	0.154	−0.176
Control group ($n = 30$)	SASC	0.263	0.222	−0.140	0.188	0.275	−0.035	0.209
	FNE	0.238	0.143	−0.047	0.146	0.099	0.007	0.160
	SAD	0.049	0.117	−0.131	0.067	0.248	−0.057	0.077
Both groups ($n = 60$)	SASC	−0.107	0.170	−0.239	−0.312*	0.065	−0.210	−0.235
	FNE	−0.161	0.110	−0.216	−0.314*	−0.016	−0.306*	−0.185
	SAD	0.015	0.171	−0.161	−0.166	0.144	0.017	−0.194

SASC, social anxiety scale for children; FNE, fear of negative evaluation; SAD, social avoidance and distress; PHCSS, Piers-Harris child self-concept scale; BEH, behavior adjustment; INT, intellectual and school status; PHY, physical appearance and attributes; FRE, freedom and anxiety; POP, popularity; HAP, happiness and satisfaction. *$p < 0.05$.

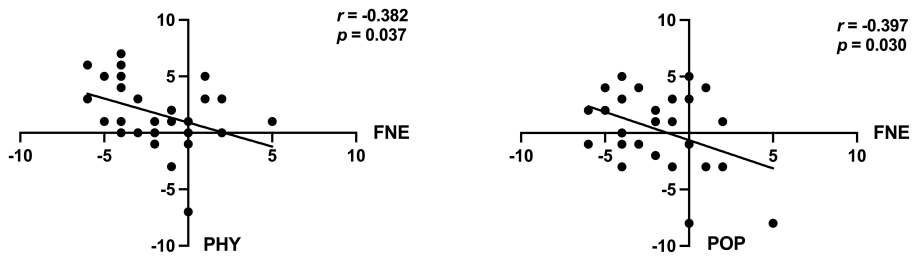

FIGURE 4
Trends in correlations between social anxiety and self-concept in the intervention group. FNE, Fear of Negative Evaluation; PHY, Physical Appearance and Attributes; POP, Popularity.

mediators of this delayed effect (Ho et al., 2020). Social anxiety or other negative emotional and psychological factors may have temporally mediated the effects of the intervention on self-concept.

Our findings highlight a correlation between the amount of change in social anxiety and self-concept from T0 to T1. Previous studies have corroborated this relationship.

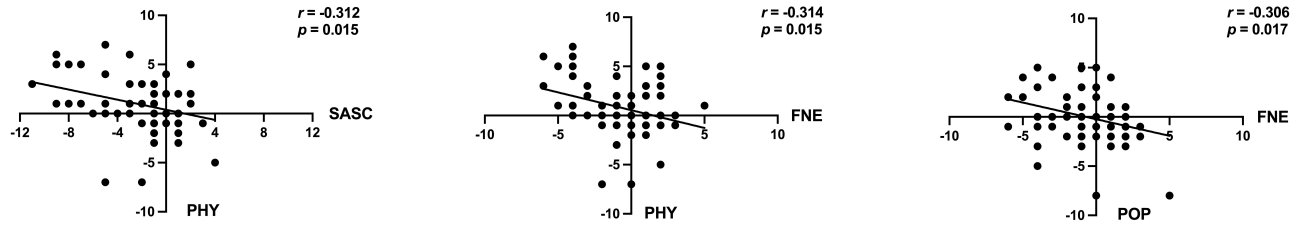

FIGURE 5
Trends in correlations between social anxiety and self-concept in both groups. Note: SASC, Social Anxiety Scale for Children; FNE, Fear of Negative Evaluation; PHY, Physical Appearance and Attributes; POP, Popularity.

Lindfors et al. (2014) found that self-concept influenced anxiety symptoms and work ability outcomes over 3 years of psychotherapy for anxiety disorders. Kley et al. (2012) identified self-concept as a predictor of outcome in social anxiety treatment for children and adolescents. The relationship between social anxiety and self-concept can be traced back to the cognitive model, which posits that socially anxious individuals are driven by the desire to make a good impression but doubt their ability to do so, leading to heightened self-focus and negative self-concept (Gilboa-Schechtman et al., 2017; Goldin et al., 2021). In addition, Spurr and Stopa (2002) view this relationship from an evolutionary perspective, emphasizing the importance of self-concept content based on social hierarchy and affiliation systems. Overall, various models emphasize the interdependence of social anxiety and self-concept (Hofmann, 2007).

There are some limitations to our study. First, the relatively short follow-up period and the small sample size, limited to LBC from the Hunan region, may restrict the generalizability of our findings to other regions in China. Second, our assessments relied on self-reported scales, which, despite their reliability, may be subject to bias and may not be as accurate as objective measures such as cortisol levels, heart rate variability, and other physiological indicators (Van der Aar et al., 2022). Third, in the absence of an otherwise active control group, the improvements in social anxiety and self-concept that we observed in the intervention group may have been related to an increase in weekly social interactions rather than a direct effect of the dance intervention itself. Therefore, further clarification of the specific effects of the dance intervention on these psychological variables is needed in subsequent studies, particularly to distinguish the relative roles of dance activities and social interactions in improving social anxiety and self-concept in the LBC.

5 Conclusions

This study provides empirical support for the use of dance interventions in the mental health of LBC, demonstrating that they are effective in improving social anxiety and self-concept. The study is also highly generalizable and can be widely applied in schools and other settings, which is highly relevant. Future research could further explore the effectiveness of combining different types of dance and other mental health interventions to enhance the psychological wellbeing of the LBC population.

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 the study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of Hunan Normal University. 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 minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

XL: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. QY: Conceptualization, Methodology, Formal analysis, Software, Funding acquisition, Writing – review & editing. ZZ: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. MZ: Conceptualization, Methodology, Software, Writing – review & editing. CL: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. WD: Conceptualization, Software, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

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.2025.1491743/full#supplementary-material

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frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 22 May 2025
DOI 10.3389/fpsyg.2025.1545461

OPEN ACCESS

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RECEIVED 16 December 2024
ACCEPTED 07 May 2025
PUBLISHED 22 May 2025

CITATION
Qiu S, Ruan C and Wang Y (2025) Anxiety relief in the post-pandemic era: a randomized trial on the integration of digital technology into dance art healing.
Front. Psychol. 16:1545461.
doi: 10.3389/fpsyg.2025.1545461

Anxiety relief in the post-pandemic era: a randomized trial on the integration of digital technology into dance art healing

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Trial design: This randomized controlled trial examined the effectiveness of digital technology-integrated dance therapy in alleviating anxiety symptoms associated with post-pandemic isolation.

Methods: Participants, including both professional and amateur dancers, were randomly assigned to either a traditional dance therapy group or a digital dance therapy group utilizing smart fitness mirrors. Anxiety levels were assessed using the Positive and Negative Affect Schedule (PANAS) before and after the intervention and a semi-structured interview was conducted. The trial spanned 3 months, with participants engaging in structured dance therapy sessions twice a week.

Results: The findings revealed that digital dance therapy led to a significant improvement in overall anxiety reduction, as indicated by enhanced PANAS scores post-intervention. Participants in the digital dance group exhibited a notable increase in positive emotions, whereas reductions in negative emotions were less pronounced and, in some cases, even showed a slight increase. Approximately half of the participants experienced a significant decrease in anxiety symptoms, with the digital intervention demonstrating greater effectiveness compared to traditional dance therapy. Additionally, qualitative feedback indicated widespread acceptance of digital dance tools, with participants recognizing their potential in alleviating social and body image anxiety.

Conclusion: While digital dance therapy shows promise in enhancing positive emotions and reducing anxiety, its effectiveness in addressing negative emotions remains inconclusive. The study highlights the need for extended intervention periods, larger sample sizes, and further refinement of digital tools to optimize therapeutic outcomes. Future research should explore long-term efficacy and improve human-computer interaction in digital dance therapy.

KEYWORDS

post-pandemic era, anxiety, dance, art healing, digital technology, somatosensory interaction

1 Introduction

In the post-pandemic era, global society has undergone an unprecedented transformation. The public health crisis triggered by the COVID-19 pandemic has not only reshaped people's lifestyles and work patterns but has also profoundly affected their psychological well-being. Research has shown that multiple factors—such as social isolation, economic stress, health

concerns, and uncertainty about the future—brought about by COVID-19 have led to a complex and serious psychosocial situation (Smith et al., 2020). The World Health Organization has recognized that such self-isolation/social distancing measures may result in individuals becoming more anxious, angry, stressed, agitated, and withdrawn (World Health Organization, 2020). Among these, anxiety is particularly prominent. Anxiety is one of the most prevalent mental health disorders (Bandelow and Michaelis, 2015) and is defined as a persistent feeling of worry, fear, or nervousness (Mental Health, 2020), making it a significant mental health challenge in the post-pandemic era. The pervasive feelings of isolation, helplessness, and disruption to daily life have exacerbated anxiety, posing a serious threat to individuals' mental health (Wang et al., 2021). The UN E-Government Survey (Vereinte Nationen, 2020) assessed the digital transformation of governments during the pandemic and found that digitalization demonstrated strong adaptability and resilience. Digital tools, such as social media and videoconferencing, enabled people to stay socially connected during quarantine, facilitating social interactions and alleviating psychological stress. The World Health Organization (Ting et al., 2020) has also issued guidance stating that digital healthcare services, such as online consultations and telemedicine, have improved access to healthcare services during the pandemic.

In this context, it is particularly important to explore ways to effectively alleviate anxiety. Art therapy is a healing process when art forms act as a medium in the field of psychotherapy (Huili et al., 2023). Research on art healing in the last decade has shown that art and cultural engagement have a positive impact on people's health (Howarth, 2018). Abbing et al. (2018) used a Cochrane analysis to explore the effectiveness of art therapy for adult anxiety disorders, but it did not conclude the effectiveness of AT for adult anxiety disorders, and the experimental approach of the study needs to be updated to be consistent with the study of anxiety in people's lifestyles in the post-pandemic era. Ni and Hu (2012) concluded in her 2012 review that most Chinese researchers are committed to reducing mental pain and alleviating depression and anxiety in post-disaster patients. The study suggests that there is still a lot of room for the development of art therapy in China in the fields of education and healthcare, and the development of information technology will also have an impact on the art therapy model. In light of these developments, the necessity of exploring online art-based therapy became increasingly apparent. Online therapy not only offered a viable alternative for those unable to access in-person sessions but also leveraged digital technology to provide new avenues for psychological intervention.

Digital technology, with its convenience, accessibility, and ability to offer personalized experiences, has become a key tool in the realm of mental health services. It transcends geographical barriers, enabling interventions for mental health conditions such as anxiety. Argo et al. (2014) demonstrated the potential of such technology through their multi-sensory exposure therapy, which combined sound, music, and visual stimuli to create an immersive experience for patients with anxiety (Argo et al., 2014). This digital therapy allowed patients to engage in psychological treatment from the comfort of their homes, alleviating anxiety-driven avoidance behaviors. Thus, online art-based therapies are not merely a temporary solution during the pandemic but represent a promising direction for the future of mental health services. Huili et al. (2023) and others integrated somatosensory interaction technology into picture books in their study in 2023, designed a somatosensory interactive game for a group of children with autism, and verified that somatosensory game therapy and traditional picture book therapy have their own advantages. However, research on somatosensory interactive digital devices for anxiety and other psychological conditions in China remains scarce, with even less focus on integrating such technology into dance therapy. The rapid development of digital technology has also brought more new forms of dance, Kinect's real-time capture of dancers' movements, Musk's robotic coaches, and GPT-4's personalized plan generation and customization have all made the intervention of digital AI coaches at the level of personal health and life an inevitable trend.

As a form of art therapy, dance art healing not only focuses on the movement and expression of the body but also emphasizes the feelings and connections of the mind. It helps individuals enhance their self-awareness, thereby achieving the goals of reducing stress, relieving anxiety, and promoting mental health (Christensen et al., 2021). Koch et al. (2019) demonstrated in a 2019 meta-analysis that DMT and dance interventions can improve clinical outcomes, cognitive outcomes, and (psycho)motor outcomes. Her study included both group and individual therapy sessions, based on the development of dancers or movement coaches from diverse backgrounds. Karkou et al. (2019) used qualitative meta-analysis and quantitative meta-analysis for people aged 16 to 65 years to put together a systematic review of studies on the effectiveness of DMT for people with depression. A systematic review of the studies was conducted and the results showed that DMT alone can have a positive impact on patients with a primary diagnosis of depression, but with 81% of its participants being female, this study has some gender limitations. Neither of these studies categorized the volunteer dancers by professional status (i.e., professional dancers versus amateur dancers). The present study, however, took into account the professional nature of dance, where varying degrees of dance technique may affect the release of anxiety. As demonstrated by subsequent experiments, professionalism was not an influencing factor ($p > 0.05$).

In the spring of 2020, the outbreak of COVID-19 led to the closure of dance studios and other in-person therapeutic spaces worldwide. As a result, many traditional forms of psychological interventions, such as dance therapy, were forced to pause, and mental health issues— particularly body image anxiety and social anxiety caused by the isolation of the pandemic— surged. Adilogullari (2014) used a quantitative scale to study the effects of a 12-week Latin dance workout on social body image anxiety and concluded that dance was effective in reducing social anxiety, but his study did not mention the factor of body changes. Karkou et al. (2019) summarized that, in all studies, scales measuring depression severity have been found to be sensitive to capturing mood, body image, health anxiety, and many other factors related to the diagnostic criteria for depression. However, Karkou did not suggest strategies to alleviate such anxiety. There is limited research on dance movement therapies for relieving body image anxiety and social anxiety. This study, therefore, explores effective dance movement therapies for relieving body image anxiety and social anxiety, taking into account the legacy of anxiety from the pandemic.

Therefore, this study aims to explore how digital technology, especially somatic interactive smart devices, can alleviate anxiety through dance art healing in the post-pandemic era. Specifically, we will focus on how digital platforms can support the development of remote dance art healing activities and adopt a mixed research approach, i.e., a combination of psychological scales, questionnaires,

and semi-structured interviews, to analyze the mechanism by which it enhances participation, therapeutic effects, and expands the scope of benefits. At the same time, we will also explore how digital technology can be combined with the characteristics of dance art healing to design personalized, interactive, and enjoyable intervention programs to better meet the mental health needs of different populations.

The significance of this study lies in the fact that, on the one hand, it enriches the means of intervention in the field of mental health and provides new ideas and methods for alleviating anxiety and other psychological problems. On the other hand, it promotes the application and development of digital art in the field of mental health and demonstrates the great potential of the fusion of science and technology and humanities in promoting human mental health. Through this study, we expect to provide a scientific basis and practical guidance for effectively intervening in anxiety problems in the post-pandemic era and, at the same time, lay the foundation for further exploration and application of digital art in the field of mental health.

2 Dance movement therapy

Dance Movement Therapy (DMT) is a therapeutic form that takes place in well-controlled clinical settings for the purposes of therapy and personal growth (Christensen et al., 2021).

The historical development of Dance Movement Therapy (DMT), as a therapy that combines dance with psychotherapy, can be divided into three professionally focused phases: emotional body/movement, body/mind, and social/relationships (Miller, 2016). The birth of DMT is closely linked to the development of modern dance, and many of the pioneers of modern dance made important contributions to the early development of DMT. Marian Chace, a key figure in the establishment and development of DMT—recognized as one of the founders of modern dance therapy—was invited to join the staff of St. Elizabeth's Hospital in Washington, DC in 1942. Her work laid the foundational practice for integrating dance and the therapeutic process, greatly influencing the field of DMT (Bunney, 2013). Another important early dance therapy pioneer, Mary Whitehouse, emphasized the role of dance in personal growth and self-expression, and, along with Chase, contributed to the early development of DMT (Bunney, 2013).

Rudolf Laban began to link the body to the mind, emphasizing the interplay between physical movement and mental processes. His system of Movement Analysis (Laban Movement Analysis) provided a scientific tool for observation and analysis, making dance therapy more systematic and specialized (Karkou et al., 2019). In 1916, Carl Gustav Jung documented the idea of dance as a psychotherapeutic treatment (Chodorow, 2013). Jung's analytical psychology emphasized the importance of the unconscious and symbols in psychotherapy, and his theories provided deep theoretical underpinnings for DMT, helping visitors explore the unconscious within. Wilhelm Reich's theory of bioenergetics emphasizes the interaction between the body and the psyche, and he believes that physical tension is closely related to psychological conflict. His theory provides DMT with a theoretical basis for exploring psychological issues on a physical level (Feldman, 2015).

The use of DMT as an intervention to enhance emotional regulation and control has attracted increasing attention in applied research in psychology and therapy. DMT can help individuals improve body image, reduce stress, and enhance emotional, cognitive, social, and physical integration (Berrol, 1990). This aligns with efforts to address body image anxiety and social anxiety triggered by the isolation during the COVID-19 pandemic (Zhang et al., 2020; Swami et al., 2021). Röhricht and Priebe (2006) applied dance therapy to the treatment of patients with schizophrenia and achieved significant results, providing important evidence for the use of DMT in the treatment of mental illness. Judith Kupfer applied dance therapy to the treatment of post-traumatic stress disorder and developed a corresponding treatment model. This not only expanded the application of DMT but also demonstrated its effectiveness in treating trauma. Mary Ann Cleveland, on the other hand, made an important contribution to the development of dance therapy for children and adolescents by using it to help them deal with emotional problems and build relationships. This shows that DMT can be applied in a variety of settings such as mental health, medical, educational and community (Koch et al., 2014).

Dance has primarily been viewed as a form of recreation or entertainment, with little role in healing. However, there have been significant developments in the health applications of dance over the past 40 years, and growing evidence and recognition of its therapeutic benefits of dance in disease prevention and rehabilitation (Kshtriya et al., 2015). Recent studies have highlighted the therapeutic potential of dance, particularly in the context of Parkinson's disease (PD). Morris and Slade investigated the feasibility and impact of online dance therapy on consumer engagement among individuals with PD (Morris et al., 2021). Their research demonstrated that engaging in online dance sessions not only enhanced participant engagement but also contributed positively to their emotional well-being. Similarly, Bek et al. (2025) explored the challenges and opportunities associated with digital dance programs for PD patients. Their findings underscore the efficacy of dance as a multimodal intervention that integrates mental, musculoskeletal, and neurological processes. This integration can lead to improvements in various domains, including procedural learning, attention, memory, coordination, rhythm, balance, and gait. Notably, dance therapy has shown promise in addressing cognitive, emotional, and neurological disorders prevalent among PD patients. These studies collectively reinforce the growing recognition of dance as a valuable therapeutic tool in disease prevention and rehabilitation, particularly for individuals with neurological impairments such as Parkinson's disease.

Kshtriya's extremely team conducted a comprehensive literature search for different dance interventions using six different databases, primarily using literature analysis and review, to critically review the existing literature on the neurological effects of dance interventions (Kshtriya et al., 2015). While the study provides a rich overview and theoretical analysis, further research is needed regarding the direct effects of dance on neurobiological factors.

A systematic review conducted by Koch et al. (2019) evaluated the effects of dance and dance movement therapy (DMT) on health-related psychological outcomes. The review identified 41 studies (dance interventions: $N = 20$; DMT: $N = 21$) published between January 2012 and March 2018, encompassing a total of 2,374 participants. The authors noted that the difference in population made comparisons difficult because most dance intervention studies came from preventive contexts, and most DMT studies came from institutional healthcare contexts with more severely impaired clinical

patients. This study suggested that DMT and dance interventions impacted different domains: DMT decreased depression and anxiety and increased quality of life, interpersonal and cognitive skills, whereas dance interventions increased (psycho-)motor skills.

A meta-analysis evaluated the effectiveness of dance movement therapy (DMT) and dance interventions for psychological health outcomes. Results suggest that DMT decreases depression and anxiety and increases quality of life and interpersonal and cognitive skills, whereas dance interventions increase (psycho-)motor skills. Most dance intervention studies came from preventive contexts, and most DMT studies came from institutional healthcare contexts with more severely impaired clinical patients, where there were smaller effects (Cox and Youmans-Jones, 2023). This distinction highlights the need for tailored therapeutic approaches, especially as we explore how digital tools can enhance both preventive and clinical applications of art-based therapies.

The authors of this article also believe that dance can help individuals recover from clinical levels of dysfunction. However, different clinical populations would likely benefit from different dance practices. Thus, using hobby dances (e.g., Argentine tango, ballet, ballroom, hip hop, etc.) as a therapy for clinical conditions (cancer, trauma, Parkinson, dementia, ADHD, etc.) still requires substantial empirical support from research in healthy populations to formulate clear hypotheses about why the choice of one specific dance style (and not another) might be beneficial for a specific health problem. Such targeted assessments are currently not common practice, and researchers often treat "dance" as a single, unified entity, which it is not. This heterogeneity makes the results appear inconclusive and piecemeal, deterring policymakers from making targeted investments into the health effects of dance practice as a recreational activity with important psychophysiological and health benefits.

3 Problems of anxiety caused by COVID-19

A study conducted a large-scale survey of psychological distress in the Chinese general population during the COVID-19 period. The results demonstrated the incidence and severity of psychological distress brought about by COVID-19. Society is currently burdened with a high level of mental health issues, which is specifically characterized by body image anxiety and social fear. These findings provides a concrete basis for the development and implementation of relevant mental health intervention policies to address this challenge efficiently and effectively (Qiu et al., 2020).

3.1 Body anxiety

The stress and anxiety caused by the coronavirus (COVID-19) pandemic pose a serious threat to the mental health of the global population, and, by extension, to body image outcomes. Some pre-pandemic research—mostly involving samples of undergraduate women—has shown that perceived stress (i.e., a person's appraisal of stress caused by environmental conditions) and stressful life events were associated with greater body dissatisfaction [e.g., (Haddad et al., 2019; Johnson and Wardle, 2005; Murray et al., 2011)]. Stratified regression results indicated that COVID-19-related stress and anxiety are associated with more negative body image, over-and-above-perceived stress, stressful life events, and trait anxiety (Swami et al., 2021). It is possible that COVID19-related stress and anxiety diminish coping resources to manage threats to body image, increase exposure to thin/athletic ideals via media messaging (e.g., given increased screen time under lockdown; see Pietrobelli et al., 2020), and heighten concerns about weight and/or shape changes that occur during conditions of lockdown (e.g., because of decreased physical activity) (Cooper et al., 2022; Rodgers et al., 2020). COVID-19-related stress may also be associated with a greater frequency of negative body ruminations that lead to a preoccupation with body shape and/or weight, as well as a desire to reassert a degree of control through bodywork (Ruggiero et al., 2008). Women have adopted unhealthy weight control behaviors to manage their weight, thereby moderating the body image anxiety associated with the COVID-19 pandemic; whereas men seek to reaffirm a sense of control and increase their masculine capital through a desire for stronger muscles and contemplation of perceived body image (Swami et al., 2021). Efforts to address negative body image under lockdown conditions will require new palliative interventions (e.g., telemedicine, and guided self-help interventions) (Cooper et al., 2022).

3.2 Social anxiety disorder

The confinement situation during the COVID-19 pandemic is not really an "enclosed space" but more related to the reduced daily activities. The majority of people were ordered to stay at home for long periods and work remotely. This resulted in reduced physical activity, which negatively impacts mental health in the community, as physical activity directly reduces general negative emotions (Zhang et al., 2020). This isolation led to increased stress, which caused anxiety that may have developed into coronophobia, related to the avoidance of public places and events—social anxiety disorder (SAD) (Amin, 2020; Lee et al., 2020).

Among anxiety disorders, social anxiety disorder, characterized by a severe fear of social interactions and attention, which the core experience being an extreme dread of judgment and negative evaluation by others, has been exacerbated by the pandemic's constraints. It is often accompanied by a heightened awareness of perceived flaws or failings (American Psychiatric Association, 2013). Individuals with higher social phobia tend to pay more attention to themselves than to others in social situations, this self-focus exacerbates anxiety (Clark and Wells, 1995).

Some studies have shown that SAD has been exacerbated by the pandemic's constraints (Xia, 2024). COVID-19-induced online environments can amplify other-focused perspectives. Since people are often required to pay closer attention to others' thoughts and feelings without direct physical interactions, many people might have become more concerned about others' potentially negative responses because of the avoidance of social situations (Tei and Wu, 2021). People are concerned about their value in the eyes of others, as well as the misery they may cause others due to quarantine or societal rejection (i.e., fear of infecting or troubling others, in addition to dread of being infected). Furthermore, many people are still concerned that their COVID-19 status will be leaked to others. Meanwhile, according to the Compensatory Internet Use Theory of Internet Use Disorder (IUD) (Dieris-Hirche et al., 2023), Internet use

serves as a means to alleviate negative emotions. However, excessive Internet users may also be more susceptible to the rapid dissemination of misinformation and unfounded fears through online media.

People expect art healing to provide emotional relief, self-expression, and therapeutic benefits, especially during times of stress or crisis. Engaging with art—whether through creating or observing—offers individuals a means of processing complex emotions, reducing anxiety, and fostering a sense of well-being (Daniel, 2021). During times of collective trauma, such as COVID-19, people have shown a high level of motivation to heal or alleviate anxious psychological issues through this art-based healing, through online dance (Rugh et al., 2024).

4 Healing mechanisms based on body perception in digital art

4.1 Digital technology in art healing

Body-awareness-enhancing and body-centered therapies are gaining popularity. These methods include yoga, tai chi, mindfulness therapy, meditation, body-oriented psychotherapy, etc. Mehling argued that "body awareness is a complex, multidimensional concept that requires a more nuanced conceptualization" (Mehling et al., 2009).

With the rise of digitalization, there is more room for art healing. These technologies include, but are not limited to, the following currently popular forms: apps, various types of image creation and film editing software, animation, gaming, virtual reality (VR), and participatory environments, tablet technology, light painting, artificial intelligence, digital storytelling, and other technological media. There are two main applications of digital technology in somatic art healing: art therapy using somatic tools and art creation using digital media during therapy (Zubala et al., 2021).

The use of online somatic tools for art therapy is particularly well-suited to teletherapy, a field of cognitive-behavioral therapy conducted online that allows human cognitive behaviors as well as bodily senses to be embodied in symbolic, metaphorical, and projective artistic methods through any medium. For example, Tsinghua University scholars have created a brain-machine-painted dream based on real-time EEG analysis and algorithmic design, which visualizes and analyzes brainwave signals for different needs. It can be used for health management, sleep monitoring, and healing services for perceptually impaired groups.

The use of digital technology in art therapy is not limited to online communication tools but extends to the application of digital media for the purpose of art-making. A challenge identified in the early stages of discussions on the use of technology in art therapy was the need for increased collaboration between art therapists, designers and developers in order to devise technological solutions suitable for art therapy practice (Gussak and James, 1999). Limited attempts to develop art therapy-specific electronic devices to date have lacked in-depth input from art therapists at the technical stage, and, consequently, there has been inappropriate integration of the established processes of art therapy with technology (Mihailidis et al., 2010; Mattson, 2015). In effect, art therapists who incorporate digital arts media into their practice elect to use painting apps that are not necessarily suitable for art therapy practice. Therefore, how digital technology can be integrated into art healing in teletherapy has yet to be further explored.

4.2 Main tools and platforms

Technology and science have long been devoted to exploring their ability to visualize the complexities of human experience, physical properties, and human communication, and dance has maintained an important relationship in its participation in these developments. Increasingly, dance works transform information about dance movement, form, and spatial location into digital signals that are stored, processed, and presented through computer technology. This digitization process can be realized with the help of a variety of technological tools, including motion capture technology, virtual reality, augmented reality, artificial intelligence, etc. (Whatley and Varney, 2009).

There are significant differences between dance under digital technology and real dance in terms of presentation, interactivity, and dissemination (Anker, 2020). Digital technology preserves dance as a digital file, which can be played repeatedly and is easy to modify. In terms of dissemination, digital dance is mostly disseminated in virtual spaces such as online platforms, and has a wider range of dissemination compared to traditional dance forms like live performances and recordings. Through specific devices, digital dance enhances interactivity. From the perspective of perceptual visualism proposed by Don Ihde, digital technology provides the dancer with an extension of the body that is not limited by space and time, allowing the body to remain "present" in an "absent" way (Strutt and Cisneros, 2021; Song and Dong, 2021).

In summary, we have divided dance healing with digital technologies that exist today into two categories: dance healing using somatic digital tools and dance creation using digital media during therapy.

During the quarantine phase of the pandemic, digital technologies were utilized for self-management as well as physical healing to stay physically active at home. Key examples of the use of digital interactions during the pandemic included smart speakers (e.g., Tmall Genie, Xiaodu), tracking of physical activity content on media platforms such as Bilibili (following netizens such as Frederick Liu and Pamela) (Sun et al., 2020), use of fitness apps (e.g., KEEP), and use of smart fitness mirrors (e.g., FITURE, Xiaodu, etc.) (Yu et al., 2022; Zhong et al., 2020). The first three are examples of dance healing using digital media, while the latter involves dance healing using somatic interaction digital tools (see Figure 1 for details). Somatosensory interaction with the help of digital technologies such as motion capture, emotion detection, and virtual reality allows for the digitization of the body's movements and perceptions. By amplifying subtle changes in the body, somatosensory technology enables participants to see their real-time status and enter a positive feedback loop (Chang et al., 2023).

In somatosensory interactive art healing installations, such as smart fitness mirrors, the designer employs the theories of psychological Gestalt in Merleau-Ponty's *Phenomenology of the Body*. For example, the influence of the visual senses on the body is utilized to provide the psychological catharsis necessary for regulation of anxiety in young people.

Table 1 aims to explore how emotional problems caused by the COVID-19 pandemic can be alleviated through digital somatosensory

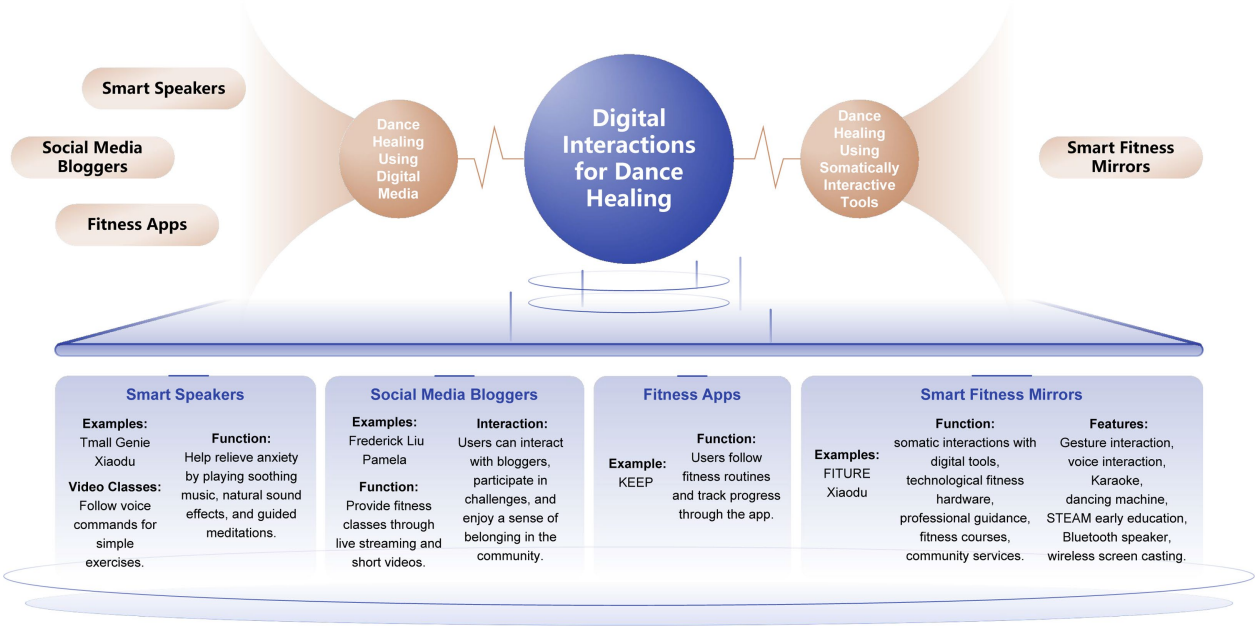

FIGURE 1
Digital tools to assist in healing realization.

TABLE 1 Theoretical foundations and strategies for mitigating emotional problems with digital somatic interaction products.

Construct reasons	Theoretical basis	Construct elements	Appeal or strategy
Lack of physical activity in the home due to isolation from the pandemic may cause body image problems.	The relationship between digital somatic interaction products and the likelihood of people participating in home-based exercise.	Digital somatosensory interactive devices suitable for home use should have intelligent feedback features.	Clarify the specific smart digital somatosensory interactive products to be used and specify the time of use.
Isolation from the pandemic has reduced the need for socialization, leading to social anxiety and emotional distress in some populations.	Dance healing, as well as a comfortable environment, are important factors in alleviating social fears and addressing emotional stability.	The home environment should provide space and equipment suitable for dance practice and take into account the individual needs of the user.	Groups or professional dancers affected by the pandemic quarantine, with dance hobbies, experience, or professional backgrounds, were selected to use the products at home and to track the process and results of their use.

interactive products. Based on an analysis of the causes of anxiety in young people, combined with psychotherapeutic theories, the table proposes specific design requirements and strategies aimed at optimizing the use of digital somatosensory devices at home. In particular, by discussing smart devices suitable for home use, Table 1 emphasizes the role of these products in promoting physical activity and social interaction, helping users to reduce the anxiety and stress generated during the quarantine period of the pandemic.

5 Method

5.1 Participants and procedures

This study was carried out with a randomized controlled experimental design. A total of 200 participants were recruited for this study using convenience sampling, a type of non-probability sampling, through open recruitment via social media and existing contacts. Following the Self-Assessment Scale for Anxiety (SAS) psychological assessment, 152 subjects were excluded, and 48 participants were ultimately selected for the study. Of these, 14 were male and 34 were female, with ages ranging from 18 to 50 years. The selected participants were then thoroughly analyzed and randomly assigned to two groups. The control group (TDR) consisted of volunteers who danced in traditional dance studios after the pandemic, while the experimental group (SFM) consisted of volunteers who danced at home after the pandemic using digital devices such as the FITURE Magic Mirror Smart Fitness Mirror to track changes in mood and anxiety. The experimental group consisted of 24 participants (16 females and 8 males), and the control group consisted of 24 participants (18 females and 6 males). The mean age of the SFM participants was 25.83 ± 6.96 years, while the mean age of the TDR participants was 27.96 ± 7.30 years. Analysis of variance (ANOVA) revealed that there were no significant differences between the two groups of participants in terms of age, gender, job, type of dance, and skill level ($p > 0.05$).

Inclusion criteria for participants were: self-assessment by participants via the Self-Rating Anxiety Scale (SAS) and clinical

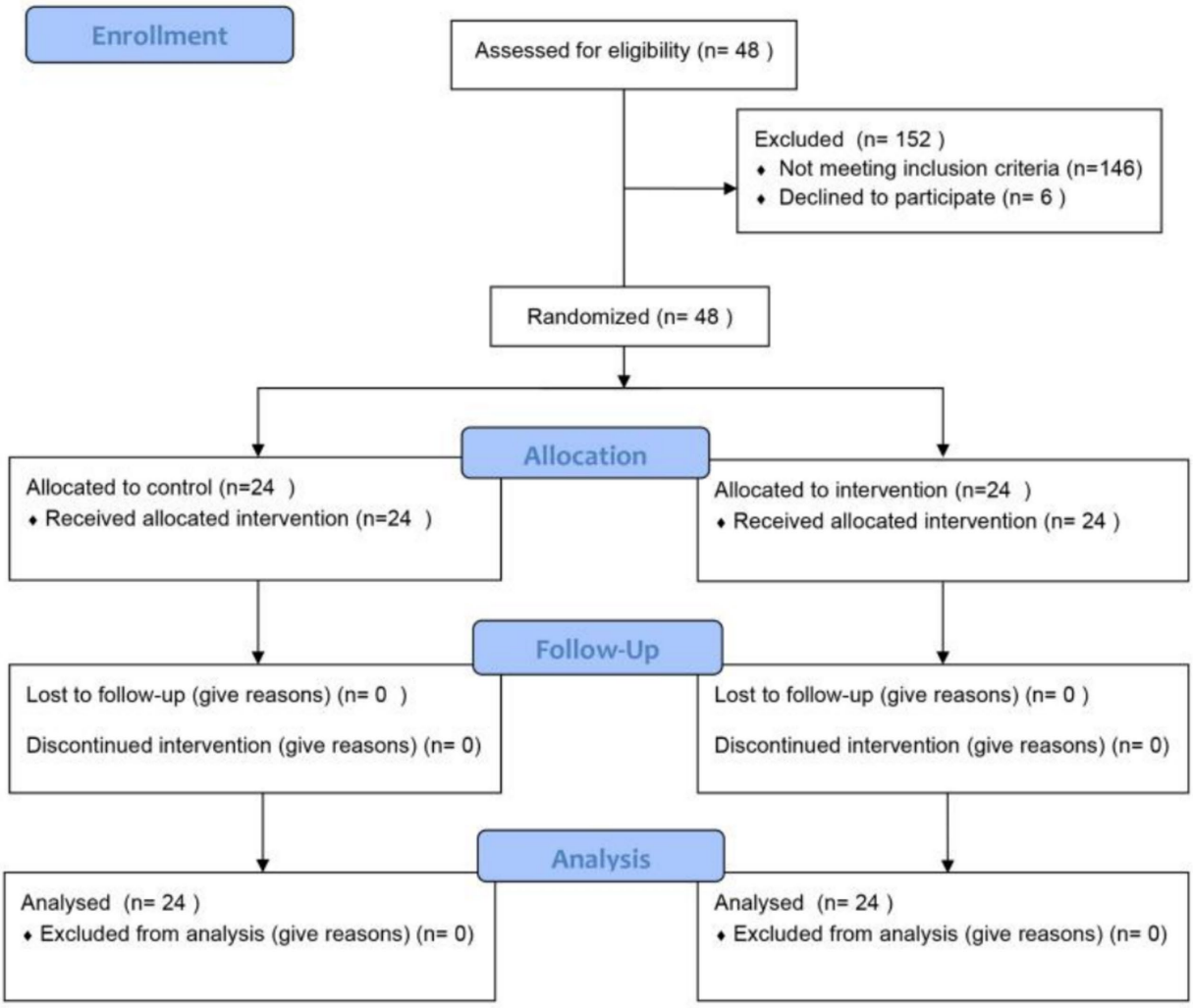

FIGURE 2
Consort flow diagram.

psychologist review of the scale results to screen a group of dancers with anxiety levels in the normal or mild range. Participants had not received psychoeducational or cognitive-behavioral training in the 3 months prior to the intervention. The CONSORT flow diagram of the study regarding the inclusion of the participants is shown in Figure 2.

After receiving the complete study instructions, all participants agreed to participate and signed a written informed consent form. The overall implementation framework included dance therapy architecture, experimental design, assessment, intervention design, and empirical testing. All participants volunteered for the experiment and reserved the right to withdraw at any time.

5.2 Measures

Using a randomized controlled trial (RCT) approach, this trial aims to assess whether the use of digital technology (e.g., smart fitness goggles) in dance therapy is effective in alleviating anxiety associated with pandemic isolation and compare it to traditional dance therapy.

5.2.1 Intervention

This study required a baseline assessment of all participants prior to the experiment to understand their initial anxiety levels after pandemic isolation.

Both the TDR and SFM groups participated in a 3-month intervention. During this time, participants engaged in weekly self-directed dance training in a traditional dance studio or at home using smart fitness mirrors, depending on their group assignment. Participants in both groups were assessed at three time points: baseline (T0, before the start of the experiment), midterm (T1, 1 month post-intervention), and endpoint (T2, 3 months post-intervention). At each time point, participants' mood changes were assessed using the Positive and Negative Affect Schedule (PANAS). There was no private communication between groups of participants.

5.2.2 Mental health status

The Self-Assessment Scale for Anxiety (SAS) (Wang and Chi, 1984), which uses a 4-point scale to rate the frequency of symptoms as defined by the items, provides a comprehensive assessment of volunteers' mental health and subjective feelings of anxiety.

The scale consists of 20 items, and its delineation values were drawn by distribution in a large sample of people, with a normal upper limit of 40 points for the total crude score of normal Chinese people. In this study, the severity delineation criteria were based on the current common hospital criteria (psychological testing software), while referring to the manual of commonly used psychological assessment scales (Dai, 2010) for delineation, with standardized scores of <50 points for no anxiety, ≥50 points for mild anxiety, ≥60 points for moderate anxiety, and ≥70 points for severe anxiety (Duan and Sheng, 2012).

This trial categorized participants into four groups based on the results of the pre-intervention questionnaire: Category A: normal range (total score less than 50), Category B: mild anxiety (total score between 50 and 60), Category C: moderate anxiety (total score between 60 and 70), and Category D: severe anxiety (total score greater than 70). A total of 48 volunteers in categories A and B were then randomly assigned in half by number to either an experimental group that used the smart fitness mirror (digital devices) at home (SFM Team) or a control group that was in a traditional dance room (TDR Team). The screening criteria for the volunteer samples in this experiment were: a total score <60, and volunteers who met the above criteria were selected as members of the experiment. The internal consistency of the overall scale was good with $\alpha = 0.821$. The instrument proved to be a reliable and valid indicator of mental health in the general population (Dunstan and Scott, 2020; Liang et al., 2020).

5.2.3 Measurement of positive and negative emotions

At each time point, participants' mood changes were assessed using the Positive and Negative Affect Scale (PANAS). The scale consists of a positive affective subscale and a negative affective subscale, each containing five items, and is designed to measure psychological satisfaction in the general population. The scale is designed to be used as both a between-subjects and within-subjects measure of state or trait affect (Clark and Watson, 1994). Affective balance is calculated as a positive affect score minus a negative affect score, with an additional factor of 5, which ranges from 1 to 9. The use of assessment scales is a reasonable approach due to the wide variation in anxiety symptoms and the varying degrees of impact from the epidemic among dance enthusiasts in the group. The use of assessment scales is a reasonable approach due to the wide variation in anxiety symptoms and the varying degrees of impact from the epidemic among dance enthusiasts in the group (Humphries et al., 2023).

In order to control for additional variables, the experimental procedure ensured that the intervention was of the same duration for both groups, and was conducted twice a week for one and a half hours, with psychometric tests being administered before the experiment, after 1 month of the experiment, and after 3 months of the experiment, and that any additional interventions were scrupulously documented and excluded from the analyses. Also, experimenters were not allowed to perform additional traditional studio dance interventions. All questionnaire data were analyzed using a 2-group (traditional ballroom dance group, game group) × 3 times (pre-test, test, and post-test) repeated measures ANOVA. The internal consistency of the overall scale was good, $\alpha = 0.841$.

5.2.4 Satisfaction and propensity to use smart fitness mirrors

After the experiment, in order to better collect participants' experiences and feedback, we also considered using a five-point Likert scale as well as a qualitative method: semi-structured interviews to complement the experiment.

The System Usability Scale questionnaire (SUS) assesses participants' satisfaction and propensity to use smart fitness goggles and consists of six items. Measured on a 5-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree (Brooke, 1996), the questionnaire included questions such as: 'This product relieves the anxiety of sociopaths and home-bound individuals like the participants' and 'I would be more likely to practice dance with this type of smart digital product than in a traditional dance studio/gym.' The overall internal consistency of the scale was good, $\alpha = 0.806$, and the instrument demonstrated validity and reliability in both dance and healthcare populations using digital technology devices (Mol et al., 2020; Martins et al., 2025).

5.3 Data collection

Participants in both the TDR and SFM groups were assessed using the Positive and Negative Affect Scale (PANAS) at baseline and at 1 and 3 months post-intervention (from July 2024 to October 2024) and were assessed using satisfaction and propensity questionnaires 1 month after the end of the intervention (November 2024), along with additional interviews. Participants were contacted prior to the assessment, given 1 week to complete the questionnaire, and reminded if they had not done so within the given period to ensure timely data collection.

5.4 Statistical analysis

We used methods such as density and quantile plots to assess the normal distribution of variables, supplemented by Shapiro–Wilk tests. Per-protocol analyses were performed (i.e., only participants who completed the entire study were included). Data were analyzed as the change from baseline (T0) to 1 month (T1) and 3 months (T2) for each group, determined by the mean difference and its 95% confidence interval (CI). For continuous variables, between-group differences at each time point were determined using independent-samples t-tests, while within-group differences over time were analyzed using paired t-tests. A two-way repeated-measures analysis of variance (ANOVA) was conducted to examine the interaction between group (SFM team vs. TDR team) and time (T0, T1, and T2) on PANAS scores for mood and anxiety levels. Psychological data was analyzed using SPSSAU(The SPSSAU project., 2024). The psychological data are presented as mean ±SD (standard deviation). Statistical significance was assumed for $p < 0.05$.

6 Research results

A total of $N = 48$ participants were included into analysis, samples from different groups did not show significant differences in gender, age, occupation, amateur/professional dancers. For more information, see Table 2.

The differences between the positive mood, negative mood and overall mood of the experimental and control groups were not significant between pre-experiment and post-experiment. After the intervention, the TDR group showed an increase in positive emotions and a decrease in negative emotions compared to the pre-intervention

TABLE 2 Baseline characteristics of all included participants.

Characteristics	Group (Mean ± SD)		t	p
	TDR (n = 24)	SFM (n = 24)		
Gender	1.25 ± 0.44	1.33 ± 0.48	−0.624	0.535
Age	1.92 ± 1.10	2.33 ± 1.20	−1.252	0.217
Occupation	3.08 ± 1.50	3.21 ± 1.89	−0.254	0.801
Amateur/Professional Dancer	1.46 ± 0.51	1.63 ± 0.49	−1.151	0.256
SAS Self-Assessment Scale Results (Present Mood State)	40.83 ± 9.33	41.33 ± 11.76	−0.163	0.871
Anxiety from new COVID-19 quarantine	2.00 ± 0.72	2.08 ± 1.14	−0.303	0.764

*$p < 0.05$ **$p < 0.01$.

TABLE 3 Changes in positive mood, negative mood, and overall mood of experimental and control groups at each time point.

Group	Traditional dance room						Smart fitness mirror					
Time point	T0		T1		T2		T0		T1		T2	
Value	Means	SD	Means	SD	Means	SD	Means	SD	Means	SD	Means	SD
Positive	27.96	4.41	29.17	5.49	29.00	4.67	26.58	4.86	28.42	5.68	30.00	5.42
Negative	24.88	5.86	23.38	3.74	23.38	4.99	24.04	4.70	23.79	3.89	24.17	4.46
Result	1.46	0.83	1.17	0.38	1.25	0.61	1.79	0.98	1.42	0.83	1.21	0.59

T0, T1, and T2 represent the time after the quarantine of the pandemic, 1 month of treatment, and 3 months of treatment, respectively. Positive represents positive mood, negative represents negative mood, and result represents final overall mood.

period, but none of the differences were significant ($p > 0.05$), as shown in columns TT0 & TT2 in Table 3. However, there was a significant improvement in the total score of the SFM group compared to the pre-experiment ($p < 0.01$), as shown in columns ST0 & ST2 in Table 3.

6.1 Comparison of the differences between the experimental group and the control group before and after the trial

Table 3 shows the changes in the positive and negative mood results and factor scores of the test and control groups before and after the test, and it can be seen that the mean values of the positive mood increased in both groups, but the magnitude was larger in the SFM group; the mean values of the negative mood decreased in both groups; and in terms of the mean values of the results, both groups decreased, with the largest drop in the SFM group (the result of a high positive mood was recorded as 1, the result of an equal positive and negative mood was recorded as 2, for high negative mood is noted as 3). Comparison of the differences in pre and post changes showed (see Tables 4, 5 for details) that after 3 months of group dance healing, most of the anxiety in both groups improved, with the improvement in anxiety in the TDR group being more significant ($p < 0.01$) after 1 month as well as after 3 months of group dance healing.

The results of the experiment showed a significant improvement ($p < 0.01$) in the total score of SFM from pre-intervention (T0) (1.79 points ± 0.98 SD) to mid-intervention (T1) (1.42 points ± 0.83 SD) to post-intervention (T2) (1.21 points ± 0.59 SD). In contrast, the overall mood of TDR in the control group did not improve significantly ($p > 0.05$) from T0 (1.46 points ± 0.83 SD) to T1 (1.17 points ± 0.38 SD) to post-intervention (T2) (1.25 points ± 0.0.61 SD) (see Tables 2, 3).

The data in the T0, T1, and T2 columns in the traditional Dance Room group (hereafter referred to as the TDR group) in Table 3, as well as the TT0&TT1, TT0&TT2, and TT1&TT2 columns in Table 4, showed that after 3 months, although the control group's positive mood increased and negative mood declined, the differences were not significant ($p > 0.05$).

6.2 Comparison of changes between the experimental group and the control group before and after the trial

As can be seen from Figure 3, the positive mood scores of both the experimental and control groups improved before and after the test, but the magnitude of the improvement varied, with the experimental group showing a particularly significant increase in positive mood ($p < 0.001$). In contrast to the control group, the negative scores of the experimental group increased, suggesting that the smart fitness mirrors did not give the volunteers more improvement in their negative emotions. In contrast, the outcome scores of the experimental group decreased after the trial, implying that the volunteers in the experimental group had improved their anxiety (the outcome was recorded as 1 for high positive mood, 2 for equal positive and negative moods, and 3 for high negative moods), and the improvement was also highly significant ($p < 0.001$). In contrast, outcome scores in the control group increased after the trial, and improvement was not significantly different ($p > 0.05$).

Remarks: Efficacy rate = (post-treatment score - pre-treatment score)/pre-treatment score. Generally speaking, the absolute value of the efficacy rate ≧50% is considered effective, and ≧25% is considered effective (the positive and negative values of the efficacy rate are analyzed on a case-by-case basis).

TABLE 4 Comparison of the significant differences between different time points within the same group of the experiment.

Group	Traditional dance room						Smart fitness mirror					
Time point	TT0 & TT1		TT0 & TT2		TT1 & TT2		ST0 & ST1		ST0 & ST2		ST1 & ST2	
Value	t	*p*	t	p	t	p	t	p	t	p	t	p
Positive	−1.796	0.086	−1.401	0.174	0.228	0.822	−2.161	0.041*	−3.345	0.003**	−2.889	0.008**
Negative	1.889	0.072	1.429	0.166	0.000	1.000	0.343	0.734	−0.136	0.893	−0.857	0.400
Result	1.574	0.129	1.155	0.260	−0.811	0.426	3.245	0.004**	3.245	0.004**	0.000	1.000

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; Replacing the Traditional Dance Room (TDR) group with T and S for the Smart Fitness Mirror group. For example, TT0 denotes the basal test phase of the TDR group. Table 5 follows the same structure.

TABLE 5 Comparison of significant differences at the same time within different groups of the experiment.

Time point	TT0 & ST0		TT1 & ST1		TT2 & ST2	
Value	t	*p*	t	*p*	t	*p*
Positive	1.199	0.243	0.581	0.567	−0.846	0.406
Negative	0.774	0.447	−0.399	0.694	−0.634	0.533
Result	−1.498	0.148	−0.44	0.664	0.225	0.824

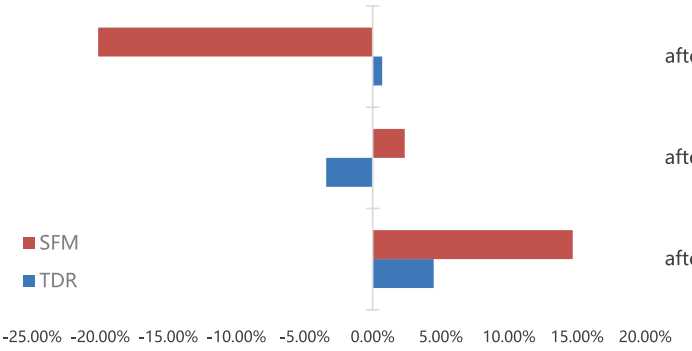

FIGURE 3
Comparison of the efficacy rate of each group after the trial.

From the data, the absolute value of the efficacy rate of the two groups did not exceed 25%, both in terms of the outcome and the factor scores. The positive efficacy rate for the experimental group and the negative efficacy rate for the outcome indicate that the anxiety of the experimental group's personnel was reduced after the intervention. However, the negative efficacy rate was positive, indicating that some anxiety was not alleviated. In contrast, the TDR group showed a positive resultant efficacy rate, although the positive mood was positive and the negative mood was negative. This suggests that in the control group, some members of the group received increased anxiety symptoms from the pandemic isolation than in the absence of the intervention treatment, anxiety was not better alleviated, and interpersonal relationships became more sensitive.

6.3 Intervention effect of the experimental group

Of the members who participated in the art healing trial using the Digital Intelligent Dance device, all volunteers' anxiety improved and no one became worse (see Table 6 for details). From the results, 26% of the volunteers had an extremely significant intervention ($p < 0.001$), changing from negative to positive, and 1 volunteer had a significant change from high negative mood to equal positive and negative mood, while 70% of the volunteers did not have a significant change, but all of them tested high in positive mood. In terms of the numerical change in positive mood, more than half of the volunteers showed an increase in positive mood, with 12% of the volunteers showing an extremely high increase in positive mood (values >10) and 17% of the volunteers showing a significant increase in positive mood, however, 25% of the volunteers showed a decrease in positive mood instead. In terms of the change in the value of negative emotion, 17% of the volunteers had no change in the before and after values, 37% of the volunteers had a decrease in negative emotion, of which 12% of the volunteers had a significant effect on the decrease in negative emotion. And nearly half of the volunteers' negative emotions increased instead, with no significant trend.

As shown in Table 7, in the experimental group, the mean value of positive mood before the intervention was 26.58, and the mean value of overall mood was 62.68. After participating in the

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TABLE 6 Intervention effects in the experimental group.

ID	Values of positive mood change	Values of negative mood change	Changes in overall mood
1	−2	4	No change
2	10	−6	Negative to positive
3	15	9	No change
4	3	0	No change
5	0	0	No change
6	−1	−1	No change
7	3	0	Negative to positive
8	3	0	No change
9	2	3	No change
10	1	4	No change
11	6	−4	Negative to positive
12	1	−1	No change
13	3	−2	Negative to positive
14	13	−9	Negative to positive
15	−1	1	No change
16	9	−9	Negative to positive
17	1	1	No change
18	0	3	No Change
19	−1	−3	Negative to equal
20	5	2	No change
21	6	5	No change
22	−2	−3	No change
23	−3	1	No change
24	11	8	Equal to positive

The numbers are all for the values of mood after 3 months of treatment minus the values of mood after quarantine of the epidemic.

TABLE 7 Changes in positive symptoms.

Group	Pre-test means	Under-test means	Post-test means	Rate of increase
Positive	26.58	28.42	30.00	12.87%
Result	1.79	1.42	1.21	−32.40%

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

three-month art healing program, the mean value of positive mood increased to 28.42 and then finally to 30.00, while the mean value of overall mood decreased to 1.21, a reduction of 32.40%. These results indicate that the anxiety of the volunteers in the experimental group was significantly reduced through art healing. Additionally, the smart fitness mirror had a notable therapeutic effect on the anxiety caused by the pandemic quarantine and was more effective than dancing in a traditional dance studio.

6.4 Results of the interviews

After the completion of the trial, each volunteer was interviewed, and some of the interviews, as well as the results, are shown in Table 8.

We used one-way ANOVA to study the two groups' perceptions of digital smart products such as the smart fitness mirror. From the results, both groups of volunteers showed significance ($p < 0.05$) for the following questions, implying that the different groups of samples are different for all.

Both groups of volunteers were willing to use smart dance devices when they were upset, and those who had used smart fitness mirrors (mean 2.00) were more willing to use smart dance devices to ease their uneasy moods compared to those who only practiced in traditional dance studios (mean 3.62). In the choice of AI dance instructors as well as teachers in traditional dance studios, volunteers in the SFM group (mean 2.12) felt that the AI dance instructors could help them get into a better dancing state, whereas volunteers in the TDR group (mean 4.21) still felt that the real-life teachers were more approachable and able to solve problems at any time. Whereas both groups of

TABLE 8 Likert scale ANOVA results.

ANOVA results				
Questions	Group (Mean ± standard deviation)		*F*	*p*
	TDR (*n* = 24)	SFM (*n* = 24)		
Q87_1.I am willing to use smart dance devices when I feel emotionally unsettled.	3.63 ± 1.35	2.00 ± 0.98	22.910	0.000**
Q88_2.The smart AI dance coach helps me get into a learning state better than a traditional dance teacher.	4.21 ± 1.02	2.13 ± 1.23	40.896	0.000**
Q89_3.Smart dance devices help alleviate the anxiety of people like me who have social anxiety or prefer staying at home.	3.54 ± 1.41	1.96 ± 0.75	23.488	0.000**
Q91_5.I prefer using smart digital products to practice dance compared to traditional dance rooms/gyms.	4.04 ± 1.08	1.88 ± 0.80	62.317	0.000**
Q92_6.I feel anxious about others noticing my body in traditional dance rooms, but using the smart fitness mirror at home alleviates this anxiety.	3.83 ± 1.40	1.92 ± 0.83	33.153	0.000**

*$p < 0.05$ **$p < 0.01$.

volunteers felt that smart dance devices like smart fitness mirrors could somewhat alleviate the social anxiety left over from the pandemic, both also felt that home smart fitness mirrors could avoid the problem of body image anxiety being exposed to the general public. As a result, both groups of volunteers preferred to continue their dance training in their original respective ways. Dancers in the SFM group believed that smart devices such as smart fitness mirrors were easy to use, flexible in terms of time, and alleviated the cost of traveling and class enrollment, which could alleviate the uneasy emotions of body anxiety and social anxiety. Dancers in the TDR group believed that traditional studio teachers can better instruct dancers face-to-face on standardized movements, are more interactive, have a better sense of dance atmosphere, and are more able to keep dancers focused.

7 Discussion

From the results of this study, it is clear that the quarantine of the pandemic did leave people with anxiety, and the body image anxiety, as well as the social fear anxiety mentioned in this paper, are just some of the high prevalence types of anxiety among many others. Anxiety is currently a high-prevalence psychological disorder in our population, with prevalence rates of about 20–30% and 15–25%, respectively (Shi et al., 2020; Chen et al., 2023; Bin et al., 2024). The SAS self-assessment scale as well as the PANAS Positive and Negative Scale can directly assess people's anxiety, but the symptoms of anxiety are complex and diverse, and some of the symptoms of other factors may be related to it, such as obsessive-compulsive disorder, hostility, phobias, sensitivity to relationships, and somatization, etc., Anxiety often triggers interpersonal sensitivity, and this psychological stress in turn manifests itself through somatic symptoms (Tellawi et al., 2016).

The trial found that the findings aligned with those of Moratelli et al. (2023). Age, occupation, and gender factors had no significant effect on improving anxiety remaining after pandemic isolation. Being a professional dancer or not did not make the effect of anxiety improvement more significant ($p > 0.05$). The status of filling out the positive and negative mood scale shows that all volunteers improved their mental health after participating in the 3-month dance healing process, but there were differences between different groups, with the Smart Fit Mirror group having a more significant effect ($p < 0.001$). However, close to half of the volunteers in the SFM group's negative emotions increased instead after the trial, which was not a significant trend but indicated that the effect of the Smart Fitness Mirror on the alleviation of negative emotions still needs to be improved, and was not as effective as that of positive emotion promotion. This finding resonates with the discussion on integrating technology into mental health treatment, emphasizing the potential of digital tools and the need for careful implementation to avoid negative effects (Bond et al., 2023; Olawade et al., 2024; Coelho et al., 2025).

Post-trial interviews revealed a generally positive attitude toward digital dance products. Participants acknowledged that these devices could alleviate social anxiety stemming from the pandemic and address body image anxiety when exposed to the public. However, individuals unfamiliar with such products expressed a preference for traditional dance studio environments, citing the value of face-to-face interactions and skepticism toward AI dance instructors.

Although this study found that dance healing is effective in relieving anxiety, more than half of the volunteers failed to achieve significant therapeutic effects within a short period due to the limited duration of the intervention (3 months). This result aligns with existing literature emphasizing the importance of intervention length (Salihu et al., 2021). Therefore, further relevant studies need to extend the intervention time, increase the sample size, and explore the long-term efficacy of smart fitness mirrors in individuals with different anxiety levels. In addition, AI dance coaches currently still suffer from insufficient human interaction in their interactions with users, and future research should aim to improve technological interactions in order to increase users' trust and dependence on digital devices. Additionally, the lack of human interaction with AI dance coaches may limit user trust and engagement, pointing to the need for enhancing technological interactions to foster better human-computer synergy. Future AI dance instructors will likely have enhanced language comprehension, refined emotional perception, and more flexible physical coordination. At that time, AI coaches can interact with students in a deeper and more personalized way, providing more targeted guidance and companionship. This study not only provides new ideas for the field of dance healing, but also provides

TABLE 9 A new approach to dance healing based on digital technology.

Emotional condition	Recommended approach	Details
High Positive PANAS (Positive Emotion)	Traditional Studio Classes	Enroll in a dance studio for in-person classes, assuming the same dance fundamentals.
High Negative PANAS (Negative Emotion)	Digital Smart Dance Equipment (Home)	Use smart fitness mirrors or similar digital dance equipment at home.
Large Difference Between Negative and Positive (≥ 5 points)	Combination of Digital Equipment & Traditional Classes (Early Stage)	Use digital equipment at home along with traditional studio classes at the start.
Equal Positive and Negative Emotions	Dancer's Preference	The choice can be made based on the dancer's personal preference.

valuable references for the direction of human-computer interaction and emotional computing in the field of digital intelligence.

7.1 Practical significance

Our study focuses on analyzing whether the integration of digital technology into its method is more effective in treatment outcomes in the context of the prevalence of dance therapy. The experimental results verified the unique positive significance of dance therapy incorporating digital somatic technology in relieving anxiety, i.e., this therapy has stronger intervention advantages in relieving body image anxiety and alleviating social fears compared to dance therapy in traditional dance studios. More importantly, AI coaches are unable to provide the emotional support, encouragement and psychological guidance that real coaches can provide, which will greatly affect learners' motivation and sense of achievement. Therefore, the incorporation of digital technology can be an important complementary tool to traditional dance therapy.

In the context of digital technology, AI dance coaches provide users with personalized and efficient dance teaching through motion capture, data analysis and other technologies, filling geographical and economic gaps. However, AI dance coaches currently lack the ability to provide the emotional support, encouragement, and psychological guidance offered by human coaches, and tend to generate similar styles of dance movements, leading to homogenization of dance therapy styles and weakening the diversity of dances, which can greatly affect the motivation and sense of achievement of those being treated. All of these issues require us to think deeply and develop appropriate measures while enjoying the convenience of AI (Liu, 2024).

This paper will provide a literature base for future research on digital technologies, especially AI dance coaches, and in particular, the integration of somatically interactive digital technologies into dance healing to reach the goal of online dance therapy with no consideration of the user's dance expertise, thus alleviating the symptoms of body image anxiety and social anxiety that are left over from the post-pandemic era.

7.2 Foresight

In summary, Digital Dance Healing should consider human-machine synergy even more in the future, combining AI coaches with real coaches to take advantage of each other's strengths. AI coaches are responsible for providing real-time, efficient and personalized basic teaching and feedback, while real coaches are responsible for giving emotional value, psychological guidance, and imparting an understanding of dance culture. Expanding the diversity of training data for AI coaches is also a priority, including different styles and cultures of dance to avoid homogenization. Technicians should also think about how to incorporate cultural elements into AI algorithms so that the AI can convey the cultural connotations behind the dance. We have also summarized a new approach to dance healing based on digital technology based on the research done, as shown in Table 9.

8 Conclusion

Overall, the dance art therapy was significantly effective in alleviating the dancers' anxiety left over from the quarantine of the pandemic, especially body image anxiety as well as social anxiety, and the dancers' positive emotions were enhanced. Through randomized scientific control, the smart fitness mirror group was found to be more effective than the traditional studio group in relieving body image anxiety as well as social anxiety. The study also found that by using digital devices such as smart fitness mirrors, dancers were able to better express and understand their emotions, enhancing self-awareness and emotion regulation.

However, the current study still has some limitations, such as a relatively small sample size due to the geographical distribution of subjects. In future studies, we will further expand the sample size and track it over time. In particular, we will overcome geographical limitations and develop new measurement approaches from various perspectives to refine the findings and provide a more comprehensive and in-depth mental health assessment for dancers. This will help obtain stronger evidence supporting the integration of digital technology into dance art therapy.

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

SQ: Conceptualization, Data curation, Investigation, Methodology, Project administration, Software, Validation,

Visualization, Writing – original draft. CR: Formal analysis, Project administration, Resources, Supervision, Writing – review & editing. YW: Funding acquisition, Resources, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This research was funded by the Zhejiang Federation of Humanities and Social Sciences, grant number 22NDJC074YB, and the National Social Science Foundation Art project, grant number 20CH194.

Acknowledgments

We would like to thank the reviewers for their time and effort devoted to improving the quality of this research.

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.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE Systematic Review
PUBLISHED 04 June 2025
DOI 10.3389/fpsyg.2025.1547802

OPEN ACCESS

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RECEIVED 18 December 2024
ACCEPTED 12 May 2025
PUBLISHED 04 June 2025

CITATION
Liu X, Soh KG and Lu Y (2025) Effect of dance on social physique anxiety and physical self-esteem among adults: a systematic review. *Front. Psychol.* 16:1547802. doi: 10.3389/fpsyg.2025.1547802

Effect of dance on social physique anxiety and physical self-esteem among adults: a systematic review

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Background: Physical activity has been widely recognized for its positive impact on mental health. Dance, as a form of physical activity, has garnered increasing attention in recent years. Existing literature suggests that dance specifically contributes to enhancing physical wellbeing and promoting emotional development. This systematic review aims to assess the impact of dance on social physique anxiety and physical self-esteem in adults.

Method: A systematic literature search was conducted across multiple academic databases, including Embase, EBSCOhost, Cochrane, Scopus, PubMed, and Web of Science. The data were then systematically reviewed using the PRISMA guidelines. The quality of each study's appraisal was evaluated using the PEDro scale.

Results: Sixteen studies examined the effects of seven types of dances—Zumba, Latin dance, Salsa, Dance Movement Therapy, Aerobic dance, Belly dance, and Colombian Caribbean Folk dance—on adult's social physique anxiety and physical self-esteem. The participants in this review included adults, college students and older adults (ages range from 18 to 76). The quality appraisal scores on the PEDro scale ranged from 3 to 6. Dance interventions were found to significantly enhance physical self-esteem and self-confidence, while concurrently reducing social physique anxiety and negative self-evaluation in an enjoyable manner.

Conclusion: This review indicates that dance positively affected social physique anxiety and physical self-esteem for experimental groups that participated in dance compared to control groups in the reviewed studies. These effects were consistent across all age groups. Moreover, the study demonstrates that female participants in the experimental groups experienced more significant improvements in physical self-esteem and greater reductions in social physique anxiety levels compared to male participants.

Systematic review registration: https://www.crd.york.ac.uk/prospero, identifier: CRD42022315034.

KEYWORDS

psychology, dance, anxiety, self-esteem, mental health, adult

Background

Approximately 14% of global illnesses can be attributed to mental health issues (Dubreucq et al., 2023). Recent studies have focused on the connection between mental health and physical wellness (Burns et al., 2023), as mental health encompasses both negative attributes such as anxiety and depression (Khanna and Carper, 2022) and positive attributes like self-esteem and a sense of self-worth (Usmani et al., 2023). Promoting mental health is important not only for individuals with existing disorders but for all individuals, as it contributes to overall wellbeing and quality of life (Hart et al., 2022).

Poor mental health can manifest in symptoms such as anxiety, depression, and low self-esteem, many of which are closely related to individuals' body perceptions (Wong et al., 2023). In this review, "mental health" is used as a broad term encompassing both the absence of psychological disorders and the presence of psychological wellbeing. "Psychological wellbeing" specifically refers to individuals' subjective experiences of happiness, self-acceptance, purpose in life, and emotional balance. Individuals may experience anxiety related to their physique or body shape, leading to Social Physique Anxiety (SPA) and low Physical Self-esteem (PSE). SPA refers to individuals' concerns about how their physical appearance is perceived by others in social settings (Zartaloudi et al., 2023). Engaging in physical activity has been proven to have a positive impact on aspects of mental health, such as anxiety and PSE, including improvements in self-confidence and self-perception as subcomponents of PSE, which are frequently affected by body-related concerns (Rogers et al., 2023). One form of physical activity that has gained increasing attention is dance, which has the potential to improve both physical fitness and psychological wellbeing (Hart et al., 2022). Dance has been shown to influence two important psychological constructs, namely SPA and PSE (Soltero et al., 2022). In this review, closely related psychological constructs are distinguished as follows: PSE refers specifically to an individual's evaluation of their own physical appearance and abilities; self-confidence and self-perception, although conceptually related, are regarded as components or broader reflections of self-esteem in physical contexts. For clarity and consistency, the term PSE is employed when referring to body-related self-evaluation, and the interchangeable use of related terms is avoided unless directly cited from original studies.

SPA is characterized by concern over how others may evaluate one's physical appearance (Ng et al., 2023). It can act both as a barrier to exercise, due to concerns about revealing one's physique in a public setting, and as a motivator for participation in exercise to develop a healthier and more desirable body image (Abdollahi et al., 2023). SPA is the fear of negative judgment in social situations (Kroon et al., 2023). PSE, on the other hand, reflects an individual's perception of their body and physical appearance (Alhumaid and Said, 2023). Perceived physical appearance and body image are both essential aspects of PSE, with positive body image playing a particularly central role (Boing et al., 2023). Previous research has shown that physical activity positively influences PSE, especially in adolescents (Marco et al., 2023). Identifying suitable physical exercises to effectively improve SPA and PSE is crucial.

Dance has gained popularity as a physical exercise that can reduce anxiety, boost PSE, and improve mental health (Zhang et al., 2023). Although the impact of dance on health and wellbeing has received less attention compared to other forms of physical activity, studies have shown that it can increase positive feelings such as exhilaration and enthusiasm while decreasing negative emotions like anger, despair, and stress (Lim et al., 2022; Wang, 2023). Dance has been found to have favorable effects on anxiety, sadness, physical function, disability, and memory in adults (Lin et al., 2022; Salihu et al., 2021; Salmons et al., 2022). Various dance styles, including Zumba, Latin, Dance Movement Therapy (DMT), Colombian Caribbean Folk dances, Aerobic dance, Belly dance, and Salsa, have consistently demonstrated positive outcomes such as reduced anxiety, improved mood, and enhanced self-image (Liu et al., 2023). Although DMT is a therapeutic modality rather than a conventional dance genre, it was included in this review because it employs expressive movement and has comparable psychological benefits. Moreover, regular and systematic dance participation has been associated with improved physical health and overall quality of life in older adults (Liu et al., 2021). With their accessibility and, in many cases, relatively low cost compared to other structured physical or psychological interventions, dance programs tend to have lower drop-out rates, making them an effective and sustainable method to enhance mental health (Tomaszewski et al., 2023).

Based on existing literature, women have shown greater participation in dance activities compared to men, with more studies focusing on female participants (Barna et al., 2023; Jiang, 2022). Previous research on SPA and PSE has predominantly focused on adults, especially college students, who are more susceptible to SPA (Zhong et al., 2022). This systematic review aims to summarize the effects of dance on SPA and PSE across different age groups and dance styles. By expanding the study population and considering various dance forms, this review provides substantial theoretical support and promotes the use of dance to improve physical and mental health.

Methods

Protocol and registration

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations were followed for the data collection, selection, and analysis for this study (Moher et al., 2009). This study was registered with the International Prospective Register of Systematic Reviews (PROSPERO) under ID CRD42022315034.

Search strategy

The search strategy applied Boolean operators and a strategic combination of keywords across databases. Boolean operators are logical connectors used in search strategies to combine or exclude keywords. Common Boolean operators include "AND", "OR", and

TABLE 1 Final search terms.

Component	Search terms
Population	"adult" OR "adolescent" OR "older adult"
Intervention	"dance" OR "dance movement" OR "Latin dance" OR "Latin" OR "Ballet" OR "Zumba" OR "Modern dance" OR "Classical dance" OR "Jazz dance" OR "Tap dance" OR "Dance Movement Therapy" OR "Salsa dancing" OR "folk dance"
Outcome	"social physique anxiety" OR "anxiety" OR "social anxiety" OR "social physical anxiety" OR "physical activity and anxiety" OR "anxiety about body" OR "nervousness" OR "anxiousness" OR "depress" OR "mood" OR "stress" OR "self-consciousness" OR "distress" OR "loneliness" OR "body image" OR "emotion" OR "anxiety disorders" OR "psychological" OR "psychological distress" AND "physical self-esteem" OR "self-confidence" OR "Confidence" OR "self-esteem" OR "body satisfaction" OR "self-worth" OR "self-image" OR "self-assurance" OR "assertiveness" OR "assuredness" OR "aplomb" OR "cool" OR "poise" OR "self-perception" OR "self-perceptions"

"NOT," which help narrow or broaden search results. An in-depth digital search was conducted in July 2024 using several prominent academic databases, including Embase, EBSCOhost, Cochrane, Scopus, PubMed, and Web of Science. The search was conducted using a combination of keywords related to dance interventions, psychological outcomes, and target populations. Additionally, the reference lists of relevant articles and related reviews were manually screened to identify additional eligible studies. All titles were carefully inspected to ensure relevance. Duplicate records were identified and removed using EndNote, and titles were manually screened to avoid repetitions and ensure relevance. Table 1 presents the final set of search terms used across all databases.

Inclusion and exclusion criteria

This systematic review used the PICOS (population, intervention, comparison, outcome, study designs) criteria, as shown in Table 2 (Liberati et al., 2009). There were no restrictions regarding sample size, study location, or intervention duration. On this basis, research that met the following criteria were included: (1) A full-text, peer-reviewed study published in English that investigated the effects of at least one type of dance intervention on SPA and/or PSE; (2) Only planned and organized dance intervention; (3) Studies that assessed at least one additional psychological or physical outcome related to body image or physical health (e.g., body satisfaction, emotional wellbeing, or perceived health status); (4) The participants were adults aged 18 years and older.

Studies were discarded in cases where they did not satisfy the mentioned inclusion criteria or met the following exclusion criteria: (1) The articles used the following study designs: cross-sectional, survey, investigation, protocol, and feasibility report without data; (2) Studies were excluded if participants were not generally healthy adults (e.g., those with severe mental illnesses, substance abuse disorders, or cognitive impairments); (3) Articles, meeting abstracts, book sections were not written in English; (4) Articles without an English abstract, containing data deficiencies, or having significant methodological issues (e.g., inadequate sample size, lack of proper controls, or insufficient data reporting).

TABLE 2 PICOS (population, intervention, comparison, outcome, study designs).

PICOS	Detailed inclusion criteria
Population	Adults aged 18 and above, including university students and older adults
Interventions	Dance-there were no limitations regarding type/style, individual/partnered dances, group/private classes, etc.
Comparisons	Compared to no-intervention or non-dance activity control groups
Outcomes	Social physique anxiety, physical self-esteem
Study designs	RCT or Non-RCT

Data extraction

After completing the search for relevant articles, data from eligible articles were extracted with a predetermined form, which included: (1) author, title of publication, year of publication; (2) research design or framework; (3) control group and sample size; (4) subject age and gender; (5) intervention characteristics (length, type and frequency); (6) measures index score; and (7) research results. One of the authors abstracted data into a standardized form, while the other validated the data.

Quality assessment

The Physiotherapy Evidence Database (PEDro) scale (https://pedro.org.au/spanish/learn/pedro-statistics/) is a tool designed to evaluate the methodological quality of experimental designs. It has proven to be valuable when developing systematic reviews due to its high validity and reliability (Moseley et al., 2015).

The PEDro scale is intended to assess a study's four primary methodological components, including randomization, blinding, group comparison, and data analysis. It contains 11 items: Eligibility criteria, Random allocation, Concealed allocation, Baseline comparability, Blind subjects, Blind therapists, Blind assessors, Adequate follow-up, Intention-to-treat analysis, Between-group comparisons, and Point estimates and variability (https://pedro.org.au/wp-content/uploads/PEDro_scale.pdf). However, the first item—"eligibility criteria"—is related to external validity and is not included in the final PEDro score. Thus, although there are 11 items, the maximum score is 10. Two trained independent evaluators using a yes (1 point) or No (0 points) evaluate the quality of trials in the PEDro database, and if there are conflicts, a third evaluator resolves them. The greater the PEDro score, the better the method's quality (Maher et al., 2003). To determine the quality of the method, the following criteria were used: a PEDro score < 5 indicates poor quality, while a score > 5 indicates excellent quality (González-Muñoz et al., 2023).

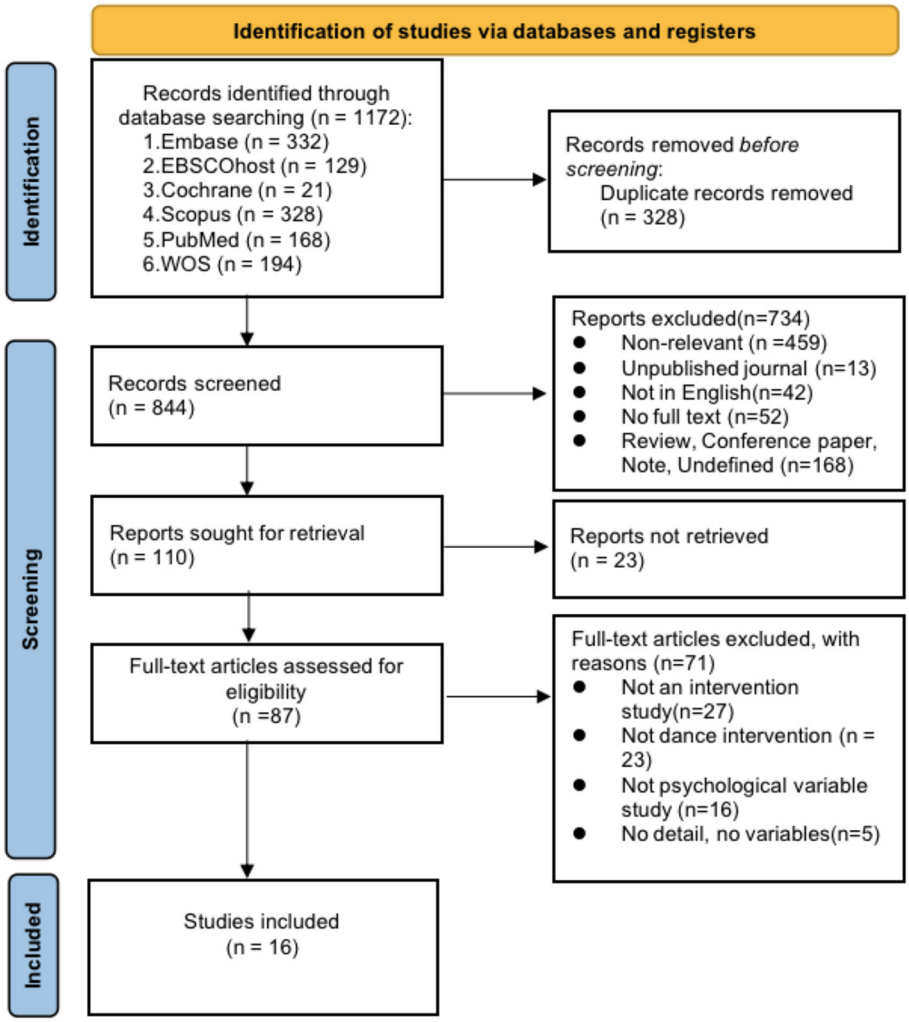

FIGURE 1
Preferred reporting items for systematic reviews and meta-analysis (PRISMA) flow chart of selection procedure.

Results

Study selection

A total of 1172 records were retrieved from Embase, EBSCOhost, Cochrane, Scopus, PubMed, and Web of Science. After removing duplicates using EndNote 20 citation management software, titles and abstracts were screened by two independent authors. Any disagreements were resolved through discussion with a third author. Following full-text review, 16 studies met the inclusion criteria. The study selection process is illustrated in Figure 1 according to the PRISMA guideline.

Study quality assessment

Table 3 provides detailed information about PEDro scale scores in each study. Data from all studies had a score of 3 to 6 on the PEDro scale. This indicates that the inclusion quality is average. All studies specified their eligibility criteria and point estimates and variability. And all studies reported on between group comparisons except two studies (Domene et al., 2016b; Donath et al., 2014). None of the studies reported on blind subject, blind therapists, blind assessors and only one study (Barene et al., 2014) reported on concealed allocation. In the context of dance interventions, blinding is often not feasible due to the interactive and participatory nature of the activity. As a result, PEDro scores may not fully capture the methodological strengths of these studies. Therefore, rather than focusing solely on blinding, future studies should enhance other areas such as randomization procedures, outcome reporting, and intervention transparency to strengthen the overall evidence base for dance and health research.

Participant characteristics

The systematic review of 16 papers is summarized in Table 4, focusing on the following aspects: (1) Sample size: The number of participants ranged from 20 (Domene et al., 2016b) to 107

TABLE 3 Summary of methodological quality assessment scores.

References	Eligibility criteria	Random allocation	Concealed allocation	Baseline comparability	Blind subjects	Blind therapists	Blind assessors	Adequate follow-up	Intention to treat analysis	Between group comparisons	Point estimates and variability	PEDro score
Domene et al. (2016b)	1	1	0	1	0	0	0	1	0	0	1	4
Barene et al. (2014)	1	1	1	1	0	0	0	0	1	1	1	6
Donath et al. (2014)	1	1	0	1	0	0	0	0	0	0	1	3
Norouzi et al. (2020)	1	1	0	1	0	0	0	1	1	1	1	6
Delextrat et al. (2016)	1	1	0	1	0	0	0	0	0	1	1	4
Pacheco et al. (2016)	1	0	0	1	0	0	0	0	0	1	1	3
Byrka and Ryczko (2018)	1	0	0	1	0	0	0	0	0	1	1	3
Rao et al. (2020)	1	0	0	1	0	0	0	0	0	1	1	3
Muyor et al. (2017)	1	0	0	1	0	0	0	0	0	1	1	3
Adilogullari (2017)	1	0	0	1	0	0	0	0	0	1	1	3
Marquez et al. (2017)	1	0	0	1	0	0	0	0	0	1	1	3
Meric and Ilhan (2016)	1	0	0	1	0	0	0	0	0	1	1	3
Barnet-Lopez et al. (2016)	1	1	0	0	0	0	0	0	0	1	1	3
Meekums et al. (2012)	1	1	0	0	0	0	0	0	0	1	1	3
Salmons et al. (2022)	1	1	0	0	0	0	0	0	0	1	1	3
Boing et al. (2023)	1	1	0	1	0	0	0	0	0	1	1	4

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TABLE 4 Characteristics of the studies examined in the present review.

References	Type of sample		Detail of intervention	Type of dance	Instruments	Type of research design	Outcomes
	Populations	Age					
Domene et al. (2016b)	$N = 20$; Adult female	18–64	Fre:2 times/week Duration:8 weeks	Zumba	HRQoL	Pre-post test	Physical appearance↑ mental health ↑;
Barene et al. (2014)	$N = 107$; Female hospital employees	25–65	Fre:2–3 times/week Duration:12 weeks	Zumba	Heart rate measurements; VAS	Pre-post test	Bodily attractiveness ↑
Donath et al. (2014)	$N = 30$; University female students	18–24	Fre:2 times/week Duration:8 weeks	Zumba	QoL	Pre-post test	Self-performance↑
Norouzi et al. (2020)	$N = 60$; Adult female	30–40	Fre:3 times/week Duration:12 weeks	Zumba	Depressive symptoms	Pre-post test	Negative Evaluation↓
Delextrat et al. (2016)	$N = 22$ Adult female	20–32	Fre:3 times/week Duration:8 weeks	Zumba	PSPP	Pre-post test	Self-performance↑; Physical self-esteem ↑
Pacheco et al. (2016)	$N = 27$; Older female	60–76	Fre:3 times/week Duration:12 weeks	Folk dances	HRQoL	Pre-post test	Physical fitness ↑; physical appearance↑
Byrka and Ryczko (2018)	$N = 64$; Adult	18–63	Fre:2 times/week Duration:5 weeks	Salsa	MVPA	Pre-post test	Physical appearance↑; Self-esteem ↑
Rao et al. (2020)	$N = 80$; Adult	30–50	Fre:3 times/week Duration:8 weeks	Aerobic dance	WHO QOL scale	Pre-post test	Anxiety ↓; Self-esteem ↑; Quality of life ↑
Muyor et al. (2017)	$N = 40$; Adult	20–25	Fre:3 times/week Duration:6 weeks	Latin	Spinal morphology	Pre-post test	Body posture↑; Physical appearance↑; Self-esteem ↑
Adilogullari (2017)	$N = 60$; University students	18–23	Fre:2 times/week Duration:12 weeks	Latin	SPAI	Pre-post test	Social physique anxiety ↓
Marquez et al. (2017)	$N = 57$; Older adults	≥ 55	Fre:1 times/week Duration:12 weeks	Latin	Self-Confidence Scale	Pre-post test	Self-confidence ↑
Meric and Ilhan (2016)	$N = 60$; University students	18–23	Fre:1 times/week Duration:12 weeks	Latin	Self-Confidence Scale	Pre-post test	Self-confidence ↑
Barnet-Lopez et al. (2016)	$N = 42$; Adult	30–60	Fre:2 times/week Duration:12 weeks	DMT	Koppitz human figure drawing test	Pre-post test	Physical self-esteem ↑
Meekums et al. (2012)	$N = 92$; Adult female	20–50	Fre:2 times/week Duration:5 weeks	DMT	CORE-OM; SIBID; self-esteem scale	Pre-post test	Psychological↓; body image↓; self-esteem ↑
Salmons et al. (2022)	$N = 49$; old adult	≥50	Fre:1 times/week Duration:12 weeks	DMT	Beck's depression inventory; hospital anxiety and depression scale; self-esteem scale	Pre-post test	Anxiety ↓; Self-esteem ↑
Boing et al. (2023)	$N = 74$ breast cancer survivors	52–58	Fre:3 times/week Duration:16 weeks	Belly dance	Body image after breast cancer questionnaire; Rosenberg self-esteem scale; female sexual function index	Pre-post test	Body image ↑; Self - esteem ↑

HRQoL, health-related quality of life; VAS, visual analog scales; MVPA, moderate and vigorous physical activity; BAQ, body attitude questionnaire; PSPP, physical self-perception profile; WHO QOL scale, World Health Organization Quality Of Life Scale; SPAI, social physique anxiety inventory; DMT, dance movement therapy; DEBQ, Dutch eating behavior questionnaire; CORE-OM, clinical outcomes in routine evaluation – outcome measure; SIBID, situational inventory of body image Dysphoria; Higher, ↑; Lower, ↓.

(Barene et al., 2014), with an average sample size of approximately 59 participants. (2) Gender: Eight articles investigated women-only samples (Barene et al., 2014; Boing et al., 2023; Delextrat et al., 2016; Domene et al., 2016b; Donath et al., 2014; Meekums et al., 2012; Norouzi et al., 2020; Pacheco et al., 2016), while the other eight included participants of both genders (Adilogullari, 2017; Barnet-Lopez et al., 2016; Byrka and Ryczko, 2018; Marquez et al., 2017; Meric and Ilhan, 2016; Muyor et al., 2017; Rao et al., 2020; Salmons et al., 2022). (3) Age: Nine studies were conducted on adults aged 18 and above (Barene et al., 2014; Barnet-Lopez et al., 2016; Byrka and Ryczko, 2018; Delextrat et al., 2016; Domene et al., 2016b; Meekums et al., 2012; Muyor et al., 2017; Norouzi et al., 2020; Rao et al., 2020), three on college students aged 18-24 (Adilogullari, 2017; Donath et al., 2014; Meric and Ilhan, 2016), and four on older adults aged 50 and above (Boing et al., 2023; Marquez et al., 2017; Pacheco et al., 2016; Salmons et al., 2022).

Dance intervention characteristics

In this review, "Latin dance" refers to ballroom Latin styles included in the studies reviewed, such as Cha Cha, Rumba, Jive, and Samba, which are distinct from Latin social dances like Salsa. The dance interventions examined in the included studies varied in type, duration, and frequency. A range of dance styles were employed, including Zumba ($n = 5$), Latin dance ($n = 4$), Dance Movement Therapy ($n = 3$), Salsa ($n = 1$), Colombian Caribbean Folk dances ($n = 1$), Aerobic dance ($n = 1$), and Belly dance ($n = 1$). The duration of the interventions ranged from 5 to 16 weeks, with 12-week programs being the most common. In terms of frequency, most interventions were conducted two to three times per week, while a few studies implemented once-a-week sessions.

Outcome

Across the 16 included studies, the majority reported that dance interventions were associated with improvements in either perceived physical appearance or PSE. Thirteen studies showed enhancements in PSE, often through positive changes in perceived body image and bodily self-perception (Barene et al., 2014; Barnet-Lopez et al., 2016; Boing et al., 2023; Byrka and Ryczko, 2018; Delextrat et al., 2016; Domene et al., 2016b; Marquez et al., 2017; Meekums et al., 2012; Meric and Ilhan, 2016; Muyor et al., 2017; Pacheco et al., 2016; Rao et al., 2020; Salmons et al., 2022). Five studies found that dance also reduced negative self-evaluation and SPA, particularly through increased self-performance and confidence (Adilogullari, 2017; Donath et al., 2014; Norouzi et al., 2020; Rao et al., 2020; Salmons et al., 2022). Two studies reported simultaneous improvements in both outcomes (Rao et al., 2020; Salmons et al., 2022).

Among the dance styles included in the studies, Zumba and Latin dance were the most frequently studied. Latin dance was shown to reduce SPA while enhancing PSE and self-confidence (Adilogullari, 2017; Marquez et al., 2017; Meric and Ilhan, 2016; Muyor et al., 2017). Zumba, DMT, and Belly dance were associated with improvements in body image and reductions in anxiety (Barene et al., 2014; Barnet-Lopez et al., 2016; Boing et al., 2023; Delextrat et al., 2016; Domene et al., 2016a; Donath et al., 2014; Meekums et al., 2012; Norouzi et al., 2020; Salmons et al., 2022). Perceived physical appearance and bodily attractiveness were assessed through self-report measures and are considered subdimensions of PSE rather than separate outcome variables.

Discussion

This review provides comprehensive evidence that dance interventions can positively impact SPA and PSE across a wide range of populations. For example, Zumba and Aerobic dance were linked to decreased SPA in women aged 18 to 40 (Donath et al., 2014; Norouzi et al., 2020), and DMT was effective for older adults, showing improvements in anxiety reduction and PSE (Salmons et al., 2022). Gender-specific outcomes were also evident: women demonstrated greater improvements in SPA reduction than men, likely due to higher initial levels of body-related anxiety (Adilogullari, 2017). These findings suggest that dance, as both a physical and expressive activity, may serve as a promising non-pharmacological approach to improving mental wellbeing. The psychological benefits were especially pronounced in women and older adults, with variations depending on dance type, frequency, and program duration (Abdollahi et al., 2023; Zhang et al., 2023).

Dance has been shown to reduce SPA by improving body confidence and reducing negative evaluation from others. This may be attributed to several mechanisms: social bonding during group sessions, redirection of attention from body image to movement, and the mastery of dance skills enhancing self-efficacy. These findings align with recent systematic reviews (Liu et al., 2023; Tomaszewski et al., 2023; Wang et al., 2022), which confirm the potential for dance to promote positive psychological states.

Dance also improved PSE across demographics. Studies found that Latin and Salsa dance improved self-perception and confidence in college students (Barnet-Lopez et al., 2016; Byrka and Ryczko, 2018; Meric and Ilhan, 2016), while DMT and Belly dance enhanced self-esteem and body image in older adults and breast cancer survivors (Boing et al., 2023; Meekums et al., 2012). These improvements are thought to arise from internal shifts in self-perception rather than external appearance, promoting a holistic appreciation of the body (Haugen et al., 2013; Tomaszewski et al., 2023).

Recent reviews (Dale et al., 2019; Tomaszewski et al., 2023; Zhou et al., 2023) support these outcomes and highlight how different dance forms and intervention durations may impact age and gender groups differently. Notably, more intense and longer programs appeared to yield stronger improvements.

In conclusion, dance interventions appear to positively influence both SPA and enhance PSE. While consistent trends are evident, future research should expand the demographic scope—particularly including adolescents and underrepresented genders—and explore the long-term effects and mechanisms of dance-based interventions in promoting mental wellbeing.

Limitations and future research

While this study contributes valuable insights into the effects of dance on SPA and PSE, it is essential to acknowledge the identified limitations. Addressing these limitations through future research endeavors would strengthen the robustness and applicability of the findings.

1. The study focused on adult participants and college students, with no studies assessing adolescents. Consequently, the findings may not fully capture the effects of dance on the mental health of younger populations. Future research should strive to include adolescents and children to provide a comprehensive understanding of the impact of dance on different age groups.
2. The literature reviewed primarily compared dance interventions with traditional exercise or daily activities. However, there was a lack of comparison between dance and other innovative forms of exercise such as high-intensity interval training (HIIT), mind-body practices like yoga and pilates, or alternative movement therapies. Additionally, there was insufficient exploration of the relative effectiveness of different dance styles.

3. The inclusion of different dance styles and age groups prevented the performance of a meta-analysis, which is generally preferred over a systematic review when feasible.
4. Gender bias emerged as a concern, as eight out of the 16 studies exclusively represented female. This exclusive representation limits the generalizability of the findings to a broader population. While future research should strive for more balanced gender representation, it is important to note that this may be difficult to address given that fewer men tend to participate in dance-based activities. nonetheless, efforts should be made to ensure a more comprehensive understanding of the effects of dance interventions across diverse populations.

Conclusion

In conclusion, this review demonstrates that dance interventions can effectively improve SPA and enhance PSE. Dance styles such as Zumba, Latin dance, Salsa, DMT, Colombian Caribbean Folk dances, Aerobic dance, and Belly dance have shown positive impacts on these psychological aspects compared to control groups, irrespective of age. Moreover, the results suggest that dance may have a more pronounced effect on improving PSE and reducing SPA in women compared to men. However, it is essential to acknowledge potential study bias and limitations. Overall, incorporating dance into mental health interventions holds promise for fostering wellbeing and body image perception among diverse populations.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

Author contributions

XL: Writing – original draft, Writing – review & editing. KS: Writing – review & editing. YL: Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was supported by the 2025 Research Start-up Fund Project of Jiangsu University of Science and Technology; the 2025 General Project of Philosophy and Social Science Research in Jiangsu Universities; the Major Project of Jiangsu Graduate Education Teaching Reform (JGKT23_A015); the Major Project of Philosophy and Social Science Research in Jiangsu Universities (2021SJZDA169); the Key Project of the 14th Five-Year Plan of Jiangsu Education Science (B/2021/01/37); the Special Key Project of the Yangtze River Delta Alliance of High-Level Industry-Oriented Universities (CSJZD202307); the Key Project of Higher Education Research of Jiangsu University of Science and Technology (GJKTZD202202); and the National Social Science Fund of China (21BTY060).

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.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 06 June 2025
DOI 10.3389/fpsyg.2025.1561150

OPEN ACCESS

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RECEIVED 15 January 2025
ACCEPTED 19 May 2025
PUBLISHED 06 June 2025

CITATION
Mao Q, Mastnak W and Guan R (2025) Chinese ethnic dance therapy: cultural anthropology and health science perspectives on Tujia ethnic dances.
Front. Psychol. 16:1561150.
doi: 10.3389/fpsyg.2025.1561150

Chinese ethnic dance therapy: cultural anthropology and health science perspectives on Tujia ethnic dances

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Introduction: Archaeological findings witness the anthropological roots of dance, while psychological, medical, cultural and aesthetic studies shed light on health promoting capacities and curative factors inhering in symbolic and expressive body movement. Since dance therapy became a multifaceted discipline in the middle of the 20th century, increasing evidence of beneficial effects has advocated the use of dance therapy in a broad spectrum of clinical and public health areas such as psychiatry, oncology, neurology, cardiology and geriatrics. Psychological and neurophysiological studies elucidated key mechanisms underlying dance therapeutic dynamics, and ethnological studies highlighted the wealth of indigenous dances alongside their impact on holistic well-being, hence the term 'ethno-dance therapy', which also relates to dance traditions of ethnic groups in China.

Methods: Narrative/descriptive ethnological research provided detailed insights into dance traditions of the 55 officially recognized ethnic groups in China such as the Uyghur, Miao and Wa. Considering dance ontological perspectives, a triad of Tujia dances was chosen for this article. On this basis as well as own field studies, cultural-anthropological, psychological, physiological and neurophysiological knowledge was used to construct hypotheses about health-relevant features and factors. In terms of meta-methodology, such inferential reasoning brings about multi-disciplinary meta-syntheses, which differ considerably from the conventional understanding of this genre.

Results: Our analysis of Tujia dances suggests nine distinct therapeutic principles and benefits regarding (i) cardiovascular health, (ii) musculoskeletal health, (iii) neuroplasticity and network connectivity, (iv) self-exploration and self-expression, (v) self-actualization and ontological anchoring, (vi) hypnotherapeutic dynamics and altered states of consciousness, (vii) symbolic interaction and ritualized social roles, (viii) therapeutically advantageous changes of attitudes, (ix) aesthetic immersion and the dance-self.

Discussion: The broad spectrum of beneficial effects of Tujia dances may improve dance therapy in various medical areas and enhance culturally sensitive public health systems. Further research should focus on underlying mechanisms, involve dances from further ethnic groups, explore cross-cultural transferability to more precisely differentiate archetypal/anthropological and culture-dependent factors, and to clearly identify dance therapeutic functions within complex medical and psychological treatment plans.

KEYWORDS

China, cultural sensitivity, ethnic minorities, ethno-dance therapy, Tujia dance, health promotion, World Health Organisation

1 Introduction

Since time immemorial, human cultures have given birth to a myriad of dance phenomena, and dance archaeology (Garfinkel, 2014) is about to discover anthropological sources of and reasons for symbolic movement and artistic body expression. Approaches combining comparative, developmental and cross-cultural psychology (Christensen et al., 2017) highlight the dual anthropological character of dances including aesthetic experience and neurobiological effects. Empirical evidence is given for six neural and bio-behavioral functions, i.e., attentional focus and flow, basic emotional experiences, imagery, communication, self-intimation and social cohesion.

Increasing awareness of health promoting factors and the healing potential of dance inspired systematic studies alongside distinct applications of dance in clinical areas and public health, and eventually resulted in the foundation of dance therapy as a new discipline. Arguing that dance became 'therapeutic in the mid to late 20th century', Kormos (2023) gave an account of the modern era of dance therapy, which focused particularly on developments in Hungary and the United States. Elucidating that the convergence of dance art and therapeutic culture engendered the development of dance-movement therapy, he refers to postmodern dance as a source of dance therapeutic methodology and lays stress on aesthetic and cultural differences between Hungary and the USA alongside their decisive impact on dance therapeutic models. This argument also applies to key principles of the present article that revolves around the complex phenomenon of Chinese ethno-dance therapy.

Regarding the international realm of dance therapy, we may distinguish between three complementary approaches dealing with (i) therapeutic features of dance traditions and genres, (ii) dance therapeutic models to treat manifest diseases or alleviate symptoms, and (iii) underlying mechanisms, e.g., psycho-affective dynamics and neurophysiological processes. By way of illustration, Expressive Flamenco (Sánchez García and Pinna-Perez, 2021) is meant to improve psycho-social, spiritual and aesthetic connections to the unconscious, as well as to help practitioners to 'transcend the self into divine connection with their authentic self', while more clinical or developmental psychological applications relate to topics such as trauma therapy (Koch et al., 2019) and personal growth of children with special needs and cognitive impairment (Mastnak, 2022). Regarding beneficial effects on the motor system, Tango therapy showed efficacy in improving gait speed and mitigating the decline of functional mobility (Bracco et al., 2023) alongside improvement of motor and non-motor symptoms in patients with Parkinson's disease (Docu Axelerad et al., 2022); and dance-music-poetry integrating 'Sega' in Mauritius became object of therapeutic and health promoting studies involving children with special needs as well as older people with mild dementia and/or deficient social inclusion causing psycho-affective issues (Mastnak et al., 2021).

Increasing evidence of beneficial effects advocates dance therapy for a broad spectrum of medical conditions such as to improve peak oxygen consumption VO_2 and health-related quality of life (HRQOL) in patients with chronic heart failure (Gomes Neto et al., 2014) and to modulate Parkinsonian gait alongside positive effects on balance, functional mobility and cognition (Hasan et al., 2022). While these effects mainly depend on physiological, e.g., cardiorespiratory, parameters or distinct synchronization within the brain's motor system, dance therapy showed benefits in complex pathological and psychosomatic areas, e.g., oncology and psycho-oncology, as well. Statistically significant improvements were found in favor of community dance for 'functional capacity, fatigue, quality-of-life and depression' (Nelson et al., 2023), while differential oncology advocates the identification of specific dance therapeutic benefits for patients with various oncological conditions such as breast cancer (Goodill, 2018).

Despite numerous studies suggesting considerable dance therapeutic benefits for cancer patients, Cochrane reviews surprise with statements such as 'we did not find support for an effect of dance/movement therapy on depression, stress, anxiety, fatigue and body image' (Bradt et al., 2015). These contradictions will not harm positive results, but rather unearth the shortcomings of Cochrane paradigms and practices alongside serious inherent systemic weaknesses. Not only that they solely assess studies with reference to their own standards, while widely ignoring scientific epistemology and correspondence theory of truth, they also neglect obvious mistakes. For instance, randomization does not necessarily create analogous samples, hence the necessity that RCTs take the estimated difference between the means of an intervention group and its control into account. Science-epistemological, mathematical and statistical research is about to reveal the multiple shortcomings of several standardized evidence-oriented research models, and novel designs such as dynamic simulation or virtual cohort studies are expected to replace what is sometimes called the 'gold standard' in evidence- based research. This innovation also applies to dance therapy and will provide complex dynamic models that combine quantitative and qualitative parameters, and respect both individualized medicine and cultural sensitivity.

Evidence-oriented research is designed to evaluate effect-sizes but cannot explore the nature of healing processes. Comparing the back-box of (early) behavioral psychology with principles of evidence based medicine, i.e., 'not to look into,' the cognitive revolution with its ambition to discover internal mental processes driving human behavior resembles today's interdisciplinary attempts to discover profound curative principles. Advanced ethno-therapeutic research integrates psychological thought, e.g., about cognitive processing and depth-psychological symbolization, neuroscientific techniques such as functional magnetic resonance imaging, and health-related wisdom inhering in cultural traditions such as communication with spirits in Mongolian shamanism.

Being crucial for developmental, re-constructive and rehabilitative cortical changes, neuroplasticity is a key factor of dance therapy. In this context, a systematic review from Brazil (Teixeira-Machado et al., 2019) summarizes that dancing is able to alter brain volumes and structures, brain functions, psychomotor adjustment, as well as levels of neurotrophic factor. All included studies demonstrated positive structural or functional changes relating to increased hippocampal volume, grey matter volume in the left precentral and parahippocampal gyrus and white matter integrity. Functional changes included alterations in cognitive performance such as significant improvement in memory, attention, body balance and psychosocial parameters. Further studies on dance and neuroplasticity coincide with these findings and highlight dance-related improvement of functional connectivity, cognitive performance and increased brain volumes in healthy older people (Nascimento, 2021), as well as positive effects on cognitive deterioration in older adults with mild cognitive impairment (Wu et al., 2021).

In addition to these genuine neurophysiological benefits, a recent systematic review (Foster Vander Elst et al., 2023) emphasized dynamic interconnections between music and dance, as well as engaged overlapping brain networks involved in perception, action, emotion and–of particular importance–eudaimonia, hence the used term 'hedonic brain networks'. Addressing the complexity of neurophysiology, psycho-affective dynamics and cultural factors, such studies hit a key issue of our article, i.e., the complementarity of culturally sensitive factors of dance therapy and anthropological invariant conditions. In other words, while dance movement in general will impact on neuroplasticity, regardless of its cultural appearance, the artistic features of dance are brimming with meaningful symbols, biographical significance and cultural familiarity. These facts inspired the authors' 'three spheres model' of dance therapy, the inner sphere representing genetically determined and anthropologically (relatively) invariant neurophysiological conditions, the middle sphere describing psychological mechanisms such as cognitive or subconscious processing, and the outer sphere consisting of distinct cultural phenomena.

While the inner sphere is inextricably intertwined with genetic, epigenetic and neuroscientific conditions, the middle and particularly the outer sphere embody genuine cultural features such as shape and meaning of the Baishou Dance (Li, 2020) – 摆手舞, literally 'hand-waving dance'–of the Tujia people in Xiangxi. The dance originates from an ancestor worship ceremony and looks back over a tradition of about 1,000 years. Akin to today's community dance therapy movements, the Sanam (Mackerras, 1985) with its gradual acceleration and characteristic movements of the neck, elbows, fingers and eyes is typical for the Uyghur people of the autonomous region of Xinjiang. Being linked to social ceremonies, this dance may evoke feelings of community-based well-being alongside ethnic identity and inclusion.

The Chinese dance genre Yangge–秧歌, literally 'Rice Sprout Song'–(Du, 2017) encompasses rich aestheticization of daily life, which goes hand in hand with self-actualization and work-identity. Artistic modes of coping and creative transformation of issues remind of expressive catharsis and cathartic symbolization in Western dance therapy. Comparable to exorcism and healing rituals of the Shang Dynasty, Nuo dance 傩舞 (Yang, 2018), Nuo sacrifice 傩祭 and Nuo ceremony 傩仪 are meant to drive away evil influences and disease, while Dunhuang dance draws inspiration from the Dunhuang grotto frescoes in Gansu province, combining aesthetic dynamics of these images with modern dance elements. Particularly the (painted) movements of flying apsaras 飞天 Fēitiān – celestial beings that accompany Buddhas – gave rise to dance therapeutic considerations for treating obsessive compulsive disorders (mental liberation), schizophrenia and psychotic disorders, where hallucinations undergo a transformation from pathological entities to a unique source of creative art.

Concluding the impact of this introduction on the present research, we integrated (Western) view and theories of dance therapy, cultural anthropological considerations and psychological as well as medical perspectives to explore Chinese ethno-dance therapy, particularly a triad of Tujia dances, which form the main part of our article.

2 Methods

Broadly speaking, there is hypotheses generating and hypotheses assessing research. Evidence based medicine is closely connected with hypotheses assessing research such as randomized controlled trials and meta-syntheses. While these methods are not geared for genuine innovative research, the world of science needs substantial progress. And yet, findings that are processed in meta-analyses may converge in a hypothesis-generating way, which gave rise to new dual study designs such as 'Neuroscience and Dance' (Foster Vander Elst et al., 2023), which comprise both a 'conceptual framework' and a 'systematic review'.

While systematic reviews and meta-syntheses follow operationalized algorithms, which enable artificial intelligence to go autonomously through relevant procedures, genuine innovative research is per se not standardized and requires human inventiveness, comprehensive thinking and epistemological talent. In other words, while in the near future AI-systems are expected to conduct systematic reviews and meta-analyses by themselves, progress in scientific research will also benefit from systemic meta-syntheses (Mastnak, 2021), which differ considerably from meta-syntheses that synthesize qualitative literature, e.g., in psychiatry (Lachal et al., 2017).

Systemic meta-syntheses involve essentially cross-disciplinary investigations, inferential reasoning and screening of relevant system-compatibility, such as in Chinese arts-based psycho-oncology (Mastnak and Mao, 2021). This model inspired the present study, which integrates data and findings about traditional dances of the Tujia population that stem both from ethnological research and own field work.

Concerning ethno-dance therapy in general and Chinese ethnic dances in particular, the second author of the present study (Mastnak, 2024) suggested a framework comprising (i) ontological identity such as determined by myths about the universe, origin of life or righteousness, (ii) social inclusion and collective support, (iii) aestheticization and expressive catharsis, (iv) symbolic exorcism, (v) trance, and (vi) mindfulness. This framework defined the first screening, which eventually resulted in the selection of a triad of Tujia dances that have, from a meta-therapeutic perspective, a complementary 'inner logic'.

Our dance-therapeutic synthesis tried to find a/the rationale behind myths and traditional wisdom, as well as explanations given by authentic experts who stem from the ethnic culture referred to. Relating to the visible shape of dances, we referred to movement analysis systems such as the classical Laban model (Bernardet et al., 2019), which focus particularly on body dynamics, movement shapes and the dynamic relationship between body and space. A further dimension involves views from dance therapeutic schools and theories, while a last perspective is dedicated to cultural psychological and symbol-theoretical considerations. Integration of these perspectives should help to unearth the essence and inner nature of the holistic phenomenon of Tujia ethno-dance therapy.

While replication of studies are considered a standard to re-assess effects of interventions under comparable clinical conditions, regarding the present research characteristics replication could result in different and/or complementary theoretical frameworks and categetorizations of health promoting benefits of Tujia ethnic dances. Starting conditions of such a study would be identical, namely based on (i) ethnological data about Tujia ethnic dances comprising both genuine raw data and scientific analyses and considerations, (ii) relevant therapeutic, medical-anthropological and dance therapeutic theories, and (iii) complex interdisciplinary methods and meta-methodological as well as epistemological reasoning. Processing

would lead to identification of health promoting and therapeutic factors and mechanisms, consequently give rise to comparative research and eventually initiate the construction of a new meta-synthetic theoretical model.

3 Results

On the basis of our investigations we assume that Chinese dance therapy covers three areas: (i) dance therapy related to Traditional Chinese Medicine TCM. Concerning the term TCM, we point out that the Chinese expression is 中医 or 中医学, which means 'Chinese medicine' or 'Chinese medical knowledge'; given that there is only one realm of Chinese medicine, experts criticize that the use of the word 'traditional' is tautological; (ii) a broad spectrum of new Chinese models integrating dance in therapeutic or health promoting frameworks, as well as other relevant concepts such as rhythmic education; (iii) curative features in dance traditions of ethnic groups in China, the so called 'ethnic minorities'. Although the third research perspective is quite new it seems to be immensely promising and may greatly impact on the future of ethno-dance therapy. This is the reason, why our findings relate to this area, particularly the Tujia ethnicity. Moreover, the Chinese realm of healing dances and dance therapy also encompasses several Western models such as Dance Movement Therapy.

3.1 Ethnicities in China and the culture of the Tujia people

Different from Western countries, Chinese passports also contain the ethnic background of the passport holder. About 90% of people with Chinese citizenship are Han, the other 10% belong to the 55 (officially recognized) ethnic minorities, which importantly contribute to the cultural richness in China. Protection of their traditions and support of their welfare is a major aim of Chinese policies, and concerns their language and culture, equal rights and enhanced self-organization.

A wealth of ethnic minorities witness the complex and dynamic history of East Asia, such as the Hmong–in Chinese language 苗族 Miáozú–in southwest China as well as in Vietnam, Laos and several other countries, or the Uighur–in Chinese 维吾尔族 Wéiwúěrzú–in the Xinjiang province in the northwest of China. Moreover, there are Korean ethnic groups, the 朝鲜族 Cháoxiǎnzú, in the northeast of China, a region that has been importantly influenced by Russian cultures. Some ethnic groups look back over very long traditions, even comparable to that of the Han. One of them is the Tujia population, 土家族 Tǔjiāzú, who lives in the mountains of the Hunan province. This region has become particularly famous as the site of the movie 'Avatar'. As far as we know, all these cultures contain healing dances and dance rituals, often combined with music and dramatic elements, which can be understood as ethnic dance therapy. Further interdisciplinary anthropological, ethno-medical and dance-therapeutic research is needed to unearth the richness of these traditions, as well as their relevance for culturally sensitive public health systems.

The Tujia ethnic group, in Tujia language 'Bifzivkar', inhabits the mountain regions at the border between central and western China, i.e., the provinces Hunan, Hubei and Chongqing. Exploring the origins of Chinese dance therapy, we came across with roots dating back to the time of the Tujia settlement in today's Zhangjiajie 张家界 region. The Tujia core area comprises the Wuling Mountains 武陵山脉 with abundant rainfall and high humidity as climatic characteristics (which is for researchers sometimes tough to bear). The unique environmental and climatic conditions had a distinct impact on how the Tujia formed their living spaces and cultures. Villages were (and still are) surrounded by magnificent mountains, steep canyons and quickly moving clouds, which evoked their ancestors' mystical fantasies and eventually gave rise to their dance symbolism. Rituals to harmonize the coexistence of humans and celestial beings used body language, and dance-dramatic performances should make the spirits benevolent. A wealth of utensils was created to strengthen religious memory, and primitive mysterious Tujia dance became one of the hallmarks of their spiritual culture.

Comparable with myriads of archaic and animistic cultures on the blue planet, also the Tujia were highly influenced by environmental factors and tried to control the 'spirits behind'. Such similarities suggest common anthropological roots and go hand in hand with the inner sphere of dance therapy as described above. For instance, the Tujia people worship the white tiger as their ancestor. Symbolically transformed, the animal's rugged, heroic and vigorous nature inheres in many ritual dance movements of the Tujia and characterize a lot of folk dances as well. In a similar way, traditional Tujia dances express, for instance, how animals wave their tails, walk, hunt or wash their faces. In sum, this holistic body-soul and human-spirit balance, which importantly embodies health philosophies, has made Tujia dances a valuable cultural heritage in China.

3.2 The Tujia dance triad and the holistic balance of health

The result section of this article revolves around the dance therapeutic features of a distinct triad of traditional Tujia dances, (i) the Hand Waving Dance 摆手舞 Bǎishǒuwǔ, which relates to work, vitality and the spices of life, (ii) the Bronze Bell Dance 铜铃舞 Tónglíngwǔ, which is a key ritual to worship nature and the ancestors, and (iii) the Maogusi Dance 毛古斯舞 Máogǔsīwǔ, which is a spiritual means to communicate with ghosts, including offering sacrifices and prayers for the future.

This triad may (or should) be understood as representation of a holistic health system, which is based on the ontological balance between three pillars of existence: (i) the actual experience of being and vigorous self-actualization in life, (ii) the people's evolutionary chain including grateful awareness of the ancestors, who handed down life alongside the wealth of culture and wisdom, and (iii) the existential forces behind, in other words, the world of spirits and gods.

In this context, health is determined by the inner dynamic equilibrium of this system, while falling out of it entails the emergence of illness. Dance is a symbolic and embodied means to celebrate, maintain and continuously readjust this ontological equilibrium, which fundamentally differs from one-dimensional principles of causality in the sense of 'one specific remedy cures one specific symptom'.

The concept of 'Tujia ethnic dance therapy', characterized by cultural specificity and therapeutic value not only aligns with

contemporary societal demands for physical-mental wellness but also facilitates the preservation and development of traditional Chinese Tujia culture (Rodsaaad et al., 2023; Jain and Brown, 2001). As a crystallization of Tujia wisdom, this dance form embodies profound cultural connotations intrinsically linked to ethnic traditions, customs and collective spirituality (Vermes, 2019). Through its choreographic elements—including body movements, gestures, facial expressions, costumes, and musical accompaniment—it conveys specific meanings and emotions that reflect interpretations of nature, daily life, and spiritual beliefs (Fausto et al., 2024; Aithal et al., 2023). These cultural components foster cultural identity and belongingness, thereby enhancing psychological resilience and mitigating psychological stress (Mandlik, 2015; Brown and Cameirao, 2023).

Dance inherently possesses psychotherapeutic potential through multiple pathways influencing mental health. First, it serves as an affective medium enabling emotional expression and regulation, particularly for complex emotions like grief and anger (Handayani, 2021). Second, dance enhances cognitive functions such as memory and attention through the neurocognitive engagement required for movement memorization (Su, 2024). Third, collective dance participation promotes social interaction, strengthens interpersonal relationships, and reduces loneliness and social isolation (Wildeman et al., 2024). Additionally, mastery of dance techniques and successful performances can elevate self-esteem and confidence (Cheng et al., 2024). Emerging evidence further suggests that dance improves physical functioning in older adults by enhancing balance, coordination, flexibility and fall prevention (Heiberger et al., 2011). These multidimensional benefits—spanning physiological, psychological, social, and neurological domains—collectively contribute to holistic well-being.

As cultural heritage, Tujia ethnic dance warrants deeper exploration for its mental health applications. Culturally embedded dance practices provide therapeutic interventions with contextualized significance, particularly as they embody historical narratives, value systems and lifestyle patterns of specific ethnic groups (Sun and Sun, 2009). Cultural elements such as traditional music, attire and symbolic movements can evoke ethnic identity and pride, reinforcing psychological belongingness and cultural confidence (Kim and Kim, 2013; Tang, 2023), which are critical factors for maintaining mental health amid sociocultural transitions (Mastnak, 2024; Capello, 2007; Pangestu, 2021). Moreover, culturally specific rhythms and movements may correlate with particular emotional states, facilitating affective expression and catharsis (Conner et al., 2020; Delattre et al., 2024). Group-based dance activities further enhance social cohesion and mitigate isolation through communal participation (Herdiani and Munggaran, 2023; Darko, 2024; Qu et al., 2023).

From a dance therapy perspective, the uniqueness of Tujia dance lies in its potential alignment between movement patterns and psychological states. As a nonverbal psychotherapeutic modality, dance therapy utilizes bodily expression for emotional release, stress reduction and self-awareness enhancement (Auliya and Yudiarso, 2022; Cai et al., 2023). Symbolic movements in Tujia dance such as nature mimicry, emotional storytelling, or harvest celebrations may aid in emotional articulation (Agung Prameswari, 2021; Fahrurrozi and Yuda, 2022). The accompanying music and rhythms also exert mood-modulating effects, with lively tempos energizing participants and slower melodies inducing relaxation (Ning, 2023; Zhao et al., 2022). Thus, integrating Tujia dance into therapeutic frameworks offers culturally sensitive and creative mental health interventions.

Empirical studies highlight the Hand-Waving Dance 摆手舞, a quintessential Tujia cultural symbol, as more than mere entertainment; it serves vital sociocultural functions in festivals, rituals and communal prayers (Tang, 2023). Participation strengthens ethnic identity and psychological well-being, particularly crucial during rapid industrialization that threatens traditional lifestyles (Zafeiroudi, 2023). Academic investigations into its primordial and modern functions aim to optimize its role in societal harmony and comprehensive well-being (Zu-guo and Wan-hong, 2010). The dance's pedagogical structure maximizes learner autonomy while fostering collective consciousness and aesthetic harmony through unique relational dynamics.

Consequently, developing Tujia dance therapy represents a necessary synthesis of cultural preservation and mental health imperatives. By harnessing its cultural and therapeutic values, this approach can advance individual wellness while safeguarding intangible heritage. The question 'What does Tujia dance therapy heal?' must be posed in a way that complies with the Tujia's systemic view of health.

From a meta-theoretical point of view, the contradiction between quantitative evidence-based medicine (in the sense of Cochrane principles) and complexity science in systemic health care (Chandler and Hopewell, 2013; Joachim and Carmel, 2013) springs to mind. While conventional evidence-based medicine narrows its epistemological value down to effect sizes (which are, from a mathematical and medicine theoretical point of view doubtable too), complexity science in medicine advocates a dynamic multi-factorial correspondence theoretical approach. From this perspective, the Tujia dance triad that we are dealing with becomes surprisingly modern and resembles much more the paradigms and features of complexity clinical and public health science than monocausal therapeutic approaches.

Moreover, we find a myriad of similarities between the Tujia dance triad and Western therapeutic approaches and schools of thought. The Hand Wave Dance is akin to cognitive behavioral approaches which support positive attitudes towards one's actual existence alongside embodied self-actualization, vigorous self-identity and the important role one plays for fruitful social dynamics. The Bronze Bell Dance goes hand in hand with the awareness of being part of the nature as well as the genetic and epigenetic transmissions that determine our deep biological determination as well as cross-generational experiences. These processes involve mindful self-discovery and complement existential philosophical issues in counselling, psychotherapy and psychiatry. And while many conventional Western methods work with cognitive reasoning and verbal exchange, the Tujia dance triad uses symbolic experience and an embodied 'recognition' with high health promoting impact.

From a dance theoretical and dance therapeutic point of view, these three dance entities are strikingly different. While the Hand Waving Dance may remind of social dances, the Bronze Bell Dance can be regarded as a dance-dramatic ritual, and the Maoguisi Dance contains Shamanic features. These differences also impact on their socio-cultural function and embedment. Together with dance therapeutic analyses, the following sections present and discuss findings about this Tujia dance triad.

3.3 Positive vitality: the hand waving dance

Different to numerous ethnological studies and documentary data about the Hand Waving Dance, which is at the same time the most popular one of this triad, there is, to our knowledge, still a complete lack of research on its therapeutic and health promoting features.

How practitioners of this dance described its features and impact on individuals as well as the entire society, served as initial source of our health-oriented considerations. They emphasized that the dance symbolizes, similar to work-dances in other cultural traditions, both features of and identity with labor, which also explains its numerous variations.

However, a deeper look at its characteristics as well as the dancers' attitudes and experiences reveals that the Hand Waving Dance goes far beyond mere transpositions of labor into artistic media, and our analyses suggest seven factors with relevance to therapy and health care: (i) consistent identity and self-actualization, (ii) contribution to and celebration of perpetual development, (iii) embodied vigor and holistic energy, (iv) joy of being and hedonic sensitivity, (v) social inclusion and mutual emotional security, (vi) mindful liberation and bodily flow, and (vii) holistic (ontological) synchronization.

While originally self-actualization was at the top of Abraham Maslow's hierarchy of needs, meaning that it rarely could be achieved, several psychological positions have underscored the crucial importance of giving full play to one's creative, intellectual and social potential, which is confronted with the dual challenge of tackling life conditions and adjusting attitudes. Practitioners may experience the Hand Waving Dance as a means to consolidate self-acceptance and role-identities in a way that also allows profound changes following mindful self-liberation (see point vi).

The wide and rotating arm movements of the Hand Waving Dance call the idea of perpetual dynamics of existence to mind, although the Buddhist belief in reincarnation and the Daoist concept of eternal transformation do not belong to genuine Tujia thought. Concerning the dynamic dance shapes, we recognized considerable differences, though. While highly artistic performances were dominated by controlled arm movements, more common performances often tended to make use of biophysical impulse-interactions, which reminded somehow of warming-up exercises in sports. But they expressed a strong innate impetus, why we assume that the second mode has higher identity characteristics than the 'professional' one. This observation also relates to mindful liberation and bodily flow. We recognized a highly natural use of biophysical responsiveness, a substantial interaction between body-awareness, muscular action and the laws of inertia and gravitation. Regarding hypotheses alongside unsolved issues, we intend further studies on this phenomenon using electrophysiological and qualitative sensory approaches.

This dissimilarity between celebrating (cultural authenticity) and performing (artistic genre) the Hand Waving Dance also affects what we refer to as embodied vigor and holistic energy. Experienced coalescence of the dance and the self seems to release energy while dissolving inner blocks. Although in Western medical and biopsychological circles the notion of energy is discussed in a very heterogeneous way, our assumption is in a sense compatible with Mihaly Csikszentmihalyi's concept of flow, certain neuropsychological positions about dynamic network connectivity and TCM views of dynamic energetic balance. Phenomenologically, practitioners describe a positive, both psychological and physiological pervasive energy. Discussing cross-cultural transferability, we assume that this very identity with movement importantly influences the dopaminergic reward system and integrating central nervous structures such as the anterior insular cortex, which also plays a crucial role in neuroaesthetics. At the moment, these considerations have hypothetic character and require psycho-physiological studies. According to subjective experiences, this positive holistic energy goes hand in hand with a most immersive joy of being, ecstatic excitement, and releases afresh the sense of mindful self-liberation.

The Hand Waving Dance is very popular among Tujia people and performed by both common people and professional dancers. It can be regarded a group or community dance with several variations including circular shapes, formations with dispersed dancers, or dramatic changes and encounters. While in our opinion many non-professional dancers looked more authentic, both realizations express a high degree of social inclusion and community-based emotional security. Symbolization of mutual support and non-manipulative participation becomes transparent and mirrors a key human desire that is well known from family and partner therapy and expressed in countless poems: mindful inner connection together with the awareness that 'no tree grows in the shadow of the other'. In this regard, we find a fascinating mode of dance synchronization which most obviously goes beyond pure technical co-ordination. At a certain point–particularly in non-professional Hand Wave Dance activities–we got the impression to witness the emergence of a holistic ontological synchronization and its soothing inner force.

The shape of the dance itself is characterized by typical arm swinging and rotating, often together with spiral torsions, which call Moshe Feldenkrais's assumption about archaic principles of human body movements to mind, although dynamic features may differ. While the flowing movements of some artistic performances look elegant, other styles involve abrupt elements that remind, for instance, of the Bakse dance and its therapeutic implications. The Hand-Waving Dance, as its nomenclature suggests, primarily features distinctive hand movements that form the core of this traditional practice. These oscillatory motions simulate various productive labor activities, domestic scenarios, and combat situations through differentiated swinging patterns (Yang et al., 2018; Liu et al., 2017). The coordinated interaction between upper and lower body movements generates unique choreographic vocabulary, characterized by isotropic extensions throughout the kinetic chain (Cai et al., 2023). A fundamental movement pattern, the 'Driving the Pig Step 赶猪步', exemplifies this through its simulation of livestock herding. This ipsilateral limb coordination (homolateral arm-leg movement) combines knee flexion, vibratory motions and downward weight shifts. Dancers lean forward while executing alternating arm swings that mimic animal propulsion, synchronized with rapid footwork conveying pursuit dynamics. This movement not only symbolizes the Tujia ethnic group's emphasis on animal husbandry but also metaphorically represents collective cooperation in agricultural productivity. The synchronized 'same-side hand swing with corresponding footstep' pattern embodies the rhythmic coordination inherent in communal labor practices. Another foundational movement, the 'Grinding Tofu Step 磨豆腐步', replicates tofu preparation through waist-centered rotations and continuous arm push-pull motions. Dancers perform spiral oscillations ('four triple-time movements') simulating millstone circumrotation,

complemented by stable footwork emphasizing endurance and equilibrium in labor processes. This movement serves as both a cultural record of traditional dietary practices and a symbolic representation of meticulous craftsmanship, reflecting the Tujia people's wisdom in natural resource utilization.

These movement patterns share common choreographic characteristics rooted in productive activities (Jianbing, 2020): (i) Sturdy movements with bold lines and dynamic force; (ii) Predominantly ipsilateral limb coordination (right arm with right leg, left arm with left leg); (iii) Restricted hand movement amplitude (generally below shoulder height); (iv) Natural torso undulations synchronized with limb movements, typically incorporating rhythmic waist rotations and knee flexion; (v) Evolving spatial formations (circular, serpentine configurations); (iv) Expressive facial relaxation with smiling countenance, conveying celebratory atmosphere.

These kinetic characteristics embody the Tujia's pursuit of 'harmonious natural philosophy'. The juxtaposition between the vigorous 'Driving Pig Step' and meticulous 'Grinding Tofu Step' reflects the Eastern philosophy of combining vigor and gentleness. Cyclical movement repetitions metaphorically signify life continuity and natural rhythms, while coordinated group patterns manifest ancestral wisdom in ecological adaptation and social cohesion. This embodied knowledge system preserves ethnic memory through corporeal semiotics, offering insights into minority cosmologies in southwest China. Contemporary dance analysis methodologies, including Laban Movement Analysis (Sutopo et al., 2019) and Systemic Functional Dance Discourse (Maiorani and Liu, 2023), enable granular decomposition of these movement units. Such approaches facilitate examination of kinetic quality, spatial utilization, and inter-movement relationships, potentially advancing applications in ethno-dance therapy.

3.4 Embodied symbolism: the Bronze Bell Dance

While everyone is invited to perform the Hand Waving Dance, the Bronze Bell Dance is only celebrated by chosen people, except 'imitations' or re-plays of the Bronze Bell Dance, e.g., in educational domains such as elementary or junior high schools. It is a traditional ritual worshiping the nature and the ancestors, which is a very common practice in China, though. Comparable to a myriad of other rituals, symbolic costumes and properties are indispensable, as well as the musical function of the drum, the gong and the Suona, a double-reed instrument similar to the Iranian Sorna and the Middle European Schalmai with its characteristic penetrating and highly expressive sound. These instruments are also akin to the ancient Greek Aulos, which was regarded a means to express and heal traumatic injuries of the soul.

The dance is characterized by forceful movements, body flexion, asymmetric arm spirals, broad stances and energetic leaps and stamping, dominated by vital impulses. In a repetitive way, music and dance are linked by intensifying accelerations, which culminate in a highly energetic standstill. The whole process is accentuated by interjections such as 哼 Hmph and 哈 Ha, which have no proper semantic meaning.

Comparing the three dances from an interdisciplinary perspective, we may differentiate awareness, evolution and function. The Swiss philosopher and anthropologist Jean Gebser (2020) suggested distinct phases of consciousness characterizing the evolution of the human mind, i.e., an archaic, a magic, a mythological, a rational and a holistic-integral one. According to his cultural-evolutionary framework, the Hand Waving Dance is the most 'modern' one, which focuses on the interplay between individuals and the society, as well as hedonistic attitudes and the delight of self-actualization.

The Bronze Bell Dance relates to Gebser's mythological stage, which is dominated by rituals and myths, as well as transcendent ontological awareness. Profound dance experiences of being (part of the) nature as well as a transient manifestation of evolutionary and hereditary dynamics relate to the genetic bond with ancestors, as well as the epigenetic involvement in cross-generational cultural experiences. Thus, the dance contributes to self-awareness alongside gratefulness and re-adjustment of one's being in a wider social and evolutionary context.

Regarding Jean Gebser's theory, the next dance we are dealing with, the Maogusi Dance, is the most archaic one. According to Gebser, the human mind is characterized by predominant states, but does not abolish the previous ones. This means that also 'modern people' encompass features of archaic, magic and mythologic awareness, use them to experience oneself and the world, and can also be used for therapeutic purposes. This decisively impacts on therapeutic means, which may also be pre-rational, e.g., beyond the repertoire of cognitive behavioral therapy. In sum, dance therapeutic approaches inspired by these Tujia dances may involve different functional features, which are also mirrored by various psychotherapeutic approaches using rituals, trance or archaic imagination.

3.5 Spiritual ontology: the Maogusi dance

The Maogusi dance mirrors the roots of Tujia Shamanism and was originally the way to communicate with ghosts and to sacrifice to them. In many archaic and animistic cultures, shamanism is brimming with dance, music, dramatic elements and symbols alongside altered states of consciousness. Being one of the pioneers of research on shamanism, Mircea Eliade (1961) pointed out that the shaman merges spiritual and medical functions, he or she is a spiritual master, who usually gained his power through initiation rituals, and a healer, who cares for the health balance in his tribe and negotiates illnesses and curative means with responsible ghosts. This also pertains to the Maogusi Dance as key ritual of Tujia Shamanism.

However, these ancient practices underwent transformations, and today we mostly find two phenomena. One is both in Tujia circles and in the wider Chinese community regarded as epic dance-theatre. It revolves, similar to myriads of epic genres in various cultures, around the origin and spirit of the Tujia population. The art of telling, remembering and celebrating a people's history belongs without a doubt to the most precious treasures of a culture. Strikingly contrasting, we also came across with simplification of the Maogusi Dance for touristic purposes, interludes on sport events or shows on funfairs. Regarding similar practices that eventually resulted in the loss of the original phenomenon, we emphatically advocate awareness of the roots and protection of cultural heritage, particularly if it is connected with health care.

From a dance therapeutic perspective, we may differentiate three possible transformations, which go beyond the original purposes, but still contain their spirit: (i) settings according to psychotic symptoms or schizotypal personality traits, (ii) communication with diseased people similar to psychodramatic and imaginative methods, and (iii) spaces for culturally sensitive spiritual interchanges and/or parapsychological experiences.

Creative dance and drama proved to be a feasible and promising means for people with psychotic hallucinations and schizotypal ideation (Howe, 2022; Moreno and Casson, 2004; Mørck and Stanghellini, 2023), to connect with their sensations in a positive way, and in some cases of medication resistance to even control them; or to take them as a source for creative developments, which may change their (often devastating) labelling as mere pathological phenomenon. Moreover, creative dance and/or dance drama can help to process symbolized (pathological) contents in a depth-psychological hermeneutic way.

This also applies to a broad spectrum of bereavement conditions, including those with pathogenic potential. For instance, in the context of child oncology, parents may want to continue communication with their deceased child and seek appropriate rituals to cope with their loss and create spiritual bonds (Yeh et al., 2000). Culturally sensitive or cross-culturally inspired psychotherapy may be nourished by individually adjusted rituals such as the Maogusi Dance, not least in cases where grieving brings about pseudo-hallucinatory sensations, e.g., hearing the voice of the deceased or seeing his or her shadow (Bilu and Witztum, 1993).

3.6 Cross-cultural dance therapeutic values

Globally, arts therapeutic discussions are highly diverse, particularly with regard to cross-cultural transferability. While several schools of thought have a certain tendency to generalization, in our opinion dance movement therapy DMT is a typical example, interdisciplinary circles rather differentiate between anthropological principles, which are relatively independent from specific cultural features, and cultural embedment which causes limited cross-cultural applicability. The authors of this article adhere to the second position, which encourages similar ethno-dance therapeutic research alongside comparative studies. Moreover, the present Tujia dance analyses raise the question of possible general dance therapeutic principles, which resulted in the following nine factors:

- Cardiovascular health. Dance therapy can be regarded as arts-based endurance training and improvement of maximal oxygen consumption (VO_2 max). For this reason, it is used in cardiac rehabilitation as well as preventative cardiology. Depending on the patient's attitude, artistic activities may be more attractive than pure cardio-training, facilitates integration of exercises into life-styles and enhances life-long sustainability. In this realm, the Fudan University in Shanghai opens 2025 a research center for cardiac rehabilitation and arts therapies with distinct focus on this topic. Research on cardiorespiratory health associated with Chinese ethnic dance traditions is intended.
- Musculoskeletal health. This area addresses the whole life-span and relates to complex functions of the locomotor system comprising muscles, adjacent connective tissues, bones and joints. In terms of neurosciences it concerns the control, adjustment and coordination of movement and related executive functions, as well as the different sports-medical forms of strengths and body flexibility. The dynamic richness of the Tujia dance triad may support musculoskeletal and neuro-motor vitality, e.g., in culturally sensitive geriatrics (Periyakoil, 2019).
- Neuroplasticity and network connectivity. Numerous studies elucidate that dance combined with music has high potential to activate the brain derived neurotrophic factor alongside neuroplasticity (Brattico et al., 2021; Muinos and Ballesteros, 2021; Toader et al., 2023), which are key factors in neurorehabilitation. By way of illustration, these therapeutic mechanisms, which also apply to the Tujia dance triad, are used at the department of neurorehabilitation of the 1st medical faculty of the Charles University in Prague to treat acquired brain injury ABI (Keller et al., 2020).
- Self-exploration and self-expression. While some dance-therapeutic models show a certain tendency to (probably) overestimate expression, the authors advocate a therapeutic balance between dance-based self-exploration and self-expression. These relate to different psychological modalities, but eventually complement each other. Self-exploration involves dance-symbolic self-experience, also as a hermeneutic gate to unconscious areas, and symbolic interaction, while self-expression is widely regarded as a cathartic mode of problem processing (Kaplan, 1975; Purcell, 2020).
- Self-actualization and ontological anchoring. Dance therapy can essentially complement self-exploration and self-expression with creative self-actualization, such as in people with chronic mental disorders who are faced with external restriction of their talents and inhibition of their inner potential (Kiepe et al., 2012). In qualitative proximity to inclusive drama in various countries, e.g., the 'Theater Apropos' in Munich, culturally sensitive and creative dance can serve as a space for arts-based self-realization (Schielicke et al., 2018). Related processes are likely to be entwined with existentialistic issues, and dance can become a way towards mindful ontological anchoring, sometimes described as rebirth of the 'dancing self'.
- Hypno-dance therapy and altered states of consciousness. Shamanic and spiritual dances such as the whirling dervishes and complex practices following Mevlana Jelal'uddin Rumi, have greatly inspired transpersonal therapeutic models and pseudo-ethnic forms of hypno-dance therapy (Harel et al., 2021; Vicente, 2007). According to principles of hypnotherapy, mainly that the state of trance belongs to the human mental repertoire, dance therapy takes advantage of the trance-inducing potential of embodied rhythmic movement as well as dance symbolism (Njaradi, 2018). In sum, the authors of this article find that dance-related altered states of consciousness, which are very common in archaic cultures, are still underrepresented in the (Western) realm of dance therapy.
- Dance-drama and social roles. There are Chinese research activities revolving around aestheticization of psychodrama, as well as the integration of role-based therapies and the arts. Similar to several Western approaches, qualitative transitions from playing social roles via symbolic identification to modification of the social self are of crucial importance. According to the authors' experiences, such processes may

importantly benefit from artistic symbolization and symbolic interaction. For instance, the Hand Waving Dance is full of such elements and may inspire ethno-dance-based models of dance therapy for culturally sensitive application.

- Therapeutically advantageous changes of attitudes. While, for instance, cognitive behavioral psychotherapy systematically supports changes of pathological cognitive patterns, the authors observed spontaneous (although sometimes not sustainable) changes of adverse, e.g., obsessive-compulsive or negativistic attitudes in Tujia-associated dance therapy sessions. There are still questions about underlying mechanisms, which may involve high role-identity, dissociation of the pathological and the performed self, as well as enhanced possibilities to alter attitudes, e.g., through trance and the activation of default mode network dynamics (Hove et al., 2015). Further interdisciplinary research is needed and may inspire novel culturally sensitive dance therapeutic models.
- Aesthetic immersion and essence. Aesthetic and creative therapies are not better than others. But they are different. In several clinical cases, arts-based therapies offered new possibilities to patients with manifest therapy resistance and therapy frustration (Danquah, 2023). Dance and dance-drama not only create flexible symbolic spaces, they also respond to the aesthetic and creative repertoire of human beings, which is witnessed by phenomenological, empirical and neuro-aesthetics. Taking these facts together with cultural anthropological findings into account, dance is not an ephemeral leisure-time distraction, but a means that goes to the roots of the human nature. And this is where ethno-dance therapy originates: an ontological and transformative means to re-connect with one's profound existential qualities.

4 Discussion

Chinese ethno-dance therapy essentially complies with guiding principles and key suggestions of the World Health Organisation (Napier et al., 2017): 'incorporating cultural awareness into policy-making is critical to the development of adaptive, equitable and sustainable health care systems, and to making general improvements in many areas of population health and well-being'. Moreover, community-based ethno-dance goes hand in hand with WHO-suggestions to enhance self-care (World Health Organization, 2022), the WHA74.14 'Comprehensive mental health action plan 2013–2030' and recent activities to boost global health promotion. It is the explicit intention of the authors to not only conduct research on Chinese ethno-dance therapy, but also to go in for dance-based improvement of health according to WHO resolutions and statements.

While medical questions such as the operational lifespan of a coronary bypass call for one-dimensional quantitative answers, dance therapeutic issues mostly involve complex dynamics, and new scientific tools alongside meta-methodologies and epistemological considerations are needed. Regarding medicine and public health areas, Sturmberg and Martin (2022) call complexity sciences applied philosophy to solve real-world wicked problems. Together with translational medicine, ethno-medicine and cross-cultural psychiatry, they pave the way to interdisciplinary dance therapeutic research and its potential to bridge the gap between clinical sciences and ethnocultural traditions.

These challenges require open-minded collaboration that accepts different epistemological and ontological features of medical theories and knowledge alongside mutual appreciation of dance therapeutic traditions, schools and models. This precondition, however, cannot be taken for granted, and we observe several dance therapeutic circles tending to monopolize the 'market'. By way of illustration, dance/movement therapy DMT (Chaiklin and Wengrower, 2009), which is one of the most popular schools of dance therapy and covers a broad spectrum of clinical applications, e.g., in oncology (Abu-Odah et al., 2024). Despite the wealth of dance therapeutic schools, traditions and models such as dance-rhythm therapy (Schott-Billmann, 2020) or the healing dance Vimbuza of the Tumbuka people living in northern Malawi, which became in 2008 UNESCO Intangible Cultural Heritage of Humanity, numerous people who are involved in arts-based complementary medicine and dance therapy identify dance therapy and dance/movement therapy in a strikingly reductionist way, and the Sri Lankan dance therapy expert Mantillake (2022) claims 'decolonizing dance movement therapy'. Dance therapeutic research is called to discover and protect the enormous richness of this unlimited realm, and both discussion and action are needed.

Data availability statement

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

Author contributions

QM: Investigation, Visualization, Writing – original draft. WM: Conceptualization, Formal analysis, Methodology, Writing – review & editing. RG: Funding acquisition, Writing – review & editing, Supervision.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was supported by the National Key Research and Development Program of China (2022YFC2503903) and the Natural Science Foundation of China (U2336214).

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 reviewer RW declared a shared affiliation with the authors QM and RG to the handling editor at the time of review.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 08 July 2025
DOI 10.3389/fpsyg.2025.1441378

OPEN ACCESS

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RECEIVED 31 May 2024
ACCEPTED 12 June 2025
PUBLISHED 08 July 2025

CITATION
Shimizu D and Okada T (2025) Coordination dynamics of back-and-forth movement among expert performers: interaction in the battle scene of breaking.
Front. Psychol. 16:1441378.
doi: 10.3389/fpsyg.2025.1441378

Coordination dynamics of back-and-forth movement among expert performers: interaction in the battle scene of breaking

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Complex interactions are central to the performing arts. While recent studies have explored these dynamics through synchronization and coordination theories, they have mainly focused on collaborative contexts. In contrast, genres like jazz sessions and breaking battles involve active competition, where performers seek to outshine one another. Although prior research has identified patterns like anti-phase synchronization in such settings, coordination across expressive channels and differences from sports interactions remain underexplored. To address this gap, the present study had two objectives: first, to investigate coordination through back-and-forth movements during breaking battles, and second, to compare these patterns with those observed in interpersonal sports. We conducted an experimental study simulating a battle scene with expert break dancers, examining how they coordinated their movements and managed relative distances. The results revealed two key findings: (1) dancers maintained close distances (~1.0 m) while coordinating through anti-phase synchronization (−180° to −160° and 160° to 180° relative phases), with coordination patterns shifting dynamically—from leader-follower relationships to anti-phase and then in-phase synchronization—depending on context and time; and (2) such time- and context-dependent coordination dynamics were unique to the performing arts and not observed in interpersonal sports. This study highlights the distinctive nature of context-sensitive, multi-channel interpersonal coordination in competitive performing arts.

KEYWORDS

performing arts, interpersonal coordination, competitive context, breaking, back-and-forth movement, relative distance, relative phase

1 Introduction

In the domain of the performing arts, which encompasses dance, theater, and musical performance, performers actively interact with each other to deliver compelling performances (Bailey, 1980; Merker et al., 2015). Both some performers and researchers have described this interaction as a fundamental aspect of the performing arts (Bailey, 1980), as the complex dynamics between performers captivate the audience's attention. Moreover, several theories suggested that such interaction plays a crucial role in human society (Fitch, 2006; Kirschner and Tomasello, 2010; Merker et al., 2009; Ravignani et al., 2014), as it fosters and strengthens social bonds, thereby contributing to the development and maintenance of communities. Given that humans benefit from living in large social

groups (Dunbar, 1998), musical performances and dance have become widespread across all cultures and societies. Recent studies have indicated that participating in musical and dance activities can enhance interpersonal relationships, as individuals experience a sense of connection and cohesion through shared performance (Kirschner and Tomasello, 2010; Weinstein et al., 2016; Wiltermuth and Heath, 2009)

In recent years, several researchers have sought to investigate the complex interaction among performers by applying frameworks of synchronization and coordination (e.g., Keller et al., 2014; Ravignani et al., 2014; Walton et al., 2015, 2018; Washburn et al., 2014). Synchronization phenomena have been studied across various fields, including physics, biology, and psychology. They investigated the behavior matching of multiple objects, insects, or people, such as the swinging of clock pendulums, the flickering of firefly lights, and audience applause (Buck and Buck, 1966; Huygens, 1665; Jones, 1964; Néda et al., 2000; Okazaki et al., 2015; Ramirez et al., 2016; Strogatz, 2003). A study particularly relevant to our research involves the synchronization and coordination of human behavior using the Dynamical Systems Approach (Haken et al., 1985; Schmidt et al., 1990). These studies have investigated the timing matching of behaviors, such as leg swings and rocking chair movements. It was suggested that the behaviors of these individuals tend to stable in either in-phase synchronization, where actions are perfectly timed, or anti-phase synchronization, where actions occur at opposite times (Richardson et al., 2007; Schmidt et al., 1990; Schmidt and O'Brien, 1997). Furthermore, it has been proposed that in-phase synchronization is more stable and easier to transition into compared to anti-phase synchronization. These studies represent efforts to understand the mechanisms of synchronization and entrainment from the perspective of the dynamical systems approach. Defining synchronization clearly can be challenging, as different research domains use varying definitions. However, based on the definition and the features of phenomena in psychology, the current study defines "synchronization" as the periodic repetition of similar actions with matched timing, like in-phase synchronization and anti-phase synchronization (e.g., Bernieri and Rosenthal, 1991; Fujiwara and Daibo, 2016). Additionally, we define "coordination" as encompassing a broader range of behavior matching, which includes not only synchronization but also leader-follower relationships and polyrhythms (Konvalinka et al., 2010). In these forms of behavior matching, deviations in timing (leader-follower relationships) or period (polyrhythms) are observed among individuals' actions.

A similar emphasis on synchronization and coordination has been gradually gaining attention in the domain of the performing arts. For example, studies examining the hand movements of two pianists during improvisations revealed that their movements tended to align in in-phase synchronization (Walton et al., 2015, 2018). Similarly, Kimmel and Preuschi (2015) investigated the head movements of tango dance pairs and found that these movements also tended to follow in-phase synchronization. These studies primarily focused on performers' interactions within a collaborative context, where multiple performers aim to achieve a shared goal, such as delivering a captivating and well-structured performance. The findings indicated that, in this collaborative context, performers often coordinated their movements in an in-phase synchronous manner.

While the studies mentioned above have provided valuable insights, certain genres of the performing arts, such as jazz sessions and breaking battles, can exist within a different context—competition. In this competitive setting, performers actively compete with one another, striving to deliver more captivating performances than their counterparts. Several qualitative studies have suggested that, in such competitive contexts, performers engage in unique interactions. For example, Shimizu and Okada (2013) qualitatively investigated battle scene in dance and proposed that dancers sometimes reference and build upon the performances of their co-dancers. These dancers focused on specific aspects of their co-dancers' performances, occasionally incorporating and developing them within their own performances. However, only a limited number of studies have quantitatively investigated these interactions among performers in a competitive context.

Several studies examining interpersonal interactions in competitive contexts have primarily focused on everyday conversations (Abney et al., 2014; Paxton and Dale, 2013, 2017). These studies compared the coordination of participants during collaborative conversations (e.g., discussions about personal interests such as their favorite music and TV programs) with their coordination in competitive dialogues (e.g., debates on social issues). The findings indicated that, in competitive contexts, individuals exhibited more frequent time-lagged coordination (behaving similarly at different times, akin to anti-phase synchronization). Furthermore, compared to collaborative contexts, participants in competitive conversations demonstrated significantly less in-phase synchronization of their movements.

In the domain of performing arts, although the number of studies remains limited, we reference two studies that have examined performers' interactions in competitive contexts. Keller et al. (2017) explored coordination among traditional chorus singers in Germany. In their study, a situation was created where girls of the same age appreciated their singing, thereby enhancing the competitive context among the singers. The study compared the coordination of their voices in this context with other situations. The results indicated that, in the competitive context, bass singers emphasized their individual voices while maintaining harmony with other parts (Alto, Soprano, Tenor). Additionally, Shimizu and Okada (2021) examined coordination among expert breakdancers during battle scenes. This study employed relative phase analysis to investigate the coordination of rhythmic movements among the dancers. The findings revealed that the dancers dynamically adjusted their coordination patterns according to the context. When not performing, i.e., before or after the battle (when the competitive context was relatively weak), the dancers synchronized their rhythmic movements in-phase, aligning their rhythms. In contrast, during the performance (when the competitive context was more intense), the dancers exhibited anti-phase synchronization, where they moved in opposite rhythmic timings.

These previous studies suggest that in competitive contexts, performers' behaviors often exhibit anti-phase synchronization. They align certain aspects of their behavior, such as frequency, while simultaneously differentiating other aspects, such as timing. However, to fully capture the dynamics of performers' interactions

in competitive settings, further investigation is needed in two key points. First, it is essential to explore coordination across multiple expressive channels. As suggested by studies on traditional choruses and breaking battles, performers often coordinate specific behaviors, such as their voices or rhythmic movements, in an anti-phase synchronous fashion. However, in real performance contexts, performers engage in active interactions through a variety of expressive channels, including facial expressions, gestures, rhythmic movements, and back-and-forth movements. In these performance situations, performers must coordinate these diverse channels, sometimes forming a complex and comprehensive state of coordination. A deeper examination of this multichannel coordination is necessary to more accurately capture the nature of performers' interactions.

Second, it is crucial to investigate why anti-phase synchronization occurs more frequently in competitive contexts. The studies mentioned above have not explored this aspect in detail. Drawing from the open communication nature inherent in the performing arts (Okamoto, 2008; Okamoto et al., 2005), Shimizu and Okada (2021) proposed that the specific situations and goals of the performing arts, which involve performers showcasing their interactions to an audience, may facilitate this anti-phase synchronization. In a competitive context, each performer aims to highlight their own performance and demonstrate superiority to the audience. Shimizu and Okada (2021) speculated that performers may contrast their performances with those of others by concurrently aligning and misaligning some aspects of their actions, in an effort to emphasize the uniqueness of their performance. This dynamic, they suggested, leads to frequent anti-phase synchronization. However, this hypothesis has not been sufficiently investigated. To deepen our understanding, it is necessary to explore the underlying factors contributing to anti-phase synchronization in competitive contexts. Additionally, a more detailed investigation into how the open-communication nature of these contexts shapes the features of performers' interactions is required.

In light of these findings, we turned our attention to another expressive modality in dance—namely, back-and-forth movements—and investigated how such movements are coordinated among expert dancers in battle performances. While Shimizu and Okada (2021) demonstrated anti-phase synchronization in dancers' rhythmic movements, their study did not explore coordination across other expressive channels. Given the role of rhythmic coordination in dance, it is reasonable to speculate that similar coordination patterns, such as anti-phase synchronization, may also emerge in other movement dimensions. To test this hypothesis, we focused specifically on the coordination of back-and-forth movements. In the context of dance performance, practitioners often emphasize the importance of spatial positioning between dancers. Moreover, psychological research on personal space suggests that back-and-forth movement and the relative distance it creates between individuals can serve as a subtle but significant factor in regulating social interactions (hidden dimension, e.g., Hall, 1966; Hayduk, 1978; Kennedy et al., 2009). These perspectives support the idea that back-and-forth movement may offer a valuable lens through which to investigate the interaction dynamics of dancers in battle scenes.

Furthermore, back-and-forth movement appears to be a meaningful variable for investigating the underlying mechanisms of anti-phase synchronization in competitive artistic interactions. In the present study, we aim to clarify the dynamics of such interactions by comparing them with the coordination patterns observed in competitive sports settings. Kijima et al. (2012) and Okumura et al. (2012) investigated interpersonal coordination in competitive sports such as Kendo (Japanese fencing) and tag-taking games—activities in which two players compete to take a tag from each other's clothing. These studies focused on the coordination of relative distance and back-and-forth movements between two players. Their findings revealed that the players coordinated their movements in an anti-phase manner: when one player moved forward to close the distance, the other moved backward to increase it. This approaching–retreating relationship was actively and frequently switched, with the average and modal switching interval being ∼0.5 s. By actively coordinating their movements in this way, the two players maintained a consistent relative distance—∼2.8 m—between them. These studies also demonstrated that such coordination patterns varied dynamically depending on the distance between the players. When the distance was shorter than ∼2.8 m (the mode of relative distance), the players exhibited anti-phase synchronization; in contrast, when the distance exceeded 2.8 m, they shifted to in-phase synchronization. Moreover, these studies found that players generally maintained this coordination pattern throughout the match. It was typically disrupted only at the very end, when one player either struck the opponent or successfully removed the opponent's tag. This pattern of sustained coordination followed by sudden break was consistently observed in these forms of interpersonal competitive sports.

The aforementioned studies suggested that the coordination patterns observed in interpersonal sports, such as Kendo, are influenced by factors such as the goal of the activity (e.g., to hit an opponent's body or take their tag), the players' physical attributes, and the tools used (e.g., the length of the Japanese bamboo sword, the length of the player's arm, and the distance they can cover in a single step). These factors facilitate specific coordination patterns within the competitive framework of sports. However, in the context of performing arts, such as breaking battles, the goals and rules differ significantly from those of interpersonal sports, despite the shared competitive context. In most performing arts, physical contact with other performers is not a primary objective, and thus, performers typically do not focus on it to the same extent as athletes do. Instead, their goal is to create visually engaging interactions for the audience, as highlighted in studies on open communication (Okamoto et al., 2005; Okamoto, 2008). While athletes in interpersonal sports may occasionally pay close attention to the audience, their main focus is on the competition itself, not audience engagement. We hypothesize that these similarities (competitive context) and differences (goals and rules) between performing arts and interpersonal sports significantly influence the nature of interactions between performers and players. This study investigates the characteristics of performer interactions in dance, and compares these findings with those from previous research on sports coordination (Kijima et al., 2012; Okumura et al., 2012). By examining these interactions, we aim to uncover the unique features of performing arts-based coordination.

In light of the preceding discussion, the present study had two main objectives.

- First, we investigated the coordination of back-and-forth movements among expert breakdancers during battle performances, focusing on whether they exhibited anti-phase synchronization, similar to the rhythmic synchronization observed in previous studies.
- Second, we explored the similarities and differences between the coordination of back-and-forth movements in the performing arts (specifically breaking) and in interpersonal sports (such as Kendo and tag-taking games) (Kijima et al., 2012; Okumura et al., 2012). Through this comparison, we aimed to identify the unique features of performer interactions in competitive contexts.

We focused on expert breakdancers' battle scenes for several reasons. Breaking battle scenes, in which two dancers or teams face off and compete based on the quality of their performances, serve as a primary format for competitive interaction. Historically, breaking emerged as a form of alternative expression to gang fights (OHJI, 2001; Watkins, 2005). Furthermore, the authors have been conducting research on this performance context for an extended period, and previous studies have demonstrated that coordination among dancers can be measured and analyzed quantitatively (Shimizu and Okada, 2021). These features of breaking battles suggest that this setting provides an ideal environment for investigating performer interactions within a competitive context. In this study, we utilized the movement data collected from a previous experiment that focused on rhythmic movement coordination (Shimizu and Okada, 2021), analyzing it from a different perspective to explore the dynamics of back-and-forth movement coordination.

2 Methods

2.1 Participants

Seven expert breakdancers participated in this study (Experts A–G). Their mean age of the participants was 27.29 years (SD = 2.43), and the average amount of breaking experience was 10.86 years (SD = 2.54). All participants had previously won first or second place in breaking competitions in Japan. The experts were divided into two groups for the study (Group 1: Experts A, B, C, D; Group 2: Experts B, E, F, G) with each group participating in the experiment independently.

2.2 Procedures

In each group, four expert dancers were paired up to engage in battles in a round-robin format, resulting in six pairs per group. This structure led to a total of twelve battles. During each battle, the dancers performed three times in turn.

The experimental design followed a two-factor mixed design. The first factor was the type of pair as described later, comparing the Real pair condition, in which participants interacted directly with each other, and the Virtual pair condition, in which pairs were created artificially without real interaction. The second factor was the performance turn, comparing four conditions: before the performance, during the performance (A's turn and B's turn, representing the first and second dancers' performances, respectively), and after the performance. As described below, Analysis 1 focused solely on the first factor (pair type), while Analysis 2 incorporated both factors (pair type and performance turn).

The experimental situations were designed to closely replicate real battle scenes in order to capture natural interactions between dancers (OHJI, 2001; Watkins, 2005). To achieve this, the dancers determined the performance order through their interactions during the battle. Additionally, no time limits were imposed on their performances. Based on our previous fieldwork (Shimizu and Okada, 2018), we selected a specific track, *DJ Fleg "Chelles"*, to be used across all battles; however, the dancers were not instructed to perform to any particular music. Moreover, to facilitate meaningful interactions, we consulted with the dancers in advance and ensured that the experimental space was appropriately sized for the battle (see Figures 1A, B). The space size was carefully considered, as a small space could limit the dancers' ability to interact freely. Moreover, we did not disclose the true purpose of the study to the dancers beforehand. Instead, they were informed that the study was focused on biomechanics and the individual movement features of each dancer's performance. After the experiment, the dancers were fully debriefed about the actual purpose of the study. This approach was taken to minimize the potential influence of participants' awareness of being observed, as previous studies on personal space have suggested that individuals alter their social behaviors and spatial distances when they are aware that others are observing them (Hall, 1966; Hayduk, 1978; Kennedy et al., 2009).

Each dancer's position and back-and-forth movement were measured using an infrared motion capture system (OQUS 300, QUALISYS, Göteborg, Sweden). Seven markers were placed on each dancer, based on a pilot study, at locations that would not interfere with their dance performances (five markers around the neck and two on the pelvis). Given that previous studies on personal space have most commonly relied on head position as an indicator of relative distance—since people primarily perceive distance through their eyes—we focused our analysis on the movement data from the markers placed around the dancers' necks (Figure 1C). Data from three battles were excluded from the analysis due to system malfunctions and missing markers. In breaking, where movements are often acrobatic, it was occasionally difficult to capture sufficient data for some battles due to the nature of the dancers' movements.

2.3 Ethics statement

The experimental procedures were conducted in accordance with the Declaration of Helsinki. Additionally, the study received approval from the Ethics Committee of the University of Tokyo. All dancers provided written informed consent, and each participant was compensated for their involvement in the study.

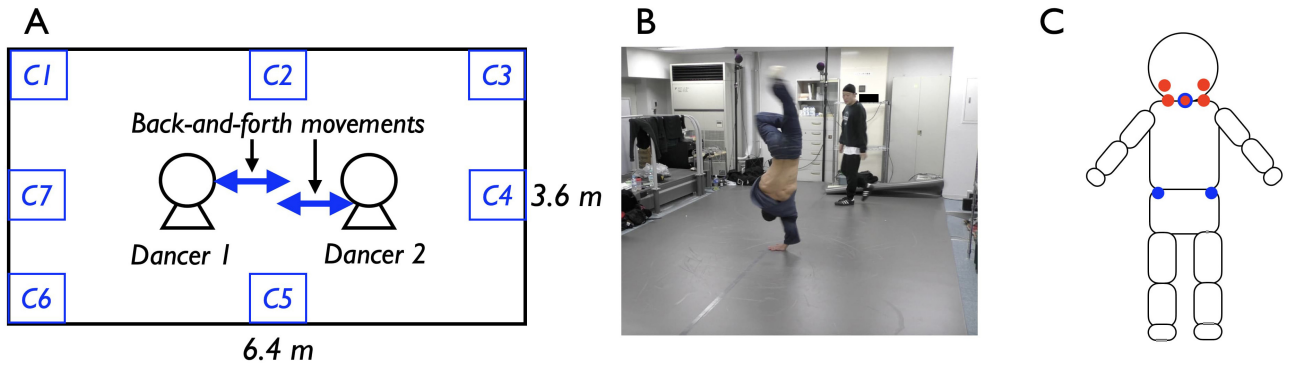


FIGURE 1
(A) Outline of the battle scene. Two dancers faced each other and showed their performances in turn. **(B)** Picture of the battle scene. One dancer showed his performance, and another dancer watched and responded to his performance. **(C)** Marker setting. The picture draws the back side of the participants. The red circle indicates the marker positions around the neck and blue circle indicates the marker positions around the trunks. In the analysis, we used the marker data around the neck, mainly the marker data of red circle with blue lines (for a few participants, this marker fell off during their performances, so other neck marker data was used). A portion of the figure has been adapted and modified from Shimizu and Okada (2021).

2.4 Analysis

Data preprocessing and analysis were conducted using R (version 3.5.2). Missing values in the movement data were imputed using spline interpolation, and the resulting time series were smoothed using a bandpass filter set between 1 Hz and 5 Hz. We set this frequency range based on frequency of the basic back-and-forth movements predicted by the pilot study. In addition, the application of a high-pass filter is a commonly used method to remove slow trends from the data and to facilitate accurate phase estimation of movement (de Poel et al., 2020). Following smoothing and filtering, we applied standard normalization by subtracting the mean and dividing by the standard deviation of the entire time series.

Next, we conducted four analyses on the collected data (Figure 2), each targeting a distinct aspect of the dancers' interactive movements:

1. The relative distance between the two dancers.
2. The coordination of their back-and-forth movements, quantified by the relative phase between their motions.
3. The duration of intervals at which the dancers switched movement directions, analyzed in relation to the coordination of their back-and-forth movements.
4. The coordination of back-and-forth movements as a function of relative distance between the dancers.

We conducted our analyses using a method developed in previous studies on Kendo matches and tag-taking games (Kijima et al., 2012; Okumura et al., 2012). Specifically, we applied this method to two datasets: the entire performance scenes and each individual battle turn (Figure 2). First, we examined the coordination between dancers throughout the full performance (Figure 2, top). Subsequently, we analyzed coordination within four distinct turns (Figure 2, bottom). Before performance (Before) captured the moments before the dancers began their performances; Turn of the first dancer (Performance, abbreviated in P1, P3, P5) corresponded to the performance of the first dancer; Turn of the second dancer (P2, P4, P6) to that of the second dancer; and After performance (After) to the phase after both performances had ended. For each analysis, we formulated specific hypotheses grounded in prior research on the back-and-forth and rhythmic movements observed in Kendo matches, tag-taking games, and breaking battles (Kijima et al., 2012; Okumura et al., 2012; Shimizu and Okada, 2021).

To evaluate these hypotheses, we conducted targeted multiple comparisons. This analytical strategy was adopted to account for the relatively small sample size in the current study. Moreover, had we employed exhaustive pairwise comparisons, the number of comparisons would have been excessive, potentially compromising the statistical power of the tests.

In the first analysis, we examined the relative distance between the two dancers throughout their performances (Figure 3). To do so, we calculated the Euclid distance between the dancers based on their movement data along the x- and y-axes (Equation 1). We then analyzed the distribution of these distances over time and identified the mode—that is, the most frequently occurring distance—within this distribution. Drawing on previous findings from studies of interpersonal coordination in sports and dance, particularly those involving anti-phase synchronization, we anticipated that the dancers would coordinate their back-and-forth movements in an anti-phase manner, thereby maintaining a consistent relative distance during their performances. Based on this expectation, we hypothesized that certain relative distances (i.e., modes) would occur significantly more frequently than others. This hypothesis was tested in the first analysis.

In the second analysis, we investigated the coordination of back-and-forth movement between the two dancers (Figure 3, Equations 2–6). This analysis involved calculating the relative phase between the dancers' movements, following procedures developed in earlier studies on Kendo matches and tag-taking games (Kijima et al., 2012; Okumura et al., 2012). First, we calculated the vector representing Dancer A's back-and-forth movement between time points t-1 and t+1 (Equation 2). We then calculated the vector representing the distance between the two dancers at time t

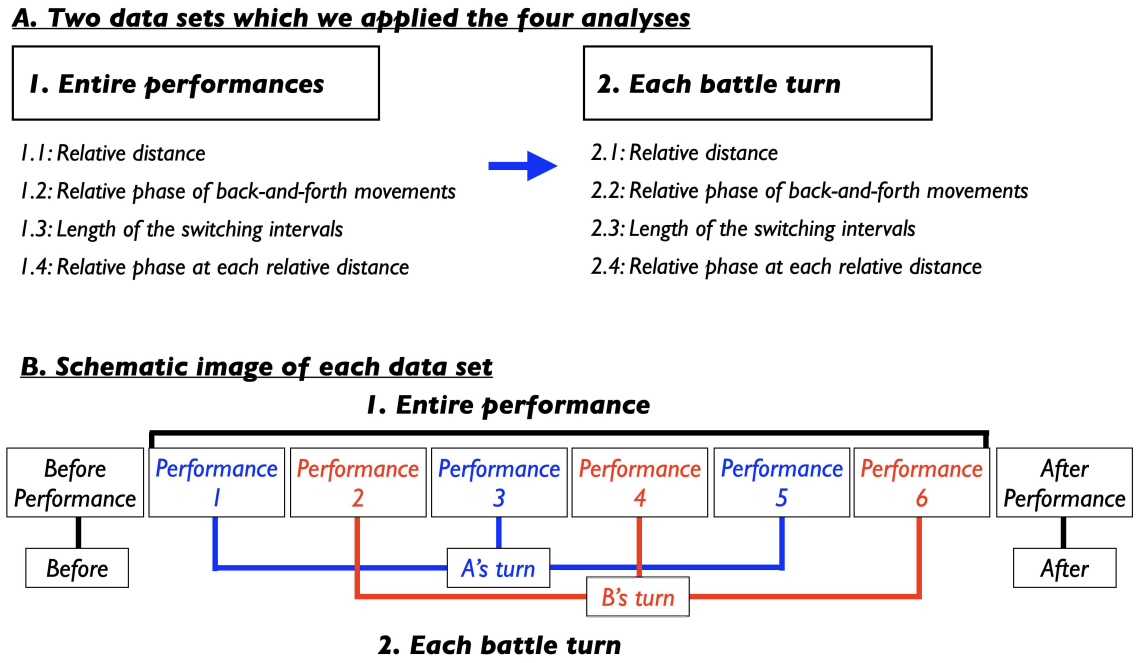


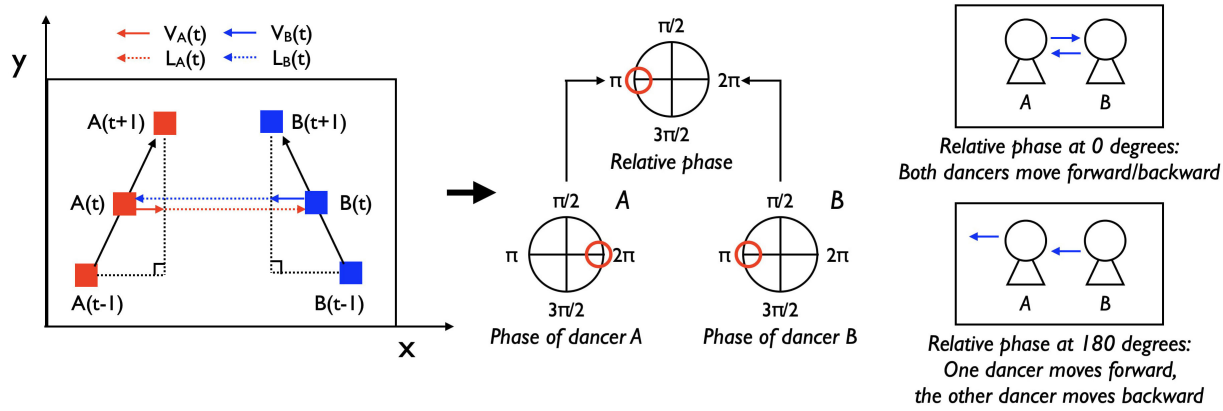
FIGURE 2
(A) Two data sets which we applied the four analyses. **(B)** Source images from which each dataset was extracted.

(Equation 3). Next, we projected the movement vector (from *t-1* to *t+1*) onto the distance vector at time *t*, thereby obtaining the directional component of Dancer A's movement toward or away from Dancer B at that time point (Equation 4). This value captured the extent to which Dancer A moved forwards or backwards in Dancer B's direction at time *t*. We performed the same set of calculations for Dancer B. Subsequently, we applied the Hilbert transform to these directional movement signals to derive the instantaneous phases of the dancers' movements (Equation 5). Finally, we computed the relative phase between the two dancers' movement phases at each time point (Equation 6), which allowed us to quantify the degree and type of coordination between them.

The relative phase provides a quantitative measure of coordination between the two dancers' back-and-forth movements. A relative phase of 0 degrees indicates in-phase synchronization, meaning that both dancers moved in the same direction at the same time (e.g., when Dancer A moved forward, Dancer B also moved forward). In contrast, a relative phase of 180 degrees indicates anti-phase synchronization, where the dancers moved in opposite directions (e.g., when Dancer A moved forward, Dancer B moved backward). Although various methods exist for analyzing synchronization and coordination in human behavior, we selected this approach to allow for direct comparison with previous studies on Kendo-matches and the tag-taking games. As mentioned in the hypothesis of the first analysis, we anticipated that the dancers would exhibit anti-phase synchronization in their back-and-forth movements during their performances. Therefore, we hypothesized that anti-phase synchronization (i.e., a relative phase around 180 degrees) would occur significantly more frequently than other coordination patterns.

We also created a Virtual pair condition to serve as a baseline for comparison with the Real pair condition (e.g., Bernieri et al., 1988; Dale et al., 2011). In the Virtual Pair condition, we generated pseudo-pairs by replacing one dancer's movement data from a Real pair with that same dancer's data from a different battle. This procedure allowed us to preserve individual movement characteristics while eliminating the possibility of real-time interpersonal coordination. Previous studies have shown that behavioral synchrony can occasionally emerge by chance, even the absence of direct interaction. Therefore, by comparing the relative distance and relative phase between dancers in the Real Pair and Virtual Pair conditions, we aimed to evaluate whether the observed coordination in the Real Pairs exceeded what could be expected from chance alone.

In the third analysis, we examined the temporal characteristics of coordination by analyzing the intervals at which the dancers switched their movement directions. Specifically, we focused on the signs (positive or negative) of each dancer's movement phase at time *t*. A positive sign indicated that the dancer was moving backward, while a negative sign indicated forward movement. Following the method proposed by Kijima et al. (2012), we calculated an instantaneous product indicator by multiplying the movement phases of the two dancers at each time point. When the product was positive, both dancers were moving in the same direction (either both forward or both backward). When the product was negative, the dancers were moving in opposite directions. We then identified the time points at which this indicator changed sign from positive to negative. Such transitions signified shifts in the coordination pattern—from synchronized movement in the same direction



$$D(t) = \sqrt{\left(x(t) - u(t)\right)^2 + \left(y(t) - v(t)\right)^2} \quad (1)$$

$$A_{t-1\to t+1} = \left(x(t+1) - x(t-1), y(t+1) - y(t-1)\right)$$
$$B_{t-1\to t+1} = \left(u(t+1) - u(t-1), v(t+1) - v(t-1)\right) \quad (2)$$

$$L_A(t) = \left(u(t) - x(t), v(t) - y(t)\right)$$
$$L_B(t) = \left(x(t) - u(t), y(t) - v(t)\right) \quad (3)$$

$$V_A(t) = \frac{A_{t-1\to t+1} \cdot L_A(t)}{L_A(t) \cdot L_A(t)} |L_A(t)|$$
$$V_B(t) = \frac{B_{t-1\to t+1} \cdot L_B(t)}{L_B(t) \cdot L_B(t)} |L_B(t)| \quad (4)$$

$$V_A(t) = P_A(t) + iP_{H_A}(t) = A(t)e^{i\phi(t)}$$
$$V_B(t) = P_B(t) + iP_{H_B}(t) = B(t)e^{i\phi(t)} \quad (5)$$

$$\Delta\phi_{AB}(t) = \left| tan^{-1} \frac{P_{H_A}(t) \cdot P_B(t) - P_{H_B}(t) \cdot P_A(t)}{P_A(t) \cdot P_B(t) + P_{H_A}(t) \cdot P_{H_B}(t)} \right| \quad (6)$$

FIGURE 3
Procedures of calculating the relative distance and relative phase of the two dancers' back-and-forth movements. We made this explanation by referring to Kijima et al. (2012) and Okumura et al. (2012). *D (t)* indicates the relative distance at time *t*, *x (t)* and *y (t)* indicate the position of dancer A at time *t* and *u* and *v* indicate that of dancer B. $A_{t-1\to t+1}$ and $B_{t-1\to t+1}$ indicate the vectors of the movements from time *t-1* to time *t+1*. L_A and L_B show the vectors of the distance at time *t*. $V_A(t)$ and $V_B(t)$ indicate the vectors of the movements to the co-dancer's direction at time *t*. $P_A(t)$ and $P_{HA}(t)$ show the phase of these vectors of dancer A, and $P_B(t)$ and $P_{HB}(t)$ show these of dancer B. Φ_{AB} *(t)* show the relative phase between the two dancers at time *t*.

to anti-phase movement in opposite directions. By analyzing the intervals between these transitions, we aimed to capture the temporal dynamics of coordination switching between the dancers.

We also examined which dancer moved forward at the time when coordination patterns changed, by checking the sign of each dancer's movement phase at those transition points. Using this information, we identified the exact time points at which each dancer switched their movement direction (i.e., from forward to backward, or vice versa). We then established the time when the dancers switched their moving direction (forward or backward) and calculated intervals between these time points. These intervals provided insight into whether the dancers were actively and frequently switching their movement directions, or whether they tended to maintain a single direction for extended periods. Previous study by Kijima et al. (2012) on tag-taking games found that players switched directions ~every 0.5 s on average, suggesting that quick directional changes are characteristic of real-time coordination in competitive interpersonal sports. Similar patterns have also been observed in studies on the competitive behavior of insects (Greenfield and Roizen, 1993; Greenfield et al., 2017), where rapid directional changes are thought to play a functional role in dynamic coordination. Based on these findings, we expected that dancers in battle performances would also exhibit short, regular switching intervals. Therefore, we hypothesized that specific short intervals would be observed statistically more frequently than other interval lengths.

In the fourth analysis, we examined how back-and-forth coordination varied as a function of relative distance between the dancers. Using the relative distance data calculated in the first analysis, we segmented the performance scenes according to distance ranges. For each distance segment, we calculated the frequency distribution of relative phases to identify how coordination patterns changed depending on the dancers' spatial relationship. Okumura et al. (2012), in their study on Kendo players, reported that coordination patterns shifted markedly—from anti-phase to in-phase synchronization—at a specific distance (mode: 2.8 m). However, as noted in their discussion, such distance-dependent coordination shifts may be closely tied to the task goals (e.g., striking the opponent with the bamboo sword) and the physical constraints (e.g., sword length, step length) inherent in Kendo matches. In contrast, competitive dance performances are aimed at creating visually engaging interactions for an audience, rather than achieving physical contact. Therefore, it is reasonable to speculate that dancers may not exhibit such abrupt coordination shifts at a particular distance. Instead, we expected that their coordination patterns would remain relatively stable across varying distances, without a drastic transition at a specific mode.

Furthermore, previous studies have indicated that dancers in battle performances dynamically adjust their rhythmic coordination over time and in response to contextual factors (Shimizu and Okada, 2021). These findings suggest that interpersonal coordination in such performances may be influenced more by temporal and contextual elements than by physical distance. Based on this perspective, we hypothesized that dancers would not exhibit a drastic change in coordination at any particular relative distance (i.e., mode). Instead, we expected that anti-phase synchronization would be observed more frequently than other coordination states across all distance ranges. Additionally, we hypothesized that the frequency of anti-phase synchronization would vary significantly depending on the performance context—specifically, before, during, and after the dancers' individual performances.

3 Results

3.1 Results of the entire performance

3.1.1 Relative distance between two dancers

Figures 4, 5A present the results of the first analysis, which focused on the entire performance scenes. Figure 4A illustrates that the two dancers maintained a relative distance of ∼1.0 m, particularly during the performance segments (P1–P6). Figure 5A, which shows the frequency distribution of the mean relative distance for each distance category, indicates that relative distances around 0.9–1.3 m were most frequently observed in the Real pair. The distribution of relative distances for the Real pair clearly exhibited a single peak. However, Figures 4B, 5A reveal that these patterns were not observed in the Virtual pair.

The statistical test confirmed these findings. Significant differences were observed between the frequency of the 1.0 m relative distance (the mode) and most other relative distances in the Real pair (corrected using the Benjamini-Hochberg method; Benjamini and Hochberg, 1995). As indicated by the asterisk in Figure 5A, 27 out of all 29 relative distances showed significant differences (93.10%). The results were as follows: $t_{(8)} = 0.54–19.35$, $p = 0.00000004–0.61$, $d = 0.13–8.35$ (detailed results are provided in Appendix A-1). In contrast, the same comparison for the Virtual pair also revealed significant differences, but the number of relative distances that showed significant deviations from the mode (1.0 m) was more limited (24 out of 29 relative distances or 82.76%). The results for the Virtual pair were as follows: $t_{(11)} = 0.36–15.37$, $p = 0.00000002–0.72$, $d = 0.07–7.67$.

Next, we examined the differences in the mode frequencies between the Real and Virtual pairs. A comparison of the mode (both 1.0 m) revealed that the frequencies were significantly different between the Real and Virtual pair [$t_{(11.84)} = 4.24$, $p = 0.001$, $d = 2.02$]. This result suggests that the specific relative distance of 1.0 m was observed more frequently in the Real pair. During the battle scenes, the two dancers maintained this specific relative distance while performing. As shown in Figure 4A, although the relative distances were not completely fixed, they exhibited some small fluctuations.

3.1.2 Relative phase of back-and-forth movements between two dancers

Figure 6A shows the results of the second analysis. In the Real pair condition, relative phase at−180–160 and 160–180 degrees were observed with high frequency, suggesting that the two dancers exhibited anti-phase synchronization in their back-and-forth movements. In contrast, the Virtual pair did not show this pattern; rather, the frequencies across all relative phases were approximately uniform.

A statistical comparison corrected using the Benjamini-Hochberg method revealed significant differences between the frequencies of the anti-phases (−180–160 and 160–180 degrees) and most other phase ranges. As indicated by the asterisk in Figure 6A, 10 out of 17 relative phase comparisons showed significant differences for the −180–160 degrees (58.82%), and 13 out of 17 comparisons showed significant differences for the 160–180 degrees (76.47%). For the −180–160 degrees: $t_{(8)} = 0.13–7.89$, $p = 0.002–0.90$, $d = 0.06–3.06$, and for 160–180 degrees: $t_{(8)} = 0.28–6.46$, $p = 0.002–0.83$, $d = 0.10–3.26$ (see detailed results in Appendix A-2). In contrast, the same analysis for the Virtual pair did not reveal similar tendencies. The frequencies of the anti-phase ranges did not significantly differ from those of other phase ranges. For the −180–160 degrees, the results were: $t_{(11)} = 0.06–2.20$, $p = 0.70–0.96$, $d = 0.02–0.89$, and for 160–180 degrees: $t_{(11)} = 0.05–1.73$, $p = 0.70–0.96$, $d = 0.02–0.81$.

Furthermore, we compared the frequencies of anti-phase synchronization between the Real and Virtual pairs. The analysis revealed that the frequencies of the anti-phase (−180–160 and 160–180 degrees) differed significantly between the two conditions. For the −180–160 degrees: $t_{(18.39)} = 3.97$, $p = 0.0009$, $d = 1.72$, and for the 160–180 degrees: $t_{(18.42)} = 4.24$, $p = 0.0009$, $d = 1.84$. These results indicate that the specific relative phases at −180–160 and 160–180 degrees were observed much more frequently in the Real pair condition. This suggests that the two dancers performed while responding sensitively to each other's movements, coordinating their back-and-forth movements in opposite directions. It is plausible that, during this coordination, the dancers maintained a consistent relative distance of ∼1.0 m.

3.1.3 Frequency of the length of the switching intervals of two dancers

Figure 7A presents the results of the third analysis. The figure indicates that the dancers tended to switch their forward and backward movement directions at very short intervals, ranging from 0.15 to 0.50 s, with the most frequent interval (mode) observed at 0.25 s. Statistical comparisons with Benjamini-Hochberg correction revealed significant differences between the frequency of the mode interval (0.25 s) and those of nearly all other intervals. With t (8) = 0.23–29.94, $p = 0.00000001–0.82$, $d = 0.09–13.22$ (see Appendix A-3 for detailed results). As indicated by the asterisks in Figure 7A, 56 out of 59 interval comparisons (94.9%) showed significant differences relative to the mode. These findings suggest that, during the battle scenes, the two dancers frequently switched their movement directions at very short time intervals. Notably, similar patterns of short-time switching of movement directions have been reported in studies examining interpersonal

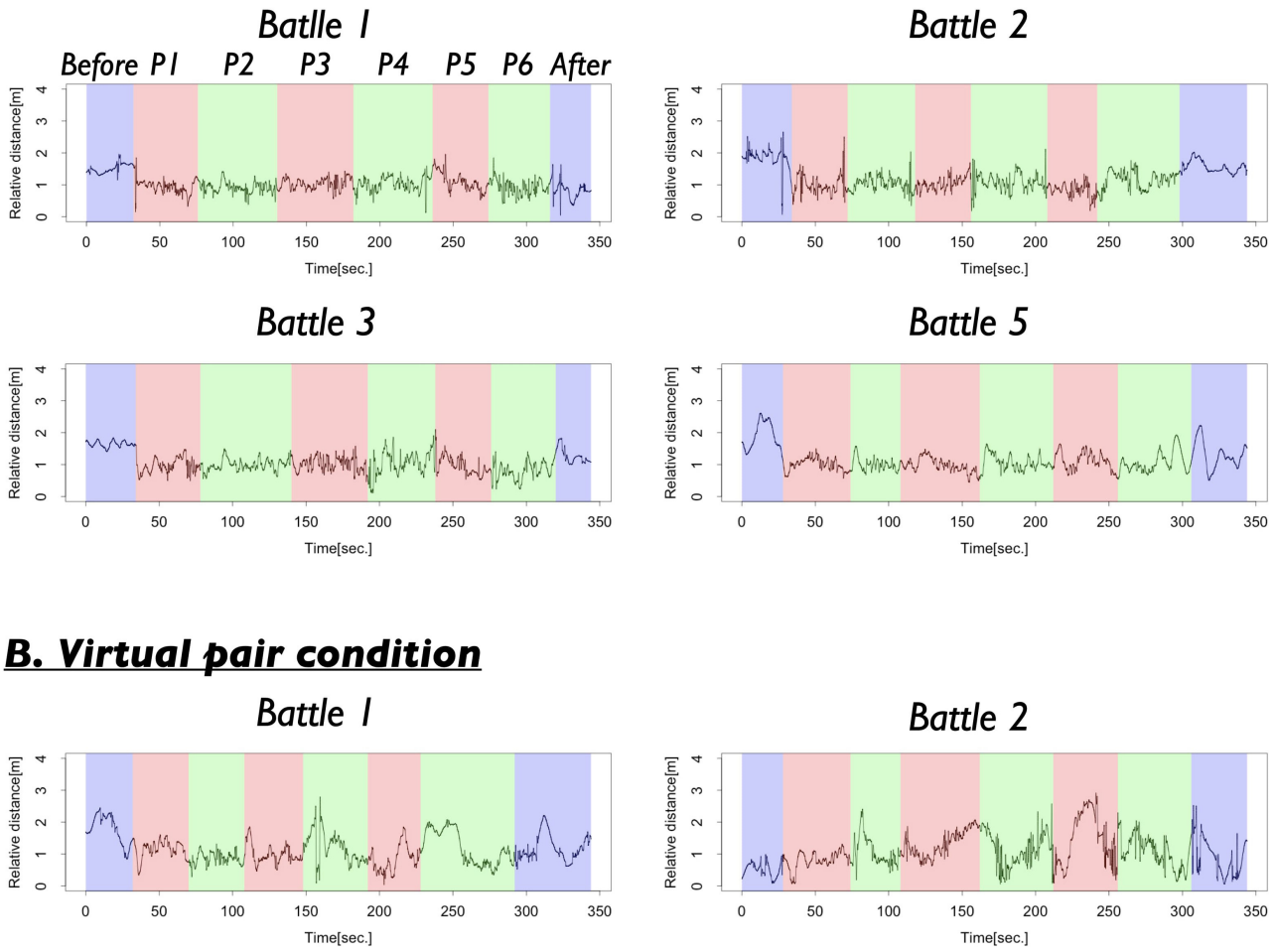


FIGURE 4
(A) Several examples of the relative distances in the Real pair condition. The spaces colored in blue show the time when both dancers did not show their performances (Before, After), those colored by red show the performance time of the first dancer (P1, P3, P5), and those colored by green show the performance time of the second dancer (P2, P4, P6). **(B)** Several examples of the relative distances in the Virtual pair condition.

coordination among athletes in competitive sports settings (Kijima et al., 2012; Okumura et al., 2012). Taken together, these results highlight that active and rapid changes in movement direction are a common feature shared between the performing arts and interpersonal sports.

3.1.4 Relative phase of back-and-forth movements at each relative distance

Figure 8A presents the results of the fourth analysis. In this analysis, we focused on relative distances around the mode value (1.0 m) observed in the Real pair condition and examined the distribution of relative phase at four distance ranges: 0.8–0.9 m, 0.9–1.0 m, 1.0–1.1 m, and 1.1–1.2 m. Figure 8A shows the results. It demonstrates that the relative phases at −180–160 and 160–180 degrees were frequently observed across nearly all distance ranges. This indicates that the dancers consistently exhibited anti-phase synchronization during their coordination, regardless of slight variations in their relative distance.

Statistical comparison with Benjamini–Hochberg correction showed that, at each distance range, the relative phase frequencies at −180—160 and 160–180 degrees were significantly different from those of most other phases, as indicated by the asterisk in Figure 8A (see Appendix A-4 for detailed results). For the 0.8–0.9 m range, −180—160 degrees: $t_{(8)} = 0.20–6.21$, $p = 0.004–0.85$, $d = 0.09–2.13$ (7 out of all 17 relative phases showed significant differences), 160–180 degrees: $t_{(8)} = 0.20–6.36$, $p = 0.004–0.85$, $d = 0.09–2.19$ (7 out of all 17 relative phases showed significant differences). For the 0.9–1.0 m range, −180—160 degrees: $t_{(8)} = 0.80–7.82$, $p = 0.002–0.45$, $d = 0.25–3.46$ (13 out of all 17 relative phases showed significant differences), 160–180 degrees: $t_{(8)} = 0.80–5.54$, $p = 0.005–0.45$, $d = 0.25–2.51$ (12 out of all 17 relative phases showed significant differences). For the 1.0–1.1 m range, −180—160 degrees: $t_{(8)} = 1.02–6.41$, $p = 0.005–0.37$, $d = 0.47–3.48$ (13 out of all 17 relative phases showed significant differences), 160–180 degrees: $t_{(8)} = 0.21–3.10$, $p = 0.004–0.84$, $d = 0.10–1.54$ (1 out of all 17 relative phases showed significant differences). For the 1.1–1.2 m range, −180—160 degrees: $t_{(8)} = 0.02–2.31$, $p = 0.94–0.997$, $d = 0.01–0.95$ (0 out of all 17 relative phases showed significant differences), 160–180 degrees: $t_{(8)} = 0.004–1.54$, $p = 0.94–0.997$, $d = 0.002–0.65$ (0 out of all 17 relative phases showed significant

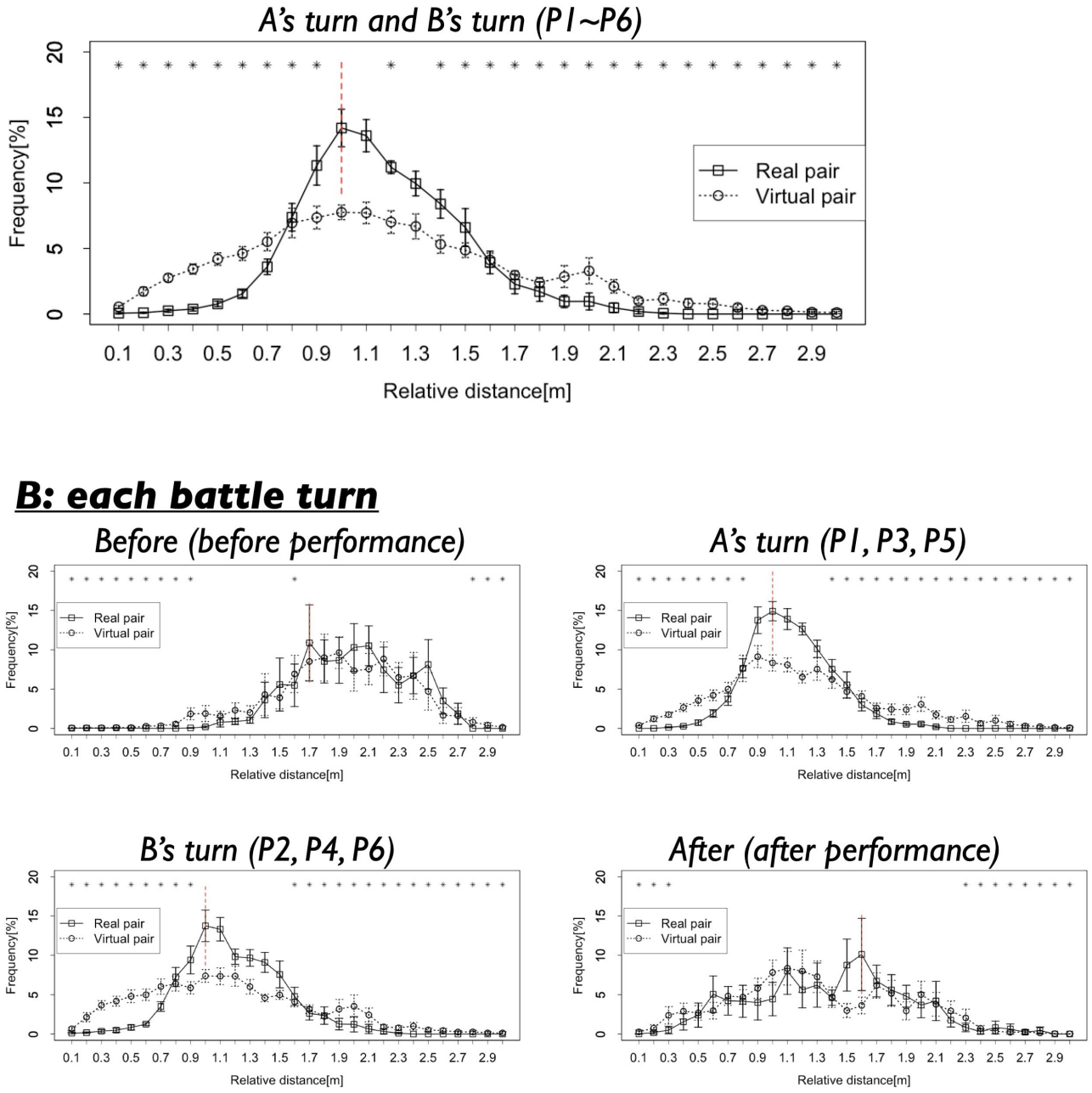


FIGURE 5
(A) Frequencies of the relative distances in the whole performance turns (P1–P6). Black vertical lines indicate standard error. Red vertical line indicates the mode. Asterisks indicate the relative distances whose frequencies show significant differences with the mode. *$p < 0.05$. **(B)** Frequencies of the relative distances in each turn.

differences). These results suggest that anti-phase synchronization was most pronounced when the dancers maintained a relative distance within ~0.8 to 1.1 m.

However, comparisons of anti-phase synchronization frequencies across the four distances ranges generally did not reveal significant differences. For the −180–160 degrees: $t_{(8)}$ = 0.45–4.36, p =0.01–0.66, d = 0.22–2.10. For the 160–180 degrees: $t_{(8)}$ = 0.13–2.12, p =0.40–0.90, d = 0.07–0.89. Significant differences were found only between the 1.1–1.2 m range and other distance ranges for the −180–160 degrees (see detailed results in Appendix A-4). These findings suggest that the dancers maintained anti-phase synchronization consistently across all distances around the mode, without dynamic changes based on their relative distance. This pattern contrasts with findings from studies on interpersonal sports, where coordination between two players shifts dramatically between anti-phase and in-phase

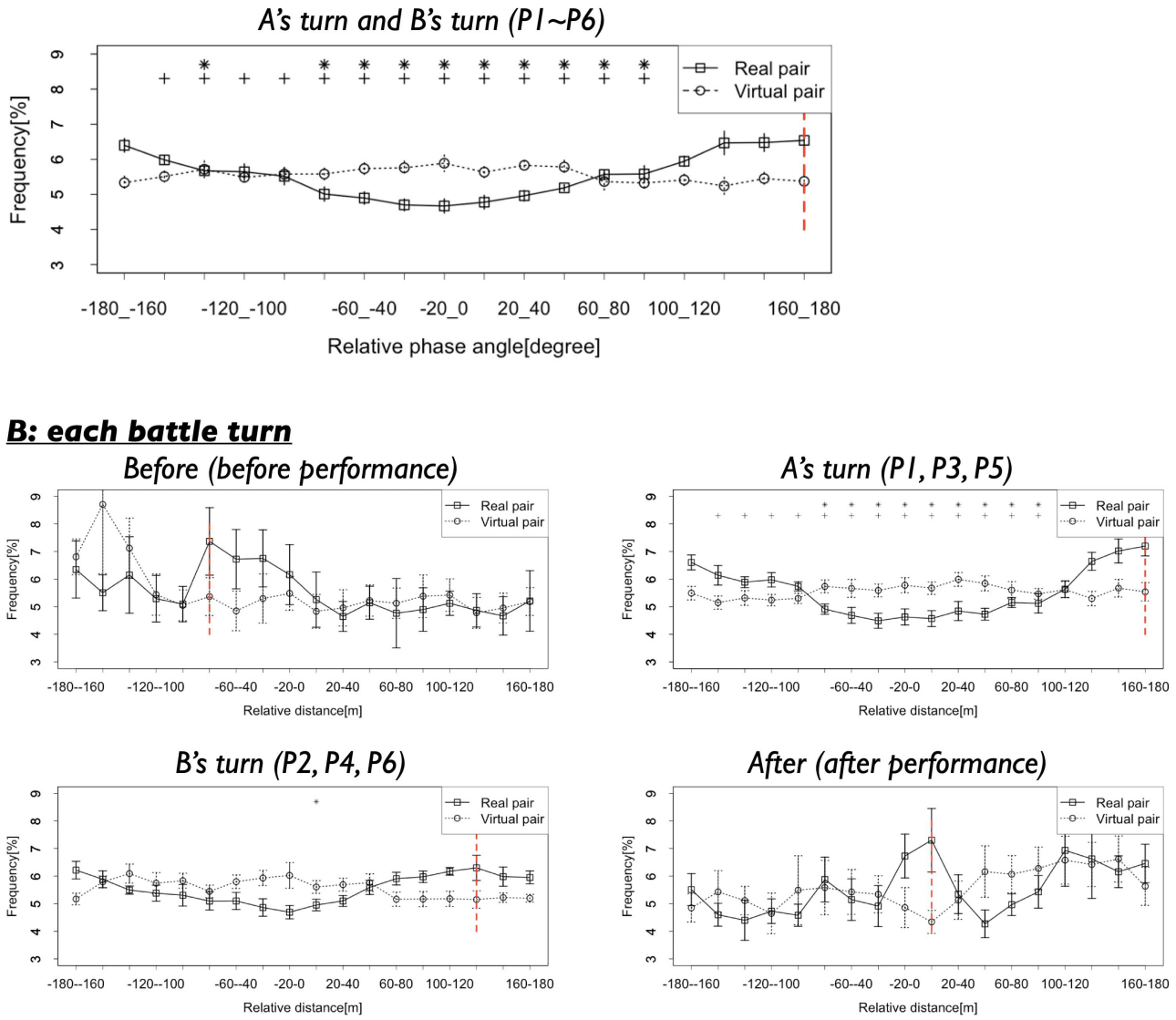


FIGURE 6
(A) Frequencies of the relative phases of dancers' back-and-forth movements in the whole performance turns (P1–P6). Black vertical lines indicate standard error. Red vertical line indicates the mode. Asterisks and crosses indicate the relative phases whose frequencies show significant differences with that at −180 to −160 degrees and 160–180 degrees (*$p < 0.05$ with −180 to −160 degrees, $^{+}p < 0.05$ with 160–180 degrees). **(B)** Frequencies of the relative phases in each turn.

synchronization depending on critical distances (e.g., proximity to reach or attack range, Kijima et al.,). Thus, we speculate that, during the breaking battle scenes, the dancers did not adjust their movement coordination based on physical factors such as arm length or the typical distance covered by a single step.

3.2 Results of each turn

3.2.1 Relative distance between two dancers

Next, we examined the results across four different turns. Before performance (Before) corresponded to the period before the dancers began their performances. A's turn represented periods during which the first dancer performed, and B's turn represented periods during which the second dancer performed. After performance (After)corresponded to the period after both dancers had completed their performances. Figure 5B shows the distribution of relative distances for each turn. In the Real pair condition, relative distance around 1.0 m were frequently observed during A's turn and B's turn, when the dancers were actively performing. The mode of the relative distances for these turns was 1.0 m. In contrast, during Before, relative distances were clustered around 1.7 m (mode = 1.7 m), and during After, a similar pattern was observed, with the mode at 1.6 m. In the Virtual pair condition, however, the distribution of relative distances remained

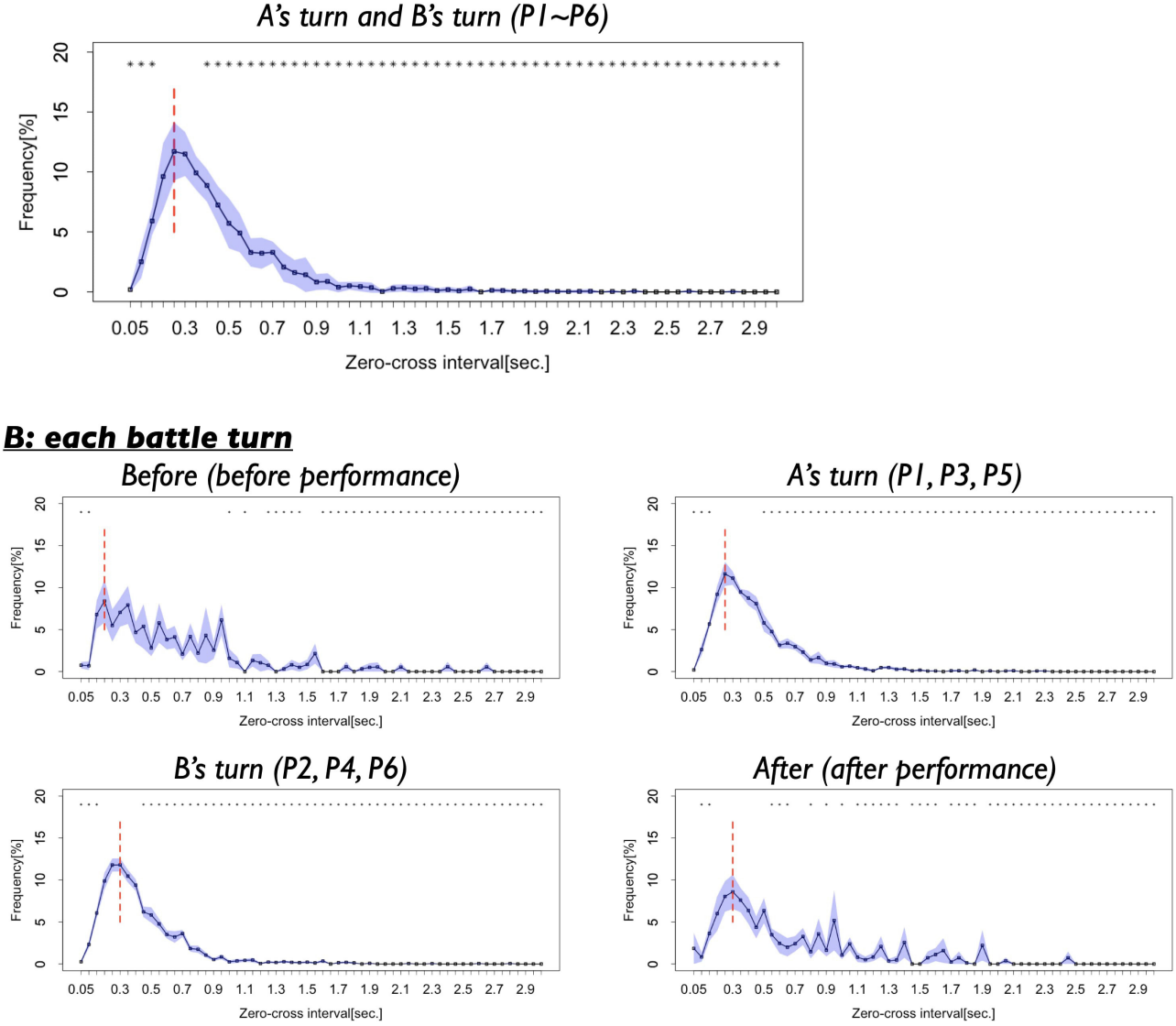


FIGURE 7
(A) Frequencies of the length of the switching intervals in the whole performance turns (P1–P6). Black vertical lines indicate standard error. Red vertical line indicates the mode. Asterisks indicate the length of the intervals whose frequencies show significant differences with the mode. *$p <$ 0.05. **(B)** Frequencies of the length of the intervals in each turn.

relatively stable across A's turn, B's turn, and After, without notable shifts. Furthermore, across all turns, the frequency of the modal relative distances in the Virtual pair was lower compared to that in the Real pair, suggesting less pronounced coordination in spatial positioning.

The statistical test supported these observations. Comparison corrected using the BH correction confirmed that, in each turn, the frequency of the modal distance was significantly different from the frequencies of many other distances, as indicated by the asterisk in Figure 5B. In particular, during A's turn and B's turn, when the dancers were actively performing, the mode frequency showed significant differences from nearly all other distance ranges. Specifically, Before: 13 out of all 29 distances showed significant differences from the mode (1.7 m, 44.83%), $t_{(8)} = 0.02\sim3.11$, $p = 0.04$–0.99, $d = 0.008$–1.47. A's turn: 25 out of all 29 showed significant differences from the mode (1.0 m, 86.21%), $t_{(8)} = 0.69$–25.98, $p = 0.000000004$–0.51, $d = 0.27$–10.58. B's turn 3: 24 out of all 29 showed significant differences from the mode (1.0 m, 82.76%), $t_{(8)} = 0.18$–12.08, $p = 0.000007$–0.86, $d = 0.04$–5.68. After: 11 out of all 29 showed significant differences from the mode (1.6 m, 37.93%), $t_{(8)} = 0.15$–4.30, $p = 0.03$–0.89, $d = 0.05$–2.03 (detailed results are provided in Appendix B-1). These findings suggest that during active performance phases (A's turns and B's turn), the dancers maintained a consistently close relative distance (around 1.0 m), whereas before and after the performances (Before and After), their relative positioning was more variable.

Further, we examined the differences in frequency of specific relative distances across turns. Comparisons with BH correction

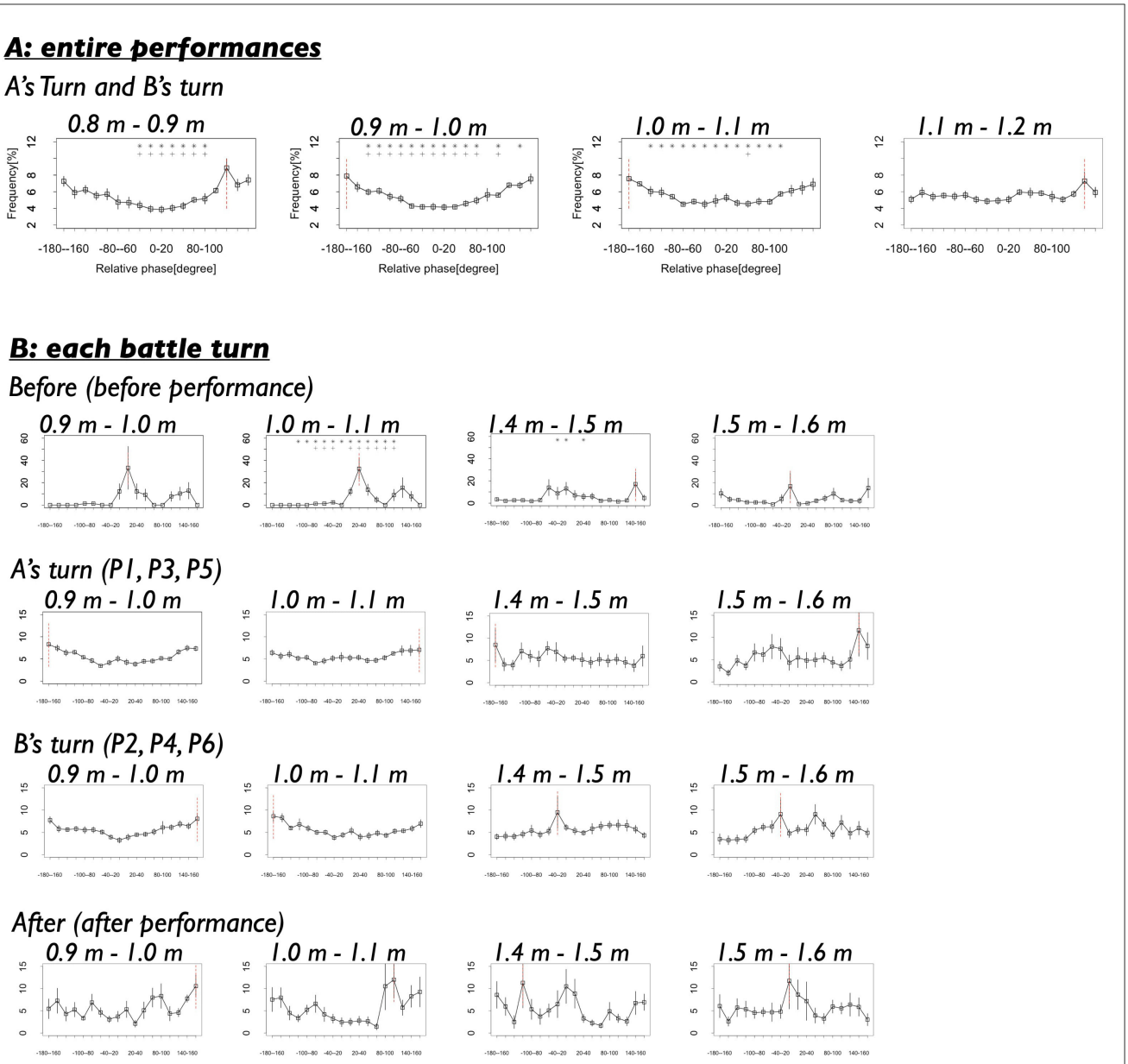


FIGURE 8
(A) Frequencies of the relative phases in each relative distance in the whole performance turns (P1–P6). Black vertical lines indicate standard error. Red vertical line indicates the mode. Asterisks and crosses indicate the relative phases whose frequencies show significant differences with that at −180 to −160 degrees and 160–180 degrees (*$p < 0.05$ with −180 to −160 degrees, $^{+}p < 0.05$ with 160–180 degrees). **(B)** Frequencies of the relative phases in each relative distance in each turn.

revealed that the frequency of 1.0 m—the modal distance during A's turn and B's turn— showed significant differences between several pairs of turns (Specifically, Before–A's turn, Before–B's turn, A's turn–After, B's turn–After). The statistics were $t_{(8)} = 0.83$–17.23, $p = 0.0000004$–0.43, $d = 0.30$–7.98. In contrast, the frequencies of 1.6 m (the mode in After) and 1.7 m (the mode in Before) did not show significant differences across turns. For 1.6 m: $t_{(8)} = 1.02$–1.94, $p = 0.26$–0.34, $d = 0.49$–0.81. For 1.7 m: $t_{(8)} = 1.06$–1.57, $p = 0.48$–0.88, $d = 0.09$–0.74. These results suggest that the modal relative distance varied across the four turns. Before their performances (Before), dancers tended to maintain a distance of around 1.7 m. During their performances (A's turn and B's turn), they moved significantly closer, maintaining distances around 1.0 m. After their performances (After), they maintained distances of around 1.6 m. However, the tendency to maintain a specific distance was relatively weaker before or after the performances compared to during the performances. In sum, these findings indicate that the dancers actively adjusted their relative distances depending on the context of the battle scene.

3.2.2 Relative phase of back-and-forth movements between two dancers

We further examined the results of the second analysis across the four turns, as presented in Figure 6B. This figure shows that, during A's turn and B's turn—when the dancers were actively

performing—the relative phases at −180—160 and 160–180 degrees were frequently observed in the Real pair condition. This pattern indicates that the dancers moved forward and backward in an anti-phase synchronization. In contrast, during Before and After—before and after the performances—this tendency was not observed. Before the performances (Before), relative phase around −80—60 degrees were more frequently observed, rather than the at −180—160 and 160–180 degrees. After the performances (After), relative phase around 0–20 degrees became predominant. These findings suggest that the dancers dynamically modulated their coordination patterns depending on the context. Specifically, their coordination shifted from a leader-follower relationships (with the first dancer acting as the leader and the second as the follower) before the performance, to anti-phase synchronization during the performance, and then to in-phase synchronization after the performance.

Statistical comparison with BH correction partially supported these findings. The comparisons confirmed that, particularly during A's turn—and to a lesser extent during B's turn—the relative phase frequencies at −180—160 and 160–180 degrees were significantly different from those of most other phases, as indicated by the asterisk and cross in Figure 6B. For A's turn, −180–160 degrees: 10 out of all other 17 phases showed significant differences (58.82%), t (8) = 0.07–4.74, p = 0.005–0.94, d = 0.03–2.59. For 160–180 degrees: 14 out of all other 17 phases showed significant differences (82.35%), $t_{(8)}$ = 0.45–7.73, p = 0.002–0.69, d = 0.16–2.93. For B's turn, −180—160 degrees: 1 out of all other 17 phases showed significant differences (5.88%), $t_{(8)}$ = 0.05–4.91, p =0.04–0.97, d = 0.02–1.78. For 160–180 degrees: 0 out of all other 17 phases showed significant differences (0.00%), $t_{(8)}$ = 0.03–3.70, p = 0.08–0.97, d = 0.01–1.76. In contrast, during Before and After, the relative phase frequencies at −180—160 and 160–180 degrees did not show significant differences compared to other phases (details results are presented in Appendix B-2).

Additionally, before the performances (Before), the frequency of the modal relative phase (−80–60 degrees) was not significantly different from the frequencies of other phases, although the effect sizes were relatively large. −80–60 degrees: 0 out of all other 17 phases showed significant differences (0.00%), $t_{(8)}$ = 0.36–2.58, p = 0.33–0.73, d = 0.19–1.01. In contrast, after the performances (After), the frequency of the modal relative phase (0–20 degrees) was significantly different from those of other phases. 0–20 degrees: 0 out of all other 17 phases showed significant differences (0.18%), $t_{(8)}$ = 0.30–4.91, p = 0.02–0.78, d = 0.006–0.70. These results suggest that the dancers dynamically adapted their movements' coordination across different turns. However, the leader-follower relationship hypothesized for Before was not strongly supported by statistically significant differences, despite the presence of moderate to large effect sizes.

Further, we examined the frequency differences of key relative phases across turns. Comparisons with BH correction revealed that the frequency of the relative phases at −180—160 and 160–180 degrees were not significantly different across turns, although the effect sizes were relatively large. −180—160 degrees: $t_{(8)}$ = 0.15–1.63, p = 0.68–0.89, d = 0.06–0.84. 160–180 degrees: $t_{(8)}$ = 0.48–2.88, p = 0.12–0.64, d = 0.24–1.40. Similarly, the frequencies of the modal relative phases Before and After did not differ significantly across turns, although again the effect sizes were relatively large. For −80–60 degrees: $t_{(8)}$ = 0.49–1.86, p = 0.39–0.64, d = 0.23–0.94. For 0–20 degrees: $t_{(8)}$ = 0.65–2.85, p =0.13–0.53, d = 0.31–1.38 (see detailed results in Appendix B-2).

Based on these results, we can speculate that the dancers actively adapted their coordination of back-and-forth movements according to the evolving dynamics of the battle situation. In particular, during their performances, the dancers tended to sustain an anti-phase synchronization, moving in opposite directions. Taking into account the findings from the first analysis as well, we propose the following sequence: Before their performances, the dancers maintained a relative distance of ∼1.7 m by moving forward and backward in the same direction, albeit with some time lags between them. During their performances, they adjusted to a closer distance of around 1.0 m, reacting sensitively to each other's movements and moving in opposite directions (anti-phase coordination). After completing their performances, they returned to maintaining a relative distance of ∼1.6 m again moving in the same direction.

3.2.3 Length of the switching intervals of two dancers

Figure 7B presents the results of the third analysis across the four turns. The figure suggests that before and after the performances (Before and After), the intervals between direction switches varied widely, ranging from 0.15 to 1.00 s. In contrast, during the performances (A's turns and B's turn), short intervals of ∼0.25 and 0.30 s were frequently observed, with the distribution exhibiting a clear single peak. There findings indicate that interval variability was relatively high during Before and After, whereas during in A's turn and B's turn, the dancers maintained more consistent, shorter switching intervals, reflecting tighter temporal coordination while performing.

Comparisons with BH correction showed that, across all turns, the frequency of the modal intervals was significantly different from those of many other intervals, as indicated by the asterisk in Figure 7B. Turn 1: 38 out of all 59 distances showed significant differences with the mode (0.20 s., 64.40%), $t_{(8)}$ = 0.04–3.81, p = 0.01–0.97, d = 0.02–1.76. Turn 2: 54 out of all 59 distances showed significant differences with the mode (0.25 s., 91.53%), $t_{(8)}$ = 0.17–14.81, p = 0.000001–0.87, d = 0.07–6.73. Turn 3: 55 out of all 59 distances showed significant differences with the mode (0.30 s., 93.22%), $t_{(8)}$ = 0.02–29.57, p = 0.000000007–0.99, d = 0.006–13.52. Turn 4: 44 out of all 59 distances showed significant differences with the mode (0.30 s., 74.58%), $t_{(8)}$ = 0.007–4.87, p = 0.003–0.99, d = 0.002–2.30 (detailed results are provided in Appendix B-3).

We also examined differences in interval frequency among turns, focusing particularly on the frequencies of the modal intervals for each turn (Before: 0.20 s., A's turn: 0.25 s, B's turn: 0.30 s, and After: 0.30 s). Comparisons with BH correction revealed that the mode frequencies in A's turn (0.25 s) and B's turn (0.30 s) were significantly different from that in Before. For 0.25 s: t (8) = 0.25–2.68, p = 0.003–0.81, d = 0.12–1.27. For 0.30 s: $t_{(8)}$ = 0.34–2.46, p = 0.04–0.74, d = 0.17–1.10. However, the frequency of the 0.20 s interval (Before) was not significantly different across turns.

$t_{(8)} = 0.42–1.20$, $p = 0.27–0.69$, $d = 0.16–0.55$ (details results are presented in Appendix B-3).

These results suggest that the dancers frequently switched their forward and backward movement directions at very short intervals, particularly during their performances. In contrast, before and after performing, the switching intervals were relatively longer and exhibited greater variability. This context-dependent modulation of switching intervals highlights a flexible adaptation of movement coordination to performance demands—a phenomenon that has not been sufficiently explored in studies of interpersonal interactions among sports players.

3.2.4 Relative phase of back-and-forth movements at each relative distance

Lastly, we examined the results of the fourth analysis across the four turns, as presented in Figure 8B. In this analysis, we focused on relative distances around the modal values for each turn (1.0 m and 1.6 m) and investigated the distribution of relative phase within specific distance ranges (0.9–1.0 m, 1.0–1.1 m, 1.4–1.5 m, and 1.5–1.6 m). Figure 8B shows that before the dancers began their performances (Before), relative phases indicative of in-phase synchronization (-20–0 and 0–20 degrees) were frequently observed across all distances. In contrast, during the performances (A's turn and B's turn), relative phases corresponding to anti-phase synchronization (-180–160 and 160–180 degrees) were predominantly observed across almost all distance ranges. After the performances (After), a mixed pattern emerged: anti-phase synchronization (-180–160 and 160–180 degrees) was frequently observed at shorter distances (0.9–1.0 m and 1.0–1.1 m) while in-phase synchronization (-20–0 and 0–20 degrees) was more common at larger distances (1.4–1.5 m and 1.5–1.6 m). These results suggest that the dancers' coordination patterns were primarily context-dependent—shaped by the performance phase—rather than strictly dependent on inter-dancer distance, except during after the performances (After) where some distance-dependent tendencies were observed.

The statistical test partly supported these findings. Comparisons with BH correction revealed that, at each distance, the relative phase frequencies associated with anti-phase synchronization differed across turns. For the distance ranges at 9.0–1.0 m and 1.0–1.1 m, the frequencies at −180—160 and 160–180 degrees were significantly different among turns (detailed results are provided in Appendix B-4).

Further, we compared the frequencies of anti-phase synchronization across distances within each turn, applying BH correction. The results showed that significant differences among distances were observed only in A's turn and B's turn at 160–180 degrees (detailed results are provided in Appendix B-4).

Additionally, we compared the frequencies of anti-phase synchronization (−180—160 and 160–180 degrees) with those of other relative phases at each distance within each turn (it should be noted that we were unable to statistically test some frequency differences in Before because the dancers rarely exhibited multiple distinct relative phases during that turn, resulting in insufficient data). The results indicated that before the performances (Before), although formal statistical test was limited, the observed frequency differences between anti-phase synchronization and other relative phases were either significant or associated with large effect sizes. In A's turn, the frequencies at −180—160 and 160–180 degrees were significantly different from those of other phases across distances. In B's turn, anti-phase synchronization was frequently observed at 1.0–1.1 m distance range, but was rare at 1.4–1.5 m and 1.5–1.6 m. After the performances (After), anti-phase synchronization was frequently observed at 1.0–1.1 m and 1.4–1.5 m, but was seldom observed at 1.5–1.6 m (detailed results are provided in Appendix B-4).

These results align closely with the patterns observed in the figure. They suggest that before and during the dancers' performances, coordination patterns did not exhibit the distance-dependent characteristics that became evident after the performances. Specifically, the dancers' coordination—including the emergence of in-phase and anti-phase synchronization—did not show rapid, distance-dependent transitions. Instead, the coordination patterns were strongly shaped by the broader battle context. This context-dependence differs markedly from the coordination patterns typically observed among sports players, where rapid distance-dependent changes often occur. These findings highlight a unique and intriguing feature of performers' interactions during competitive artistic performances.

4 Discussion

This study investigated the interactions between expert breakdancers during battle scenes as a representative form of competitive performance. Specifically, we examined the coordination of the dancers' back-and-forth movements using relative phase analysis. The results revealed that throughout the battle scenes, the dancers frequently coordinated their movements in an anti-phase synchronization pattern—when one dancer moved forward, the other moved backward. They actively switched their movement directions at short intervals and maintained a consistent relative distance of ∼1.0 m. Unlike interpersonal sports players (Okumura et al., 2012), the dancers did not exhibit drastic changes in their coordination patterns based on relative distances. Furthermore, when the battle scenes were divided into four distinct turns, it became evident that the dancers dynamically modulated their coordination patterns depending on the performance context and the timing within the interaction.

Specifically, before the performance, when the competitive context was relatively weak, the dancers frequently moved forward and backward in the same direction, albeit with some time lags, and maintained relatively long distances between each other. During the performance, when the competitive context intensified, they frequently moved in opposite directions (exhibiting anti-phase synchronization) and maintained short distances, placing them in close proximity. After the performance, the dancers again tended to move in the same direction (in-phase synchronization) while maintaining longer distances.

Based on the results of this study and previous research (Shimizu and Okada, 2021), we confirmed that performers exhibit consistent coordination patterns, such as anti-phase synchronization across several expressive channels in competitive contexts. Previous studies investigating breaking battle scenes have suggested that dancers coordinate their rhythmic movements in an anti-phase synchronization pattern (Shimizu and Okada, 2021). However, these earlier studies did not examine whether similar coordination patterns emerge across other different expressive channels under the same competitive conditions, nor did they explore the similarities and differences in coordination across multiple channels. As discussed in the introduction, performers are expected to interact through multiple expressive channels simultaneously. To fully capture the complexity of performer interactions, it is essential to consider the overall coordination state across these channels. The present study demonstrated that performers exhibited similar coordination patterns—specifically, anti-phase synchronization—across multiple expressive channels during strong competitive contexts, thereby offering an important first step toward a comprehensive scientific understanding of performer interactions. Future research should continue to develop methods and analyses capable of capturing the correspondence of coordination patterns across multiple expressive channels.

This study further illuminated important details and underlying aspects of performers' interactions. In addition to demonstrating anti-phase synchronization in the dancers' movements, we found that the dancers actively switched their forward and backward movement directions at short intervals. They also dynamically adjusted their coordination patterns depending on the performance context (i.e., performance turns). Notably, these coordination patterns were not influenced by changes in relative distance. We speculate that this context-dependent modulation of coordination is a fundamental characteristic of performer interactions. In contrast, similar coordination patterns were not observed in studies of interpersonal sports interactions, such as Kendo matches and tag-taking games (Kijima et al., 2012; Okumura et al., 2012). Specifically, in interpersonal sports, players' coordination was strongly dependent on relative distance rather than on contextual changes. Thus, the present findings highlight a key distinction between artistic performance and sports interaction: performers exhibit flexible, context-driven coordination dynamics, whereas sports players rely more heavily on distance-dependent coordination.

Careful discussion is needed to understand the background of these differences. Research on interpersonal sports, such as Kendo matches and tag-taking games, has suggested that specific goals and rules (e.g., striking the opponent's body or capturing a tag attached to the opponent) as well as physical properties (e.g., the length of a bamboo sword, arm length, and the distance covered in a single step) strongly shape coordination patterns. In these sports contexts, players consistently maintained specific interpersonal distances and adapted their coordination patterns based on these distances. Furthermore, coordination patterns in sports were not notably dependent on the progression of time during the match; players maintained stable distance-dependent coordination until the match concluded.

Unlike players in interpersonal sports, performers do not aim to strike or physically contact other performers. If the primary goal were simply to avoid contact, performers would not need to maintain close distances around 1.0 m through anti-phase synchronization, especially given that the available space would have allowed them to separate much further. Instead, goals such as open communication and expressive interaction—distinct from the objectives of interpersonal sports—likely facilitated the observed coordination patterns. In the performing arts, performers aim to present attractive performances and engaging interactions for the audience. We speculate that during competitive performances, such as breaking battles, performers sought to emphasize their individual expressions by contrasting them with those of their counterparts through anti-phase synchronization. Moreover, they may have actively modulated their coordination patterns to capture and sustain the audience's attention and interest. Given their extensive experience, expert performers may have implicitly understood how dynamic coordination patterns contribute to audience engagement, thereby exhibiting such context-sensitive behaviors naturally. However, to confirm the underlying mechanisms of this coordination, further research is needed. Specifically, studies comparing coordination patterns between experts and novice performers, as well as investigation into how different coordination dynamics influence audience attention and interest, are essential.

Furthermore, we situate our study within the framework of Beyond Synchrony, which has been proposed over the past several years to better capture the complexity of human interactions in daily life. This framework seeks to extend traditional theories of synchronization and coordination by accounting for more dynamic and multi-faceted patterns of interaction (Dale et al., 2013; Wallot et al., 2016). For example, in joint action tasks where individuals aim to achieve a shared goal, participants often display different but complementary behaviors that contribute to successful goal attainment (Richardson et al., 2015). Additionally, in everyday conversations, people coordinate their behaviors across multiple channels—such as speech, facial expressions, and gestures—forming a richly interconnected system of communication (Louwerse et al., 2012). Research investigating the influence of context on conversational coordination has also been developed within this framework (Abney et al., 2014; Paxton and Dale, 2013, 2017), highlighting how interaction patterns flexibly adapt to changing communicative demands.

Our study aligns well with the Beyond Synchrony framework and can be understood as an initial attempt to focus primarily on the influence of context and multi-channel behaviors, applying this theoretical perspective to interactions among performers. However, the present study could not fully address these aspects. Specifically, we did not quantitatively investigate complementary coordination among performers, nor did we examine the correspondence across multiple expressive channels—such as facial expressions, gestures, rhythmic movements, and back-and-forth locomotion. Future research is needed to more comprehensively capture complementary coordination patterns, such as polyrhythms, and the broader state of multi-channel coordination. This will require further development of analytical frameworks that extend current

methods for analyzing synchronization and coordination in complex, real-world interactions.

There are several important caveats, as also noted in Shimizu and Okada (2021). First, the number of dancers in the study was strictly limited. Due to the busy schedules of expert dancers, it was extremely difficult to recruit a larger sample and conduct group experiments. Given these constraints, we interpreted the results by carefully considering both effect sizes and significance tests. However, to more broadly generalize these findings of this study, it is essential to conduct future investigations involving a larger number of expert performers. Second, it is necessary to establish experimental conditions that more strongly reflect the contexts of coordination and competition. In the present study, we examined the influence of context by comparing different battle turns—before, during, and after performances. Nevertheless, to more directly and clearly capture the influence of context, it would be beneficial to compare conditions that explicitly differentiate competitive and cooperative settings. For instance, comparing interactions within a crew (cooperative) vs. between crews (competitive) in crew battles would offer valuable insights. In sum, the study of performers' interactions in competitive contexts is a highly promising research area that warrants further scientific exploration.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: this study experimented with the performances of highly accomplished dancers. Due to the nature of these dancers' work, certain restrictions were imposed on directly sharing data on the dancers' performances, which were treated as artworks. Therefore, it is difficult to publicly include the analyzed data directly in the manuscript/Supplementary material. We will share our data after direct contact with the authors and confirmation of the above restriction. Requests to access these datasets should be directed to Daichi Shimizu, tothefuture0415@yahoo.co.jp.

Ethics statement

The studies involving humans were approved by the Ethics Committee of the University of Tokyo. 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

DS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. TO: Conceptualization, Supervision, Validation, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was supported by Scientific Research on Innovative Areas 20H04573 "Construction of the Face-Body Studies in Transcultural Conditions" and the Grant-in-Aid for Scientific Research (C) 22K03073 granted to DS from the Japan Society for the Promotion of Science.

Acknowledgments

We would like to thank the seven expert breakdancers for participating in our experiment.

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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2025.1441378/full#supplementary-material

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frontiers | Frontiers in Psychology

TYPE Brief Research Report
PUBLISHED 16 July 2025
DOI 10.3389/fpsyg.2025.1525172

OPEN ACCESS

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RECEIVED 08 November 2024
ACCEPTED 03 July 2025
PUBLISHED 16 July 2025

CITATION
Jehu DA, Bek J and Hackney ME (2025) Social support may not impact physical function outcomes following a tango or walking intervention in people with Parkinson's disease: an exploratory analysis of a randomized controlled trial.
Front. Psychol. 16:1525172.
doi: 10.3389/fpsyg.2025.1525172

Social support may not impact physical function outcomes following a tango or walking intervention in people with Parkinson's disease: an exploratory analysis of a randomized controlled trial

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Poor physical function influences social support among people with Parkinson's disease (PD). Physical function can be improved through exercise, but whether social support influences intervention responsiveness is unclear. This study aimed to (1) examine the influence of 12 weeks of group exercise (tango or walking) on physical function in people with PD who reported low versus high baseline social support, and (2) determine the influence of intervention type on social support effects. This exploratory analysis of an ongoing assessor-blinded randomized controlled trial (1:1) [NCT04122690] included 40 participants with PD (69.24 ± 7.73 years; 26.3% female; Hoehn & Yahr: 2.28 ± 0.58). We used the Multidimensional Scale of Perceived Social Support to categorize participants into high or low support groups. Participants were assessed OFF medication at baseline and 12 weeks using the timed-up-and-go, 360-degree turn, forward, backward, and fast gait speed, 6-min walk, chair stand, and tandem stance tests. Participants were randomized into tango (n = 20) or walking (n = 20) groups and completed 20 sessions within 12 weeks. Left foot tandem stance trended toward improvement regardless of social support (p = 0.06). An interaction among time, support, and intervention indicated that participants in the walking group with low social support improved more on the chair stand test (p = 0.03). No adverse intervention-related events occurred. Overall, high and low social support groups improved similarly following tango or walking interventions. Those in the walking group with low support may have benefited more. Therapeutic intervention targeting physical function regardless of social network in people with PD is important.

KEYWORDS

Parkinson's disease, neurorehabilitation, social support, dance, exercise, tango

Introduction

Parkinson's disease (PD) can interfere with social functioning, which can impact the overall health of those with PD (Henry et al., 2016). Social functioning can be impacted by several factors, such as age, disease, mobility limitations, and cognitive impairment. Older adults often have a smaller social network and reduced closeness to network members compared to young and middle-aged adults, due to factors such as retirement and bereavement (Cornwell et al., 2008), as well as chronic health problems, sensory impairment, and income instability (National Academies of Sciences, 2020). In particular, mild cognitive impairment is common among people with PD, and those who are aware of their own cognitive decline may avoid social activities, especially highly demanding cognitive activities (Ho et al., 2021; Anderson, 2019) or activities requiring digital literacy (Zhu et al., 2023) due to embarrassment and stigmatization (Zhu et al., 2023). People with PD may also have difficulty recognizing emotions, and such social impairment is associated with greater PD burden (Coundouris et al., 2019). PD also leads to decreased mobility, and those who have mobility challenges tend to report social withdrawal due to a lack of required physical support, stigmatization, and embarrassment (Ahn et al., 2022; Nilsson et al., 2015). Physical function and social support appear to be related, as adults aged 18–64 years with mobility disability who were unemployed and in fair or poor health reported greater loneliness, more isolation, and less satisfaction with social activity (Hall et al., 2022). Given that social support plays a protective role in overall health (Frick et al., 2012), and that people with PD have poorer social functioning (Henry et al., 2016), it is important to understand the impacts of reduced social support in this population.

Social support protects overall health in several ways. Forms of social support can include emotional, informational (e.g., advice leading to a solution to problems), instrumental (e.g., practical help), and companionship support (Ferlander, 2007; Thoits, 2011). A greater number and quality of social ties may increase a sense of belonging to others, self-esteem, and a sense of control over life situations (Thoits, 2011). Stress-buffering effects of social ties may be the mechanism of action explaining better health outcomes with greater social support (Thoits, 2011). Social support offered as facts or recommendations from others–such as where to find less expensive and more convenient goods and services–enables subsequent behavioral changes that make everyday vexing circumstances more efficient (Thoits, 2011). Coping assistance strategies are stress buffers because they dampen situational demands and the person's emotional reactions to these demands, which can reduce the physical and psychological consequences of the stressor (Thoits, 2011). Social support also buffers the impact of adversity (Thoits, 2011). The social resource model argues that social relationships are embedded within social ties and framed as social resources or social capital, which can demonstrate benefits to physical health outcomes (Song et al., 2021). While social roles for people with PD may change throughout the course of the disease, social support can benefit people with PD by encouraging health-promoting peer social norms, such as adequate educational programs and exercise, and discouraging health-damaging behaviors such as smoking, excessive eating, and drug use (Perepezko et al., 2019). Social ties can also facilitate access to healthcare resources, such as medical referrals, life skills training, education, or support groups (Ferlander, 2007). Therefore, given the importance of social support for health outcomes, examining the impact of different levels of social support on response to interventions is important for those with PD.

Group exercise improves physical function and social connectedness in people with PD (Hackney and Earhart, 2010; McKee and Hackney, 2013). This improved connection may stem from increased socialization among participants and instructors during group exercise (Mays et al., 2021). Thus, clinical trials of group exercise often control for socialization in the design of the intervention when contrasting lifestyle intervention effectiveness with a comparison group (Capili and Anastasi, 2023; McKee and Hackney, 2013; Hackney and Earhart, 2010). However, people with PD who are socially isolated are less physically active (Terracciano et al., 2023) and exhibit poorer physical function than socially connected older adults (Ahn et al., 2022). Therefore, baseline levels of social connectedness may influence the responsiveness of physical function outcomes to intervention. A better understanding of the role of social support in physical function responsiveness to exercise interventions among people with PD could provide insight into more effective treatment strategies.

The purpose of this exploratory analysis of an ongoing randomized controlled trial (RCT) was to examine the influence of 12 weeks of group exercise (tango or walking) on physical function in people with PD who reported low perceived social support compared to those with high perceived social support. As a secondary aim, we explored whether the type of intervention (tango or walking) influenced the impact of social support on physical function outcomes. We hypothesized that people with PD with high social support would exhibit greater improvements in physical function than the low social support group following 12 weeks of either tango or walking exercise. We also hypothesized that we would observe no differences between the tango or walking interventions for the low compared to the high social support groups on physical function.

Methods

Study sample, recruitment, and randomization

The sample was drawn from the PAIRED protocol, which is a parallel, assessor-blinded RCT (1:1) that has been registered on clinicaltrials.gov (NCT04122690), and the protocol has previously been published (Hackney et al., 2020). The Consolidated Standards of Reporting Trials (CONSORT) were followed to ensure the quality of reporting (Schulz et al., 2010).

We recruited participants from the Atlanta VA Medical Center Movement Disorders Clinic and the Emory Movement Disorders Clinic, at local PD-related support groups, the Michael J. Fox Foundation FoxFinder web-based registry, educational meetings, and community events. Recruitment for the sample considered in this paper took place between November 2020 and March 2024. All participants provided written informed consent. The Emory IRB and the VA Research and Development committees approved all protocols (Emory IRB112770).

Participants met the following inclusion criteria: (1) a diagnosis of PD (ICD-10 G20) based on established criteria (Hughes et al., 1992) and determined by a board-certified neurologist with training in movement disorders; (2) asymmetric symptoms including at least three of the cardinal signs of PD (rigidity, bradykinesia, tremor,

postural instability) and showed clear symptomatic benefit from anti-Parkinsonian medications (Kempster et al., 2007); (3) aged 40 years or older; (4) a Hoehn & Yahr stage I–III; and (5) reported symptoms during their "off" time indicated by score ≥1 on UPDRS-IV item 4.3 (i.e., time spent in the OFF-state). Exclusion criteria included scoring <17 on the Montreal Cognitive Assessment (Litvan et al., 2012) or ≥18 on the Beck Depression Inventory-II (Schrag et al., 2007), or having another neurodegenerative disease.

Study staff assigned participants randomly to an adapted Argentine tango (tango) or supervised group walking (walking) program after baseline assessments. Participants were randomized using the REDCap randomization module, stratified by age and sex (Harris et al., 2009). Investigators and administrative staff, but not instructors, were blinded to treatment assignments. Participants knew their treatment but not whether they were allocated to an experimental or control group.

Procedure

The testing and training took place at the Atlanta VA North Dekalb Community-Based Outpatient Clinic. We provided transportation for participants who needed it. All participants were tested on physical function at baseline and 12–13 weeks. Participants were tested on all outcome measures at least 12 h after their last dose of anti-Parkinsonian medications (OFF-medication) at a standardized time of day to obtain an accurate assessment of disease severity and evaluate treatment effectiveness. All participants were ON medication during all intervention sessions.

Participant characteristics

Participants reported demographic characteristics on a health questionnaire (see Table 1). Global cognition was assessed using the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005). A Movement Disorders Society-certified rater (blinded to group allocation) evaluated participants on the Movement Disorders Society revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS), parts I-IV (Goetz et al., 2008). Physical activity levels were measured using the Physical Activity Scale for the Elderly (Washburn et al., 1993). Participants rated leisure-time physical activity on a 4-point Likert scale, with lower scores indicating less activity. The Paffenbarger College Alumnus PAQ (PAQ-P) is a measure of the number of kilocalories expended in a week during physical activity and queries daily blocks walked, daily flights of stairs climbed, and recreational activities (including frequency and duration of each episode) as reported on the PASE (Rubenstein et al., 2011). A total Paffenbarger physical activity score (PAS-P) is tabulated by summing the kilocalories expended during blocks walked, stairs climbed, and recreational activities. Scoring assumes all participants are the same weight (60 kg); thus, we divided the PAS-P by 60 kg, resulting in kcal expended per kg of body weight per week.

TABLE 1 Participant characteristics; mean (standard deviation).

Variable	All participants (*n* = 38)	Low support (*n* = 14)		High support (*n* = 24)		Low vs. high support (statistic, *p*-value)
		Tango (*n* = 7)	Walk (*n* = 7)	Tango (*n* = 12)	Walk (*n* = 12)	
Age, years	69.24 (7.73)	65.71 (9.59)	66.57 (6.21)	71.33 (6.21)	70.75 (8.45)	1.92 (0.07)
Female Sex, *n* (%)	10 (26.32)	2 (28.57)	4 (57.14)	3 (25.0)	1 (8.33)	2.91 (0.16)
MDS-UPDRS, part I score	10.84 (6.28)	13.86 (8.23)	11.14 (6.49)	9.08 (4.56)	10.67 (6.51)	−1.17 (0.26)
MDS-UPDRS, part II score	14.70 (9.88)	12.86 (10.29)	19.43 (12.71)	12.82 (7.32)	14.75 (10.25)	−0.64 (0.53)
MDS-UPDRS, part III score	38.37 (14.42)	43.57 (15.89)	39.57 (16.87)	36.42 (9.19)	36.58 (17.20)	−1.00 (0.33)
MDS-UPDRS, part IV score	6.08 (4.12)	6.71 (4.96)	5.71 (3.40)	5.58 (3.12)	6.42 (5.20)	−0.15 (0.88)
Time since PD onset, years	6.91 (5.41)	6.57 (4.65)	6.79 (5.58)	5.08 (4.20)	9.00 (6.61)	0.21 (0.84)
Hoehn & Yahr, score	2.28 (0.58)	2.29 (0.57)	2.36 (0.75)	2.29 (0.40)	2.21 (0.69)	−0.35 (0.73)
MoCA, score	26.37 (3.16)	26.00 (4.08)	27.43 (1.72)	26.25 (2.77)	26.08 (3.78)	−0.52 (0.61)
Education, years	16.53 (2.36)	15.71 (3.15)	16.29 (2.43)	16.50 (2.43)	17.17 (1.80)	0.99 (0.33)
PASE score	120.46 (98.02)	212.20 (172.26)	95.46 (90.09)	115.30 (48.67)	98.29 (89.40)	−0.86 (0.40)
PAS-P, kilocalories expended per week	4017.34 (5717.74)	9749.10 (7979.55)	2841.73 (5897.78)	3741.88 (5419.19)	2460.62 (3515.69)	−1.11 (0.28)
MSPSS baseline	5.93 (1.32)	4.13 (1.68)	5.14 (0.88)	6.66 (0.32)	6.71 (0.31)	5.43 (<0.001)
MSPSS post-training	6.11 (0.90)	5.48 (1.38)	5.68 (0.93)	6.22 (0.84)	6.57 (0.48)	2.31 (0.03)

MoCA, Montreal Cognitive Assessment; MDS-UPDRS, Movement Disorders Society Unified Parkinson Disease Rating Scale; PASE, Physical Activity Scale for the Elderly; PAS-P, Paffenbarger physical activity score, kilocalories expended per week; MSPSS, Multidimensional Scale of Perceived Social Support.

Stratification by perceived social support

This study operationalized social support using the Multidimensional Scale of Perceived Social Support (MSPSS). The MSPSS is a measure of perceived social support from family, friends, and significant others (Zimet et al., 1990). The MSPSS comprises 12 questions rated on a 7-point Likert scale (1 = very strongly disagree, 7 = very strongly agree), with higher ratings reflecting greater perceived social support. The MSPSS has been used in other studies to assess social support in people with PD (Ghorbani Saeedian et al., 2014; Chen, 2025). The average overall score was used to stratify participants. According to previously defined cutoffs for the MSPSS, a score of 1 to 2.9 is considered low support, a score of 3 to 5 is considered moderate support, and a score from 5.1 to 7 is considered high support (Zimet et al., 1990). Because of our sample size we categorized participants into high or low groups only; the *high social support* group reported "strongly agree" or "very strongly agree" for total perceived social support (equivalent to average scores of 6–7 on the MSPSS), and the *low social support* group reported "mildly agree," "neutral," "mildly disagree," "strongly disagree," or "very strongly disagree" (equivalent to average scores of 1–5 on the MSPSS).

Physical function outcome measures

The timed-up-and-go (TUG) is a valid and reliable measure of functional mobility in PD (da Silva et al., 2017), and involves getting up from a chair, walking 3 meters, turning around, walking back, and sitting down (Lee et al., 2020; Ries et al., 2009). Participants completed the TUG as a single task, as well as a dual task while counting backward by 3 from 100.

We measured turning with the 360-degree turn test (Prime et al., 2020). Participants were asked to turn 360 degrees left at a self-determined pace, and we recorded the time to completion. Turning measures are valid and reliable in PD (da Silva et al., 2017).

We measured forward, backward, and fast gait speed across 6.1 meters. We instructed participants to walk at their usual pace during the forward and backward gait conditions, and as fast as they could without running during the fast gait speed condition. The time to completion was recorded in seconds and converted into a gait speed in m/s. These assessments have been sensitive to the effects of PD (Hackney and Earhart, 2009; Hackney and Earhart, 2010). Gait measures are valid and reliable in PD (da Silva et al., 2017; Kocer et al., 2023).

Participants completed the 6-min walk test, which is valid and reliable in PD (Bailo et al., 2024), and were asked to walk as far as they could without running (ATS, 2002). The total distance was measured in meters.

For the chair stand test, participants were asked to stand up and sit down from a chair as many times as possible in 30 s. The number of chair stands was recorded. Sit-to-stand and stand-to-sit measures are valid and reliable in PD (da Silva et al., 2017).

For the tandem test, participants were asked to stand as long as possible with one foot in front of the other for up to 30 s with left or right foot in front. Participants completed two trials, of which the best was used in analyses. The tandem test is valid and reliable in PD (Thomas et al., 2004).

Intervention design and structure

All intervention participants were asked to complete 20 lessons that were 90 min each in length within 12–13 weeks after baseline assessments. According to the social resource model, social relationships can benefit physical health (Song et al., 2021). Therefore, all participants had a similar exposure to social interactions with the research team. The rate of perceived exertion (RPE) on the Borg scale and heart rate (HR) were taken pre-warm up, post-warm up, and at 15-min, 30-min, and 45-min time points. Participants wore a chest-strapped Polar heart rate monitor during the exercise session, and were monitored with a connected IPad during the sessions. For the Borg, participants were asked to work at a rate of perceived exertion between 4 to 6 on a 10-point scale. They were coached accordingly to ease up or exert themselves more if the values did not fall within this range. If participants missed a training session, they were contacted and invited to make up for the missed session if they were willing to do so.

Tango program

Participants were paired with a neurologically healthy partner (trained staff, university student, caregiver, or friend). The instructor and several trained assistants monitored all participants. Class sizes consisted of 6 or fewer pairs of participants plus their partners to maximize safety. Participants danced leading and following roles and rotated to new partners every 15 min to enhance motor learning and social interaction. Tango was intended to engage participants in developing an understanding of the temporal relationship of movement to music and connecting previously learned and novel step elements. The dance classes included 15-min practica where participants learned previous steps, 25-min standing warmup, 45-min partnered and rhythmic enhancing exercises, and 5-min cooldown. All instructors were trained on motor impairments, fall detection and prevention, and the American Council on Exercise-certified training on adapted tango methods by one of the authors (MEH). In terms of social interaction, participants had the opportunity to speak one-on-one with their dance partner, who changed every 15 min, as well as the instructor.

Walking program

Participants allocated to walking received the equivalent dose, volume, frequency, and intensity of exercise as the tango group. Participants reported to the same facility and received equal contact and monitoring from study staff. Walking sessions consisted of a 20-min warm-up, with tips for safe walking mechanics; 45 min of walking outside with breaks as needed; and 5 min of stretching and balance exercises (Wells et al., 2023). Walking for exercise expends 4.28 metabolic equivalents (Knaggs et al., 2011), similar to 4.3 metabolic equivalents spent on tango dancing (Santos-Silva et al., 2021). Participants started slowly and worked their way up to 60–65% of their heart rate maximum and set clear goals regarding speed and length of walking. Participants also used an application on their phones to record the distance walked and the number of steps taken. The outdoor overground walking took place in a safe, non-cluttered environment in groups, with staff and assistants. During poor weather or if preferred, participants walked indoors. In terms of social interaction, participants had the opportunity to speak with a group of participants who walked at a similar pace, as well as the instructor.

Analysis

Demographic characteristics at baseline were compared between high and low social support groups using independent t-tests (except for sex, which was analyzed using Fisher's exact test). Baseline measures of physical function were compared between the high and low social support groups using independent t-tests.

The primary analysis examined the effects of time (baseline, post-intervention) and social support (high, low) on each of the physical function outcomes using linear mixed-effects models (LMM). The models included fixed effects of Time and Support as interaction terms and random intercepts for participants.

A secondary analysis examined whether the specific intervention received might influence outcomes. The factor Intervention group (walking, tango) was added to each model as an additional interaction term (Time*Support*Intervention). Models with and without this factor included were compared using likelihood ratio tests, and the best-fitting model for each outcome is reported below.

Finally, we examined the effects of interventions on social support levels, using LMM to analyze main effects and interactions of Time and Intervention on the total MSPSS score. Statistical analyses were conducted in R (R Core Team, 2023) using the packages "lme4" (Bates et al., 2015) and "emmeans" (Lenth et al., 2024). The alpha was set at <0.05.

Results

Participant characteristics

At the time of this exploratory analysis, 1,119 people with PD were initially contacted by phone or mail advertising. Of these, 827 declined to participate, 133 did not respond and 44 died. Screening of 115 individuals was completed, of which 38 did not meet the eligibility criteria, and 16 dropped out after initial screening and before baseline assessments. Sixty-one participants consented to participate in the study, 6 of whom did not complete baseline assessments. Therefore, at the time of this analysis, 55 participants were randomized into tango or walking. However, 17 of these participants had incomplete data, including missing MSPSS scores, not remaining in the study long enough to complete 12–13 weeks of training, or were excluded for other reasons. As such, we include in these analyses 19 participants in each arm with complete data (Figure 1). Exercise adherence was high for both walking (95.5 ± 19.9%) and tango (97.2 ± 6.88%) interventions. Based on the total MSPSS score, the final analysis included 24 participants with high perceived social support (12 in the tango group, 12 in the walking group) and 14 with low perceived social support (7 in each group). There were no adverse events reported as a result of either intervention. Across the two intervention groups, no significant differences were found between participants with high vs. low social support on any of the demographic characteristics (Table 1) or

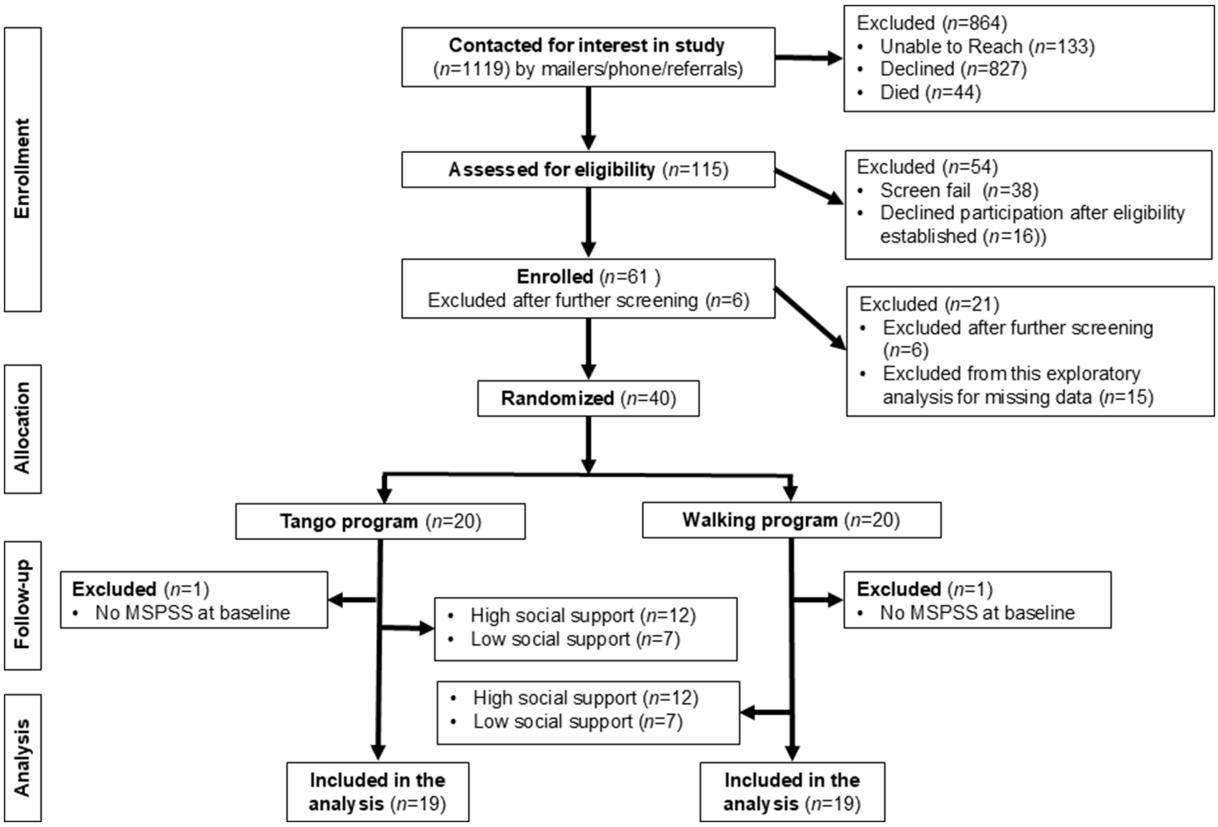

FIGURE 1
Study flow diagram and procedure for the PAIRED trial.

TABLE 2 Physical outcome measures at baseline in participants with low or high social support; mean (standard deviation).

Variable	Low support (n = 14)				High support (n = 24)				Baseline comparison low vs. high support (t, p)
	Baseline		Post-training		Baseline		Post-training		
	Tango	Walk	Tango	Walk	Tango	Walk	Tango	Walk	
TUG single, s	12.79 (10.00)	14.20 (6.00)	15.20 (14.51)	11.78 (5.19)	12.50 (6.91)	10.93 (3.35)	10.25 (9.06)	11.31 (3.66)	0.07 (0.95)
TUG dual, s	15.51 (9.21)	21.22 (13.31)	17.89 (9.26)	21.51 (19.14)	23.94 (29.86)	23.14 (27.74)	15.15 (9.04)	15.13 (6.04)	0.48 (0.63)
360 turn left, s	3.79 (3.49)	5.43 (2.31)	4.14 (1.97)	5.06 (3.61)	6.28 (7.27)	5.14 (3.66)	3.63 (3.17)	4.80 (2.27)	−0.01 (0.99)
360 turn right, s	3.95 (3.40)	6.68 (5.45)	13.80 (35.12)	6.56 (7.04)	10.23 (21.68)	5.32 (3.25)	3.59 (2.92)	5.44 (3.22)	0.92 (0.36)
Gait forward, m/s	1.09 (0.40)	1.01 (0.20)	1.08 (0.36)	1.02 (0.35)	1.02 (0.38)	1.05 (0.33)	1.22 (0.44)	1.02 (0.30)	0.19 (0.85)
Gait backward, m/s	0.67 (0.37)	0.50 (0.15)	0.63 (0.23)	0.73 (0.44)	0.64 (0.27)	0.65 (0.34)	0.73 (0.41)	0.55 (0.28)	0.87 (0.39)
Gait fast, m/s	1.56 (0.59)	1.29 (0.27)	1.37 (0.52)	1.36 (0.83)	1.38 (0.43)	1.55 (0.51)	1.79 (0.59)	1.44 (0.63)	−0.20 (0.84)
6-min walk test, m	425.20 (134.46)	313.59 (118.19)	343.23 (141.00)	308.36 (155.44)	348.24 (146.66)	308.20 (152.26)	381.69 (173.60)	364.90 (145.92)	−1.20 (0.25)
Chair stand test, total #	14.00 (7.85)	8.14 (3.67)	11.67 (3.63)	11.17 (2.95)	11.67 (4.08)	11.55 (2.42)	12.71 (6.85)	12.13 (3.72)	0.46 (0.65)
Tandem left foot, s	18.12 (14.99)	20.76 (11.68)	17.68 (11.64)	16.24 (12.93)	21.20 (13.03)	20.75 (10.92)	23.40 (10.22)	24.24 (10.92)	−0.95 (0.35)
Tandem right foot, s	13.69 (15.32)	22.89 (9.22)	21.40 (9.46)	20.65 (11.89)	22.05 (12.00)	20.05 (11.45)	23.48 (9.88)	21.53 (12.15)	0.43 (0.67)

TUG, Timed Up and Go; TUG dual uses the cognitive dual task. # in this case means "total number of chair stands.

physical function measures (Table 2) at baseline. Levels of social support (MSPSS scores) did not change significantly from baseline to post-intervention, and there was no interaction between time and group on MSPSS score.

The influence of social support on physical function following tango or walking interventions

Full model outputs for the LMM are provided in Supplementary material 1. In the primary analysis, a non-significant trend indicating an effect of time was found for the tandem stance test with the left foot forward [b = 4.33, SE = 2.27, t(38.23) = 1.90, p = 0.06; Figure 2]. A trend indicating an effect of support was found for the six-minute walk test [b = 280.57, SE = 145.16, t(63.60) = 1.93, p = 0.06]. No other significant effects were found on any of the outcome measures.

Secondary analyses found that including the intervention group significantly improved the fit of the model for the chair stand test, with a significant interaction between time, support, and intervention group [b = 3.50, SE = 1.53, t(37.48) = 2.28, p = 0.03; Figure 2]. Comparison of estimated marginal means revealed a significant improvement in participants with low social support receiving the walking intervention [adjusted M = −3.07, SE = 0.83, t(43.6) = −3.42, p = 0.001], but not in participants with high support receiving the walking intervention, or participants with either low or high support receiving the tango intervention (p_s > 0.1). Adding the intervention group did not significantly improve the model fit for any of the other outcome measures.

Discussion

To our knowledge, this is the first study to examine whether baseline social support levels influence potential benefits in physical function following therapeutic intervention among people with PD. We found that both high and low social support groups similarly improved in physical function following group exercise (tango or walking). Secondary analyses examining the potential influence of intervention type revealed that people with PD who had low baseline social support and received a walking intervention demonstrated more improvement in the number of chair stands than those who received tango in the high or low social support groups or those in the walking program with high social support.

Contrary to our hypothesis, we found that participants with either high or low social support exhibited largely similar physical function improvements. Across high and low social support groups, participants showed a trend toward improvement in the left tandem stance test. Additionally, both groups showed a clinically meaningful improvement in fast gait speed (>0.1 m/s; Palombaro et al., 2006) following the 12-week intervention. This finding is encouraging, as the intervention likely not only challenged physical function but also fostered social integration, social cohesion, and a sense of belonging (Hawkins et al., 2016) among participants and staff. This social cohesion may have been particularly important for those with low social support, as it could have provided them with the social resources they needed, greater resilience, and a greater propensity for improved physical function outcomes, which aligns with the social resource model (Song et al., 2021). However, it is possible that the low social support group did not socially connect during the intervention, and the improvements in physical function

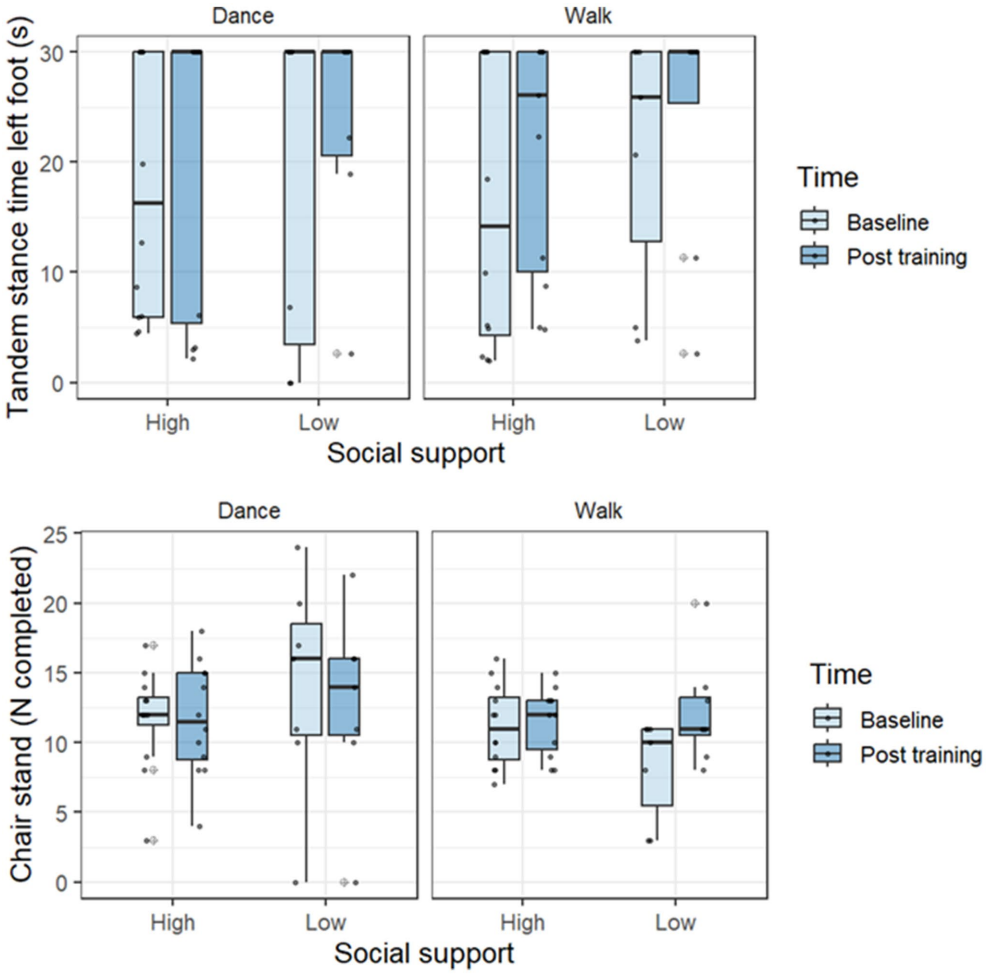

FIGURE 2
Performance on the tandem stance test and chair stand test at baseline and post-training in participants with high and low perceived social support. Boxes show medians with interquartile ranges; dots represent individual datapoints. Tandem stance time showed a trend toward increasing regardless of social support level, while the number of chair stands completed increased significantly in participants with low social support in the walking intervention only.

could be solely due to exercise. Nevertheless, our findings highlight the importance of therapeutic intervention in improving physical function regardless of social support in people with PD.

Our exploratory analysis of an ongoing RCT only found an improvement in one outcome measure (chair stand test) for participants in the low social support group receiving the walking intervention compared to the high social support group receiving the walking intervention or those with high or low social support receiving the tango intervention. While the dose, volume, frequency, intensity, and adherence of exercise were similar in the walking and tango interventions and led by the same intervention staff, differences in the level of social engagement or the specificity of training may explain these findings. For example, the topics of discussion during the tango program were likely centered on problem-solving when learning new tango moves, which may have increased cognitive demands for people with PD, especially those with concomitant mild cognitive impairment, as they have shown to have reduced attention capacity (Saunders and Summers, 2011). In contrast, the walking program likely involved socially engaging, participant-driven conversations. These differences in conversational content and social dynamics may explain the walking program's superior improvement in physical function. We did not record the conversations, so this explanation remains speculative. Social engagement is a major motivator for older adults to engage in physical activity (Spiteri et al., 2019). Alternatively, the walking program may have more closely mimicked the biomechanical demands of the chair stand test, leading to greater improvements. Walking involves repetitive activation of lower body muscles (e.g., quadriceps, hamstrings, and glutes) in a rhythmic, weight-bearing manner, similar to the sit-to-stand motion, which requires concentric and eccentric contractions of these muscle groups. In contrast, tango dancing, while engaging lower body muscles, emphasizes complex, multidirectional movements (e.g., pivots, steps, and turns) that may not directly translate to the repetitive, linear motion of the chair stand test. The principle of training specificity suggests that exercises closely aligned with test movements yield greater improvements (Fleck and Kraemer, 2014). Nevertheless, the improvements in the number of chair stands were only observed in the walking group with low social support, and not high social support; thus, the specificity of training may not

fully account for the different results. In sum, social connectedness and/or the type of exercise may have contributed to greater improvements in the number of chair stands in the participants with PD with low baseline social support in the walking program, compared to those with high baseline social support in the walking program or participants in the tango program.

Researchers have questioned why some participants respond to interventions while others do not. Prospective cohort data from people with PD document a robust predictive relationship between greater social support and better health outcomes (Terracciano et al., 2023; Ahn et al., 2022). Prospective longitudinal studies have demonstrated that both structural aspects (e.g., large social network size and cohesion) and functional aspects (e.g., high perceived emotional support) of social support are associated with better physical function among older adults with chronic kidney disease (Slaven et al., 2021). Social support has a robust relationship with improved health through projected security of surviving future health crises, reinforced positive health habits (e.g., healthy eating, exercise), and improved health through social ties (e.g., dampened stress; Ross and Mirowsky, 2002). Nonetheless, our preliminary findings provide evidence that low baseline social support may contribute to greater responsiveness to a walking intervention among people with PD.

Current research demonstrates that people with PD with mobility limitations are at risk of low social connectedness and tend to have poorer health outcomes (Ahn et al., 2022). However, our findings highlight that people with PD who have low social support exhibit similar improvements in physical function following an intervention as those with high social support. Our findings emphasize the importance of therapeutic intervention for people with PD who have varying levels of social support.

Since the present study is the first exploratory analysis examining the role of social support in exercise intervention outcomes for people with PD, larger and longitudinal trials are needed. We defined the level of social support based on the total MSPSS score, but it is unclear whether other aspects of social support not captured by this measure, such as the existence or quantity of social relationships, their formal structure (e.g., density or reciprocity), or the actual content of these relationships (e.g., positive or negative), drive differences in responsiveness of physical function measures to exercise. Future research could consider using scales that measure social networks, such as the Lubben Social Network Scale (Lubben, 1988). The average MSPSS score in the low social support group was 4.6/7 points, and all participants had the means to participate in this study. Possibly, those with very low social support may not have the necessary resources, such as time outside of work, to participate in an intervention. The interventions may have directly improved social network and physical function, or it is possible that the intervention had a positive effect on physiological, cognitive, or psychological function as well as symptoms of PD, which may also explain improvements in the high and low social support groups. Social support and lower physical function may also be correlated, and sometimes those who have the most room for improvement have the biggest gains after physical rehabilitation. Future work could consider examining the proportion of participants in trials who are recruited and retained who have low compared to high baseline social support. Future studies should also examine more objective measures of social inequalities that may influence social support, such as low socioeconomic status or other social determinants of health.

Conclusion

This exploratory analysis of an ongoing RCT found that people with PD who have high or low baseline social support similarly improved in physical function following a 12-week tango or walking intervention. These results may have implications for clinical care management and lifestyle interventions in people with PD. Given the broader relationship between social network and future health outcomes, clinicians should still monitor people with PD who have low social support, even if they respond similarly to intervention.

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 the Emory IRB and the VA Research and Development committees approved all protocols (Emory IRB112770). 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

DJ: Conceptualization, Investigation, Methodology, Visualization, Writing – original draft. JB: Conceptualization, Formal analysis, Funding acquisition, Methodology, Visualization, Writing – review & editing. MH: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Visualization, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. The PAIRED trial is funded by a United States Department of Veterans Affairs Merit Award (I01 RX002967). JB was supported by funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement no. 101034345. These funding agencies did not play a role in the study design.

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.2025.1525172/full#supplementary-material

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TYPE Original Research
PUBLISHED 14 August 2025
DOI 10.3389/fpsyg.2025.1522274

OPEN ACCESS

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RECEIVED 04 November 2024
ACCEPTED 30 July 2025
PUBLISHED 14 August 2025

CITATION
Yu L, Gu Y, Chen L and Wan J (2025) Experimental effects of multi-dance sport training on student performance: a dual analysis of physical fitness and aesthetic skill development.
Front. Psychol. 16:1522274.
doi: 10.3389/fpsyg.2025.1522274

Experimental effects of multi-dance sport training on student performance: a dual analysis of physical fitness and aesthetic skill development

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Introduction: This study addresses growing concerns about declining physical fitness and insufficient aesthetic literacy among university students. These issues are compounded by the limitations of traditional physical education in supporting holistic development. Dance-based interventions are proposed as a potential solution to bridge this gap.

Methods: A randomized controlled trial was conducted involving 90 female physical education majors, who were randomly assigned to one of three intervention groups: rumba, waltz, or yoga. Participants underwent 16 weeks of systematic training. Physical and aesthetic adaptations were evaluated using standardized physical tests and psychometric assessments.

Results: All three interventions led to significant improvements in core strength, lower-body power, agility, and flexibility ($p < 0.05$). Rumba showed significantly greater improvements in vertical jump performance compared to waltz (MD = 4.572, $p = 0.031$), while waltz was superior to yoga in enhancing flexibility (MD = −3.196, $p = 0.027$). Aesthetic assessments revealed that waltz significantly enhanced kinesthetic awareness (MD = −17.660, $p < 0.001$), likely due to its rotational and spatial characteristics. Rumba yielded greater gains in aesthetic interpretation (MD = 17.290, $p < 0.001$), attributed to its expressive and articulated movements.

Discussion: The findings highlight the genre-specific advantages of dance modalities in fostering both physical and aesthetic development. These results provide empirical support for incorporating dance-based training into higher education physical education curricula to promote holistic student development.

KEYWORDS

sports dance training, students' comprehensive quality, athletic physical fitness, aesthetic ability, rumba and waltz

1 Introduction

With the rapid development of information technology and the deepening of globalization, the demand for talent in modern society has shifted from specialized to comprehensive. This transformation continually drives educational reform, making comprehensive quality education a key component of education reform (Tu et al., 2022; Yang, 2023). Comprehensive quality is generally defined as an integrated manifestation of multiple capabilities, including physical fitness, psychological resilience, cultural literacy, aesthetic awareness, and social adaptability, reflecting an individual's level of coordinated development across various dimensions (Su and Zhang, 2024; Lu et al., 2024). Among the

various pathways for enhancing comprehensive quality, sport dance stands out in higher education for its unique combination of artistic expression and physical training. It not only contributes to improving students' physical functioning and aesthetic cognition but also effectively fosters holistic development in areas such as self-confidence, teamwork, cultural understanding, and creativity (Wang et al., 2024).

Numerous studies have explored the effects of physical dance on the overall quality of students. Physical ability reflects students' health and fitness, while aesthetic ability indicates their perception of beauty. Physical dance training can significantly enhance both, providing a comprehensive measure of its impact on students' overall quality (Liguori and Calella, 2025; Soronovych and Galai, 2025). However, most current research focuses on the effects of a single type of sport dance (Tóth and Lenténé, 2024; Li et al., 2024). There is a notable gap in exploring the effects of various types of sport dances on students' overall quality. Based on this, the study aims to investigate the effects of various types of sport dance training on the overall quality of college students, focusing on athletic physical fitness and aesthetic ability. The study subjects consisted of 90 third-year female physical education majors from colleges and universities. Using a combination of questionnaire surveys, experimental methods, and data statistical analysis, we compared and analyzed the effects of various sports dance trainings on athletic physical fitness and aesthetic ability. Using a combination of questionnaire surveys, experimental methods, and data statistical analysis, the study compared and analyzed the effects of various sport dance trainings on athletes' physical fitness and aesthetic ability. The study results provide empirical evidence for designing and implementing physical education dance courses in colleges and universities, offering theoretical guidance for the future development of physical education and dance training programs.

The organization of the study is as follows:

The first part is the introduction, which outlines the study's background, purpose, and significance, while emphasizing the significant impact of physical dance on the overall quality of college students.

The second part is a literature review, which summarizes the relevant studies on sport dance and the effects of sport dance on the aesthetic ability of college students' physical fitness capacity.

The third section is the research design, detailing the study population, subgroups, and methodologies employed.

The fourth part presents the results and analysis, comparing and analyzing the effects of various physical dance training programs on college students' physical fitness and aesthetic ability.

The fifth section discusses the research findings of this study, comparing them with previous research results and providing relevant recommendations.

The sixth section, Conclusion, presents an overview of the results achieved in this study and proposes future research directions.

2 Literature review

2.1 Sports dance

Sports dance, also known as International Standard Dance or GB dance, is a performance form that combines dance art and sports competition, emphasizing both the grace and artistry of dance movements and the physical fitness and athletic skills required (Feng, 2023). Sports dance encompasses a variety of dance styles, primarily Latin dances (e.g., rumba, samba, cha-cha-cha, paso doble, and jive) and Standard dances (e.g., waltz, tango, quickstep, foxtrot, and Viennese waltz) (Pavlín et al., 2021). Dance for Sport training is a systematic and comprehensive process designed to enhance the technical level, physical fitness, and artistic performance of dancers (Yue, 2022). Feng et al. (2022) found that deep learning can effectively enhance the artistic ability of automated choreography for Dance for Sport, improving the accuracy of dance movements and boosting artistic creativity and educational practice. Cui and Guo (2022) developed an intelligent platform dedicated to training programs and integrated it with a signal processing diagnostic system, resulting in superior performance compared to traditional multimedia systems and significantly improving the training effectiveness of sport dance.

Nowadays, sports dance elective courses are offered in colleges and universities, and experts and scholars have conducted numerous studies on the effects of sports dance on college students. Jia (2021) explored the effects of sports dance on college students' mental health using the MQVA algorithm on a radio network, and found that sports dance positively impacts college students' mental health. Zhang et al. (2021) showed that regular participation in sports dance can significantly reduce depression scores among college students, potentially serving as a protective factor against depression for college students. Lei et al. (2023) also found that teaching sports dance in colleges and universities positively impacts college students' mental health by reducing psychological barriers, improving social skills, and increasing psychological literacy. In addition to its effects on mental health, studies have also shown that prolonged sports dance training can significantly improve students' immune function (Wang and Wang, 2021). This demonstrates that sports dance positively impacts students' physical and mental health.

2.2 Research on the effect of physical dance on students' physical ability

Physical fitness refers to the overall health and physical condition of students, which is usually assessed through fitness tests to understand their physical condition and develop suitable exercise programs (Lutkovskaya et al., 2021). For assessing physical fitness ability, Chen and Hsieh (2022) proposed a fuzzy evaluation model to assess individual physical fitness, with the main indexes including cardiorespiratory endurance, muscular endurance, muscular strength, and flexibility. Pramono et al. (2021) used discriminant analysis to develop a predictive model for health-related fitness status, with the main assessment indicators including age, weight, height, resting heart rate, blood glucose level, blood pressure, and maximal oxygen uptake. Colella and Monacis (2021) assessed changes in fitness levels in children and adolescents (9–14 years old) using four indices: standing long jump, solid ball throw, 10 × 5 round trip run, and 1-mile run test, and demonstrated significant improvements in single-movement strength tests among this group.

Enhancing physical fitness helps to strengthen students' physical health, learning ability, and psychological quality, cultivate good living habits and social interaction skills, promote all-around development, and lay a solid foundation for their future work and life (Quka and Selenica, 2022). Numerous studies have demonstrated that sports dance training contributes to the improvement of students' physical fitness. Wang's M. H. (2023) study found that female college students who underwent specialized training in sports dance showed significant improvements in

form, flexibility, and body composition, positively impacting their physical fitness. Brychuk et al. (2023) evaluated the effect of participation in a sports dance program on the physical fitness levels of 11–12 year old children and found that sports dance significantly improved their physical fitness levels, muscular strength, and motor skills. Sarpong (2022) assessed the fitness level of high school students in his study and found that sports dance training significantly improved students' cardiorespiratory endurance and muscular strength.

2.3 Research on the effect of sport dance on students' aesthetic ability

Aesthetic ability refers to a person's capacity to perceive, understand, and appreciate beauty, encompassing not only visual beauty but also aesthetic experiences in music, literature, art, natural landscapes, and other areas (Fingerhut et al., 2021). Research has shown that aesthetic ability is influenced by various factors such as cultural background, education level, personal experience, and emotional experience. For example, Giannouli et al., (2022) pointed out in their study that biological and cognitive factors, such as age and gender, have different impacts on the ability to appreciate art. Regarding teaching, Wang Y. (2023) study showed that in senior music education, students can enhance their aesthetic perception and analytical abilities and establish a correct aesthetic outlook by appreciating excellent musical works. Chen and Halabi (2023) used an investigative strategy to explore the role of affective teaching values on students' aesthetic ability, finding that affective teaching can significantly enhance students' aesthetic ability and learning outcomes.

Spinul and Spinul (2023) believe that sport dance has realized the fusion of sport and art, and it is a work of art with certain aesthetic value and expressive power. Through multifaceted dance training and artistic cultivation, sports dance enables students to gradually develop comprehensive and profound aesthetic abilities as they perceive, appreciate, and create beauty, resulting in a significant enhancement of their aesthetic abilities (Vasiutiak et al., 2021). Therefore, sports dance is often regarded as an important means of aesthetic education within school education. Weng et al. (2021) explored the aesthetic training methods in sports dance teaching in colleges and universities and proposed measures to enhance students' aesthetic ability through the introduction of artistic elements. Wang and Li (2023) combined theory and experiments and found that applying an aesthetic perspective in dance teaching could significantly enhance students' aesthetic satisfaction and aesthetic ability. Guo's (2022) study pointed out that dance teachers should, by clarifying teaching objectives and reforming teaching methods, help students grasp the style and essence of dance works, thereby enhancing students' aesthetic ability.

2.4 Theoretical mechanisms of different dance styles

Different types of sport dance exhibit distinct training mechanisms in relation to physical fitness development and aesthetic enhancement, due to variations in movement structures, bodily engagement modes, and aesthetic pathways. Clarifying the technical features and psychological mechanisms of each dance genre provides a robust theoretical foundation for understanding their differential intervention effects.

As a representative of Latin dance, rumba emphasizes rhythmic transitions and emotional expressiveness. Its movement composition features frequent knee bends, hip rotations, and wave-like body motions, which intensively activate core lower limb muscle groups such as the gluteus maximus and hamstrings, thereby significantly enhancing students' explosive leg strength and overall coordination (Wu, 2024). Moreover, rumba encourages the internalization of emotional tension through bodily articulation, allowing students to engage deeply with the fusion of rhythm and movement control—thus promoting the development of aesthetic appreciation and expressive capacity (Frías, 2023). Studies have shown that training in Latin-style dances can effectively stimulate learners' sensitivity to artistic styles, rhythmic dynamics, and emotional expression, fostering the rapid advancement of aesthetic judgment within a relatively short timeframe (Joung and Kim, 2023).

In contrast, waltz, a core genre of Standard dance, is known for its rotational progression, spatial expansion, and trunk control. The structure of its steps requires dancers to maintain graceful coordination with the melody while executing precise control over spatial lines and movement pathways (Kuliś and Gajewski, 2022). Students must integrate core stability and lower limb propulsion to achieve seamless flow in their steps, placing higher demands on flexibility and balance. The continuity of rhythm and the coordination of posture in waltz further enhance students' melodic perception and spatial compositional awareness, thereby activating their aesthetic receptivity (Kinoe and Sato, 2022). Some studies have also indicated that Standard dance training can significantly improve students' integrated experiences of rhythm, musical structure, and spatial aesthetics (Fukuhara et al., 2023).

Yoga, by contrast, represents a static form of physical training. It emphasizes breathing rhythm, joint flexibility, and muscular stretching, focusing on bodily awareness and psychological relaxation during execution (Siedlaczek-Szwed and Jałowiecka-Frania, 2022). Core poses such as seated forward folds, downward dog, and spinal twists continuously stimulate the posterior chain musculature and enhance spinal flexibility, leading to steady improvements in flexibility and motor control (Rathore et al., 2024). Although yoga lacks the spatial composition and performative expressiveness inherent in traditional sport dances, its internal rhythm regulation and attention to bodily detail can indirectly evoke students' aesthetic awareness, particularly by nurturing perceptual dimensions of aesthetic experience (Baird, 2022).

In summary, rumba emphasizes expressive contrast and rhythmic articulation, making it particularly suitable for enhancing lower limb strength and aesthetic judgment. Waltz, with its flowing rotations and spatial configurations, guides students to perceive structural beauty in movement, supporting improvements in flexibility and aesthetic sensibility. Yoga, through static stretching and somatic awareness, facilitates bodily control and foundational aesthetic engagement. These theoretical mechanisms offer strong support for the differentiated outcomes observed in the intervention effects of various dance styles.

3 Study design

3.1 Study population and subgroups

To ensure sufficient statistical power, *a priori* power analysis was conducted using G*Power 3.1. With a significance level set at $\alpha = 0.05$,

an effect size of $f = 0.25$ (medium effect), and a statistical power of $1-\beta = 0.80$, the required sample size was estimated based on a repeated-measures ANOVA model (group × time interaction). Considering potential attrition and invalid data, the final sample size was determined to be 90 participants, who were randomly assigned into three groups—Experimental Group 1, Experimental Group 2, and the Control Group—each consisting of 30 participants.

The study participants were junior female students majoring in physical education at a university. To ensure group homogeneity and the validity of the intervention, the following inclusion and exclusion criteria were applied. Inclusion criteria were: (1) current enrollment as a third-year female student in a physical education program; (2) aged between 20 and 22, in good physical health, and capable of safely participating in moderate-intensity physical activity; (3) no prior systematic experience in dance training to eliminate potential confounding from pre-existing skills; and (4) provision of informed consent and willingness to complete the entire study protocol. Exclusion criteria included: (1) diagnosed conditions affecting the musculoskeletal, cardiovascular, or respiratory systems, or any health issues compromising exercise capacity; (2) participation in other physical training programs or intensive sports activities during the intervention period; and (3) psychological health concerns or poor compliance that could hinder completion of the study. All participants signed informed consent forms and explicitly confirmed that they had no prior dance training experience, thereby minimizing potential interference from prior exposure. This study received approval from the Ethics Committee on September 11, 2023 (Approval No: WSU-IRB-2023-056) and complies with ethical standards for research involving human participants.

Experimental Group 1 received rumba training, while Experimental Group 2 underwent waltz training. The control group participated in yoga training. The choice of rumba and waltz represents typical forms of Latin and Standard dance, respectively, characterized by distinct rhythmic patterns, expressive qualities, and movement styles. Yoga was selected for the control condition to ensure a basic level of physical activity while eliminating the influence of a completely sedentary lifestyle, thus enhancing intergroup comparability. Although yoga involves physical posture control and some rhythm awareness, its primary focus on breathing, flexibility, and meditation lacks the rhythmic, expressive, and spatial-aesthetic elements unique to sport dance. Hence, it was considered a low-aesthetic-load form of physical activity for this study.

To reduce external physical activity interference, participants were advised to refrain from engaging in other high-intensity or thematically related exercise programs during the intervention period. Activity compliance was monitored through self-report questionnaires and activity logs, ensuring consistency and relative independence of the intervention. All participants completed the full course of training and assessments as scheduled, with no dropouts and no missing data. Therefore, a complete dataset was used in the analysis, and no imputation or missing data handling procedures were required.

3.2 Experimental methods

3.2.1 Questionnaire method

In this study, we designed a questionnaire based on existing scales (Dan et al., 2021) to compare the changes in aesthetic ability before and after sports dance training using three indicators: sports aesthetic receptivity, sports aesthetic appreciation, and sports aesthetic creativity. The indicators are shown in Table 1. The questionnaire options were "completely disagree," "disagree," "neutral," "relatively agree," and "strongly agree." According to the respondents' answers, a score of 1–5 was assigned, and the average score of each question in each indicator was taken as the final score for that indicator. A reliability test was conducted before the questionnaire was distributed to ensure the reliability and validity of the data obtained. Ninety questionnaires were distributed before and after the training, all of which were administered face-to-face. The subjects were instructed to fill in the questionnaires according to the requirements, and the final recovery rate of the questionnaires was 100%.

3.2.2 Experimental methods

Before the experiment, personal information was collected from the subjects in the three groups, and a physical fitness test was conducted simultaneously. The testing indexes are shown in Table 2. In the formal experiment, each group underwent 16 weeks of sports dance training, with two sessions per week, each session lasting 45 min. The intervention duration was determined with reference to the typical instructional period of physical education courses in Chinese universities and was further informed by commonly adopted durations in sport dance intervention studies (ranging from 12 to 20 weeks). This ensured that the program allowed for observable changes in both physical fitness and aesthetic ability within a practical and evidence-based timeframe. Prior to each training or assessment session, a standardized 5-min dynamic warm-up was conducted. This included light jogging, shoulder and knee rotations, joint mobilization, and rhythm-based movement activities designed to activate core muscle groups, enhance neuromuscular readiness, and reduce the risk of injury. Physical fitness assessments were conducted indoors in a gymnasium, with the following sequence: 1-min push-ups, 1-min curl-ups, standing long jump, 50-meter sprint, sit-and-reach test, and 1-min rope skipping. A 2-min rest interval was provided between each test to allow for adequate recovery and to minimize fatigue-related interference with performance.

To standardize training intensity and intervention pacing, the research team developed a unified instructional management protocol prior to the study. This protocol covered training frequency, session duration, movement execution tempo, class structure, and feedback mechanisms. To quantitatively regulate and monitor training intensity, thereby ensuring the scientific rigor and replicability of the intervention process, the study established the following key control parameters and execution standards:

(1) Target Heart Rate Zone Definition: The target heart rate (THR) for participants was calculated using the Karvonen formula (Equation 1), with all three intervention groups maintained within 60–80% of their maximum heart rate to ensure moderate-intensity aerobic exercise while safeguarding participant safety.

$$\mathrm{THR} = \left(\mathrm{HR_{max}} - \mathrm{HR_{rest}}\right) \times \mathrm{Intensity} + \mathrm{HR_{rest}} \quad (1)$$

Where THR refers to the target heart rate during exercise, HR_{max}denotes the maximum heart rate, HR_{res} indicates the resting heart rate, and Intensity represents the desired training intensity ratio.

(2) Heart Rate Sampling Frequency and Method: All participants were equipped with Polar H10 heart rate monitors (Polar Electro, Finland), which offer high-precision real-time

TABLE 1 Indicators of aesthetic ability testing.

Level 1 indicators	Secondary indicators	Questionnaire items
Esthetic ability	Esthetic sensibility	I agree that aesthetic education plays an important role in personal development.
		I agree that 'beauty' and 'art' are concepts I can understand and appreciate.
		I am willing to actively participate in sports or dance-related aesthetic activities in my spare time.
		I agree that watching sports competitions or dance performances enhances my aesthetic experience.
		I agree that I rarely experience beauty during sports dance training.* (reverse coded)
	Sports appreciation	I agree that the strength, flexibility, and rhythm in sports dance have artistic value.
		I am often moved by the perseverance and focus of sports dancers.
		I believe that improving aesthetic ability is beneficial for my future life and career development.* (reverse coded)
		I support integrating more aesthetic education into physical education curricula.
		I agree that costumes, movements, and spirit in sports dance performances all convey beauty.
	Sports creativity	I agree that participating in sports or dance performances helps improve my artistic creativity.
		I often feel the urge to dance or exercise when I hear music I like.
		I participate in sports dance training because I want to express my own sense of beauty through movement.
		I agree that sports dance training helps me regulate my physical and emotional states.
		I am willing to work or take a part-time job related to sports or dance in the future.

*indicates that the item is reverse coded, used for scoring direction control.

10.3389/fpsyg.2025.1522274

TABLE 2 Indicators of athletes' physical fitness testing.

Type of quality	Assessment of indicators
Upper body strength	1 min push-up
Abdominal strength	1 min curl up
Lower extremity explosiveness	Standing long jump
Quality of speed	50-meter dash
Flexibility	Sit-up-and-bend (physical exercise)
Sensitivity	1 min jump rope

monitoring and recording capabilities. Heart rate data were manually recorded at three time points during each session—at the start, midpoint (25th min), and end of training. Instructors from each group also performed on-site spot checks to verify that participants maintained heart rates within the designated target zone.

(3) Movement Rhythm and Standardized Tempo Settings: Each dance style was assigned a standardized rhythm control scheme: rumba followed a 4/4 time signature at 24–27 measures per minute; waltz adhered to a 3/4 time signature at 28–30 measures per minute; yoga employed a deep breathing rhythm at 6–8 cycles per minute. All classes incorporated both metronomes and music to ensure rhythmic consistency in movement execution.

(4) Use of Rate of Perceived Exertion (RPE): At the conclusion of each session, participants were guided to self-assess exertion levels using the Borg 6–20 RPE scale. The average RPE score was maintained between 12 and 14 ("somewhat hard"), serving as a subjective validation of whether the training intensity matched the intended moderate load.

(5) Monitoring Equipment and Recording Protocols: The monitoring toolkit included the Polar H10 heart rate monitor (for heart rate), pedometers (for physical activity volume), metronomes (for rhythm regulation), and instructional logs (for session content and intensity tracking). All training data were uploaded weekly to a centralized research platform for verification and quality control. Any outliers were either excluded or re-evaluated through secondary inspection.

Although the three intervention groups differed in movement content, they were equivalent in terms of total training time, intensity control range, and organizational flow. Intervention consistency was monitored through regular on-site inspections, verification of training logs, and periodic heart rate sampling, ensuring comparability in instructional load across groups. Due to the open nature of the physical training sessions, a strict double-blind design was not feasible. However, bias control strategies were implemented during the assessment phases: physical fitness testing and questionnaire scoring were conducted by research personnel who had no involvement in the intervention implementation, thereby minimizing the risk of subjective bias in data evaluation.

Each group was instructed by a nationally certified coach specializing in either sport dance or yoga. All instructors underwent pre-intervention training focused on unified instructional procedures, including class pacing, feedback delivery style, movement standardization, and lesson plan structure. To ensure instructional consistency, all three instructors signed an implementation agreement and were subject to periodic supervision and evaluation by the research team throughout the training period. Despite differences in instructional content, the teaching format and evaluation criteria were aligned across groups to reduce potential bias stemming from instructor variability.

TABLE 3 Structural validity testing results.

Test index	Value
KMO value	0.812
Bartlett's test of sphericity	$\chi^2 = 356.241$, df = 66, $p < 0.001$

3.2.3 Statistical methods

The experimental data were statistically analyzed using SPSS 27.0. Repeated measures ANOVA and one-way ANOVA were used to compare the post-training physical fitness test scores between groups. A p-value greater than 0.05 indicates that the data are not statistically significant, a p-value less than 0.05 indicates that the data are different, a p-value less than 0.01 indicates a significant difference, and a p-value less than 0.001 indicates a highly significant difference. To control for the accumulation of Type I error resulting from multiple comparisons, the Bonferroni correction method was applied to adjust the p-values in both between-group and within-group multiple comparisons. All p-values reported in this study reflect the adjusted results following this correction procedure.

4 Findings and analysis

4.1 Reliability and validity testing of the questionnaire

To ensure the measurement validity and applicability of the questionnaire, a pilot study was conducted using a small sample ($n = 20$) prior to the formal survey. Structural validity was assessed, and the results shown in Table 3 indicated a Kaiser–Meyer–Olkin (KMO) value of 0.812, with Bartlett's test of sphericity yielding a significant result ($\chi^2 = 356.241$, df = 66, $p < 0.001$), confirming the questionnaire's good structural validity. Based on this, internal consistency reliability was evaluated for each dimension of the questionnaire. As shown in Table 4, the Cronbach's α coefficients for aesthetic sensibility, aesthetic appreciation, and aesthetic creativity were 0.842, 0.861, and 0.879, respectively. The overall Cronbach's α coefficient of the questionnaire was 0.894. All values exceeded the threshold of 0.8, indicating a high level of reliability and demonstrating that the questionnaire yields stable and consistent measurement results.

4.2 Homogeneity test of physical quality and aesthetic ability of different groups

The physical quality indicators and aesthetic ability indicators of the three groups of subjects were tested for homogeneity before the experiment to determine whether the indicators of each group were at the same level. The test results are shown in Table 5. As shown in the table, the p-value of each index is greater than 0.05, indicating that none of the differences are statistically significant. This suggests that the physical fitness and aesthetic ability of the three groups of subjects before the experiment were at the same level, ensuring the feasibility of the subsequent experiments and the accuracy of the experimental results.

TABLE 4 Reliability testing results.

Dimension name	Aesthetic sensibility	Aesthetic appreciation	Aesthetic creativity	Total questionnaire
Cronbach's α	0.842	0.861	0.879	0.894

TABLE 5 Results of homogeneity test for each indicator.

Test category	Test metrics	Mean ± SD	*F*	*p*
Physical fitness of athletes	1 min push-up (reps)	25.8 ± 3.2	0.068	0.849
	1 min curl up (reps)	44.5 ± 3.8	0.094	0.711
	Standing long jump (cm)	182.6 ± 5.5	2.006	0.225
	50-meter dash (s)	7.52 ± 0.28	0.323	0.724
	Sit-up-and-bend (cm)	23.3 ± 2.6	1.129	0.337
	1 min jump rope (reps)	182.4 ± 7.2	0.217	0.553
Esthetic ability	Esthetic sensibility (score)	21.3 ± 3.2	1.361	0.229
	Aesthetic appreciation in sports (score)	23.7 ± 2.9	2.390	0.215
	Aesthetic creativity in sports (score)	22.1 ± 3.1	0.156	0.803

4.3 Comparative analysis of physical fitness test results of different groups of athletes

At the end of the training, a repeated measures ANOVA was performed on the test results of each index based on group (Experimental Group 1, Experimental Group 2, and control group) and time (pre- and post-experiment). The results of the analysis are shown in Table 6. As can be seen, the *p*-values for the 1-min push-up test and the 50-meter run were all greater than 0.05. This indicates that there was no statistically significant effect of time, group, or the interaction between the two on the subjects' performance in these tests. Therefore, physical dance training did not significantly improve the subjects' upper limb strength or speed. In the 1-min curl-up and 1-min rope skipping tests, time had a highly significant effect on the subjects' performance in both tests, with *p*-values of less than 0.001. However, there was no statistically significant effect of grouping or the interaction of time and grouping on the performance in both tests ($p > 0.05$). This indicates that students, regardless of the type of physical dance training they received, showed statistically significant improvements in the 1-min curl-up and 1-min rope skipping tests. This resulted in a significant increase in their upper limb strength and speed. The 1-min curl-up and 1-min rope skipping scores improved significantly, indicating that physical dance training can significantly enhance students' abdominal strength and agility.

In the standing long jump test, both time and the interaction of time and grouping had a highly significant effect on performance ($p < 0.001$), whereas grouping alone had no statistical effect on performance. This indicates that students' standing long jump performance could be significantly improved after physical dance training, with some variations depending on the type of physical dance training. Therefore, further multiple comparisons of the test results were conducted, and the results are presented in Table 7. The Mean Difference (MD) is used to represent the difference in means between groups or time points and serves as a direct indicator for evaluating the effectiveness of the training intervention. As shown by the results, after 16 weeks of sport dance training, a significant difference was observed between Experimental Group 1 and Experimental Group 2 in the post-intervention standing long jump performance (MD = 4.572, $p = 0.031$, $d = 1.016$), indicating that rumba training had a distinct advantage in enhancing lower limb explosive power. This effect may be attributed to the frequent knee bends, hip rotations, and push steps characteristic of rumba, which consistently activate core lower limb muscle groups. The explosive engagement of the quadriceps, gluteus maximus, and hamstrings likely contributes to the strength-oriented loading nature of the training. In contrast, no significant difference was found between Experimental Group 2 and the Control Group (MD = 0.129, $p = 1.020$), suggesting that the improvement in lower limb explosive strength from waltz training was comparable to that of yoga. Given that waltz involves predominantly slow, controlled movements emphasizing gliding and balance, it tends to target gait coordination rather than explosive power, which may explain the lack of significant gains in jump performance.

A significant difference was also observed between Experimental Group 1 and the Control Group (MD = −4.365, $p = 0.025$), further confirming the unique effectiveness of rumba in improving explosive lower limb strength. In contrast, yoga training mainly consists of static stretching and flexibility control, with limited stimulation of fast-twitch muscle fibers, and therefore has minimal impact on explosive performance measures. In terms of within-group longitudinal comparisons, Experimental Group 1 showed a highly significant improvement before and after training (MD = −8.476, $p = 0.000$, $d = 1.256$), corresponding to a large effect size. This further highlights the systematic and targeted effect of rumba training on explosive power enhancement. While Experimental Group 2 also achieved a statistically significant improvement (MD = −2.664, $p = 0.033$, $d = 0.507$), the effect size was moderate, indicating a relatively milder impact. The Control Group exhibited a slight, non-significant increase in performance (MD = −1.922, $p = 0.073$, $d = 0.384$), suggesting that participants without specialized training are unlikely to achieve meaningful improvements in lower limb explosiveness within a short time frame.

As shown in the results of Table 8, the performance in the sit-and-reach test was significantly influenced by both time and the interaction between time and group ($p < 0.05$), while the main effect of group was

TABLE 6 Repeated-measures ANOVA results of the test results for each indicator of physical ability.

Test metrics	Effect type	df	*F*	*p*	η^2p
1 min push-up	Timing	1	0.437	0.604	0.006
	Clusters	2	0.019	0.931	0.000
	Grouping × time	2	0.002	0.893	0.000
1 min curl up	Timing	1	21.476	0.000***	0.163
	Clusters	2	0.641	0.597	0.026
	Grouping × time	2	0.455	0.607	0.015
Standing long jump	Timing	1	52.651	0.000***	0.520
	Clusters	2	0.486	0.625	0.023
	Grouping × time	2	15.649	0.000***	0.309
50-meter dash	Timing	1	0.245	0.611	0.008
	Clusters	2	0.476	0.605	0.033
	Grouping × time	2	0.003	0.997	0.000
Sit-up-and-bend (physical exercise)	Timing	1	7.131	0.022*	0.129
	Clusters	2	1.037	0.506	0.047
	Grouping × time	2	4.392	0.26*	0.043
1 min jump rope	Timing	1	18.217	0.000***	0.185
	Clusters	2	0.366	0.526	0.013
	Grouping × time	2	0.715	0.420	0.026

* and *** indicate $p < 0.05$, and $p < 0.001$, respectively.

not significant. This suggests that sport dance training, in general, effectively improves students' flexibility, and that the degree of improvement varies across different dance styles. Between-group comparisons revealed that Experimental Group 2 performed significantly better than the Control Group after training (MD = −3.196, $p = 0.027$, $d = 0.657$), indicating a clear advantage of waltz training in enhancing flexibility. This effect may be attributed to the high demands of waltz on trunk control, expansive step execution, and overall bodily coordination. Particularly, the continuous engagement of the abdominal and posterior thigh muscles during step extension and core traction movements likely contributed to the improved trunk flexion required in the sit-and-reach task. In contrast, no significant difference was found between Experimental Group 1 and Experimental Group 2 ($p = 0.672$), nor between Experimental Group 1 and the Control Group ($p = 0.381$). Although rumba incorporates elements of hip control and movement extension, its training emphasis is primarily on weight shifting and lower limb force production. As a result, the stimulus it provides to flexibility development appears to be limited, failing to produce a significant advantage in this specific test.

Regarding within-group comparisons, only the Control Group showed a significant pre- to post-intervention improvement (MD = −4.528, $p = 0.000$, $d = 0.326$), indicating that yoga training consistently promoted students' flexibility. Yoga focuses on static stretching and joint range control, with movements such as seated forward folds and spinal extensions providing sustained stimulation to the hamstrings and lumbar musculature, directly enhancing trunk mobility and posterior chain flexibility. In comparison, Experimental Group 1 (MD = −0.512, $p = 0.824$) and Experimental Group 2 (MD = −0.580, $p = 0.715$) did not exhibit significant pre-post changes, suggesting that while dance training may support dynamic muscular control, it may lack the intensity and continuity required to produce meaningful gains in static flexibility when compared to yoga.

4.4 Comparative analysis of the results of different groups of aesthetic ability tests

Aesthetic ability, as a core component of comprehensive quality, reflects not only an individual's cognitive perception of beauty but also the multidimensional development of emotional sensitivity, artistic understanding, and creative potential. As shown in the results of Table 9, the main effect of time was highly significant across all three dimensions of aesthetic ability—aesthetic sensibility, aesthetic appreciation, and aesthetic creativity ($p < 0.001$). This indicates that regardless of the training modality, 16 weeks of sport dance or yoga intervention effectively enhanced students' overall aesthetic competence.

Significant interaction effects were observed between group and time in both aesthetic sensibility ($F = 6.257$, $p = 0.002$, $\eta^2p = 0.154$) and aesthetic appreciation ($F = 4.431$, $p = 0.013$, $\eta^2p = 0.263$), suggesting that different types of dance training produced divergent improvement trajectories in aesthetic ability. These differences are closely related to the expressive characteristics of each dance style. Waltz, as a representative of Standard dance, is marked by elegant movement structure, flowing rhythm, and strong spatial expansiveness. Students are required to perceive and simulate melodic lines and spatial configurations during training, which offers strong guidance in enhancing aesthetic sensibility. This is further supported by the multiple comparison results, which revealed that the waltz group significantly outperformed the control group in post-training aesthetic sensibility (MD = 8.433, $p = 0.006$), with a highly significant pre-post improvement (MD = −17.660, $p < 0.001$). In contrast, the most notable enhancement in aesthetic appreciation was observed in the rumba group. Rumba is characterized by its intense rhythm, emotional tension, and expressive bodily dynamics. Its training demands deep engagement in emotional expression and refined control over movement expansion and contraction. Such embodied experiences foster students' capacity to appreciate and evaluate the beauty of dance. Experimental Group 1 showed a highly significant improvement in aesthetic appreciation (MD = −17.290, $p < 0.001$), surpassing the gains made by both the control and Experimental Group 2, indicating that rumba more effectively facilitates the development of students' aesthetic discernment and evaluative understanding of dance art. It is worth noting that although the main effect of time on aesthetic creativity was also highly significant ($F = 77.635$, $p < 0.001$, $\eta^2p = 0.476$), neither the group effect nor the interaction effect reached statistical significance ($p > 0.05$). This suggests that all types of training similarly promoted students' capacity for creative aesthetic expression, with no significant divergence between groups. Such results may be attributed to the nature of the training content, which was largely centered on imitation and structured repetition, lacking elements of improvisation, movement composition, or other advanced forms of expressive practice. These limitations may have constrained the activation of students' creative potential in aesthetic domains. Overall, this study confirms the significant role of sport dance training in enhancing students' aesthetic

TABLE 7 Multiple comparisons of standing long jump test results.

Between-Group comparison	Group comparison (G1–G2)	MD (G1–G2)	SE	95% CI	*p*	Cohen's *d*
Post-training	Experimental Group 1 vs. Group 2	4.572	1.519	[1.595, 7.549]	0.031*	1.016
	Experimental Group 2 vs. Control	0.129	1.693	[−3.189, 3.447]	1.020	0.027
	Control vs. Experimental Group 1	−4.365	0.025	[−7.760, −0.970]	0.025*	0.949

Within-Group comparison	Time comparison (T1–T2)	MD (T1–T2)	SE	95% CI	*p*	Cohen's *d*
Experimental Group 1	Pre-post	−8.476	1.138	[−10.706, −6.246]	0.000***	1.256
Experimental Group 2	Pre-post	−2.664	1.109	[−4.838, −0.490]	0.033*	0.507
Control Group	Pre-post	−1.922	0.952	[−3.788, −0.056]	0.073	0.384

All *p*-values reported above have been adjusted using the Bonferroni correction method. The same applies to subsequent tables. MD, mean difference; positive values indicate Group 1 > Group 2; negative values indicate Group 1 < Group 2. * and *** indicate $p < 0.05$, and $p < 0.001$, respectively.

TABLE 8 Multiple comparisons of the results of the seated forward bending test.

Between-Group comparison	Group comparison (G1–G2)	MD (G1–G2)	SE	95% CI	*p*	Cohen's *d*
Post-training	Experimental Group 1 vs. Group 2	1.174	1.026	[−0.837, 3.185]	0.672	0.651
	Experimental Group 2 vs. Control	−3.196	1.268	[−5.681, −0.711]	0.027*	0.657
	Control vs. Experimental Group 1	1.747	1.059	[−0.329, 3.823]	0.381	1.251

Within-Group comparison	Time comparison (T1–T2)	MD (T1–T2)	SE	95% CI	*p*	Cohen's *d*
Experimental Group 1	Pre-post	−0.512	1.204	[−2.872, 1.848]	0.824	1.304
Experimental Group 2	Pre-post	−0.580	1.109	[−2.754, 1.594]	0.715	0.983
Control Group	Pre-post	−4.528	0.976	[−6.441, −2.615]	0.000***	0.326

MD, mean difference; positive values indicate Group 1 > Group 2; negative values indicate Group 1 < Group 2. * and *** indicate $p < 0.05$, and $p < 0.001$, respectively.

TABLE 9 Repeated-measures ANOVA results of the survey results for each indicator of aesthetic ability.

Test metrics	Effect type	df	*F*	*p*	η^2p
Esthetic sensibility	Timing	1	47.551	0.000***	0.377
	Clusters	2	0.783	0.366	0.042
	Grouping × time	2	6.257	0.002**	0.154
Esthetic appreciation	Timing	1	33.004	0.000***	0.441
	Clusters	2	0.377	0.700	0.022
	Grouping × time	2	4.431	0.013*	0.263
Esthetic creativity	Timing	1	77.635	0.000***	0.476
	Clusters	2	0.499	0.590	0.037
	Grouping × time	2	2.694	0.053	0.088

*, **, and *** indicate $p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively.

ability. It also reveals differentiated improvement pathways depending on the dance style: Standard dance (e.g., waltz) emphasizes perceptual guidance, while Latin dance (e.g., rumba) cultivates emotional comprehension and expressive ability. In contrast, the development of aesthetic creativity may require more open-ended, improvisation-driven training designs to fully stimulate students' creative expression.

To further explore the effects of different sport dance training methods on aesthetic sensibility and aesthetic appreciation, multiple comparisons were conducted for these two indicators. Table 10 presents the multiple comparison results for aesthetic sensibility. As shown, in the post-training between-group comparisons, Experimental Group 2 scored significantly higher than the Control Group in aesthetic sensibility (MD = 8.433, $p = 0.006$, Cohen's $d = 1.339$), indicating a notable advantage of waltz training in enhancing students' experience and perception of the beauty inherent in sport dance. The waltz is characterized by continuous rotation and fluid movement, accompanied by gentle musical rhythms and graceful body postures. It emphasizes the interaction between the body and spatial environment. This fusion of "form and emotion" enables students to develop a direct perception of rhythm, bodily lines, and emotional flow throughout the training process, thereby significantly boosting their aesthetic sensibility. Although there was a numerical difference between Experimental Groups 1 and 2 (MD = −4.770), it did not reach statistical significance ($p = 0.255$), suggesting that while Latin and Standard dance styles have distinct

TABLE 10 Multiple comparisons of aesthetic sensibility survey results.

Between-Group comparison	Group comparison (G1–G2)	MD (G1–G2)	SE	95% CI	*p*	Cohen's *d*
Post-training	Experimental Group 1 vs. Group 2	−4.770	2.984	[−10.619, 1.079]	0.255	0.954
	Experimental Group 2 vs. Control	8.433	2.714	[3.114, 13.752]	0.006**	1.339
	Control vs. Experimental Group 1	−3.725	2.833	[−9.278, 1.828]	0.442	0.621

Within-Group comparison	Time comparison (T1–T2)	MD (T1–T2)	SE	95% CI	*p*	Cohen's *d*
Experimental Group 1	Pre-post	−7.643	2.795	[−13.121, −2.165]	0.026*	1.390
Experimental Group 2	Pre-post	−17.660	2.722	[−22.995, −12.325]	0.000***	1.463
Control Group	Pre-post	−4.873	2.599	[−9.967, 0.221]	0.031*	0.750

MD, mean difference; positive values indicate Group 1 > Group 2; negative values indicate Group 1 < Group 2. *, **, and *** indicate $p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively.

TABLE 11 Multiple comparisons of aesthetic appreciation survey results.

Between-Group comparison	Group comparison (G1–G2)	MD (G1–G2)	SE	95% CI	*p*	Cohen's *d*
Post-training	Experimental Group 1 vs. Group 2	6.228	2.506	[1.316, 11.140]	0.073	0.872
	Experimental Group 2 vs. Control	−0.380	2.719	[−5.709, 4.949]	0.855	1.059
	Control vs. Experimental Group 1	−5.931	2.706	[−11.235, −0.627]	0.086	0.533

Within-Group comparison	Time comparison (T1–T2)	MD (T1–T2)	SE	95% CI	*p*	Cohen's *d*
Experimental Group 1	Pre-post	−17.290	2.647	[−22.478, −12.102]	0.000***	1.242
Experimental Group 2	Pre-post	−6.296	2.573	[−11.339, −1.253]	0.028*	1.281
Control Group	Pre-post	−5.683	2.745	[−11.063, −0.303]	0.047*	0.690

MD, mean difference; positive values indicate Group 1 > Group 2; negative values indicate Group 1 < Group 2. *, and *** indicate $p < 0.05$ and $p < 0.001$, respectively.

characteristics, they did not produce fundamentally different effects on the enhancement of aesthetic sensibility within the given training period. Likewise, no significant difference was found between Experimental Group 1 and the Control Group ($p = 0.442$), indicating that the impact of rumba on aesthetic sensibility was relatively unstable in this study. This may be due to its emphasis on emotional tension and contrast in movement dynamics, which students may not have fully internalized during the limited duration of the intervention.

In the within-group longitudinal comparisons, all three groups showed significant pre-post improvements. Experimental Group 2 demonstrated the most pronounced enhancement (MD = −17.660, $p = 0.000$, $d = 1.463$), representing a "very large" effect size and reinforcing the strong aesthetic educational value of waltz in the perceptual domain. Experimental Group 1 also showed a significant improvement (MD = −7.643, $p = 0.026$, $d = 1.390$), indicating that the movement structure of rumba, which emphasizes emotional expression and control of body curves, possesses substantial aesthetic appeal. Although the Control Group lacked dance-specific elements, it also exhibited a significant improvement (MD = −4.873, $p = 0.031$, $d = 0.750$), which may be attributed to yoga's emphasis on bodily awareness, rhythm control, and meditative relaxation. These elements likely activated students' internal perception of the body-rhythm relationship, thereby indirectly enhancing their aesthetic sensibility.

In summary, all three training modalities effectively enhanced students' aesthetic sensibility to varying degrees. Among them, waltz training demonstrated the most prominent intervention effect, likely due to the artistic quality and rhythmic fluidity of its movements, which readily evoked aesthetic experiences in a short time frame.

As shown in Table 11, although the between-group differences in aesthetic appreciation scores did not reach statistical significance ($p > 0.05$), observable trends emerged when examining mean differences and effect sizes. Post-intervention, Experimental Group 1 scored higher than Experimental Group 2 (MD = 6.228, $p = 0.073$, $d = 0.872$), with an effect size approaching the threshold for a "large" effect. This suggests that rumba may offer a greater advantage in enhancing students' understanding of the structural and stylistic features of dance aesthetics. Rumba emphasizes emotional expression, movement tension, and rhythmic transitions—its inherently dramatic and stylized nature compels students to develop a deeper awareness of artistic style distinctions and expressive nuances. This, in turn,

fosters more refined aesthetic judgment and evaluative depth. The difference between Experimental Group 2 and the Control Group was minimal (MD = −0.380, $p = 0.855$), indicating that short-term waltz training in this study did not significantly enhance students' structural aesthetic analysis. As a dance style centered on smoothness and balance, the aesthetic appeal of waltz lies more in perceptual flow and overall visual coherence, offering a more indirect influence on the cognitive dimension of aesthetic appreciation. Comparatively, the difference between the Control Group and Experimental Group 1 approached significance (MD = −5.931, $p = 0.086$), further supporting the potential of rumba training to stimulate students' interest and capability in analyzing dance construction and stylistic nuances.

In the within-group longitudinal comparisons, all three groups demonstrated significant improvements. Experimental Group 1 showed the most pronounced pre-post difference (MD = −17.290, $p = 0.000$, Cohen's $d = 1.242$), reaching a "very large" effect size, indicating that rumba training was particularly effective in deepening students' understanding and evaluation of dance structure, rhythmic design, and movement artistry. Both Experimental Group 2 and the Control Group also achieved statistically significant improvements ($p = 0.028$ and $p = 0.047$, respectively), although with slightly smaller effect sizes ($d = 1.281$ for Group 2 and $d = 0.690$ for the Control Group). The improvement in the Control Group may be attributed to yoga's emphasis on meditative focus, posture aesthetics, and bodily awareness, which can indirectly stimulate aesthetic reflection on physical expressiveness.

Although the post-intervention differences between groups did not reach full statistical significance, the observed effect sizes and within-group improvements indicate that rumba training, through its expressive richness and artistic structure, more effectively guides students toward a systematic understanding of movement style, emotional tension, and dance form. As such, it demonstrates a stronger intervention effect on the dimension of aesthetic appreciation.

5 Discussion

This study focuses on junior female students majoring in physical education at colleges and universities. It combines the questionnaire survey method, experimental method, and data statistics method to investigate the influence of multi-dance sports dance training on students' comprehensive quality from the perspectives of athletes' physical fitness and aesthetic ability. The results of the study show that after sports dance training of different dance types, the students' abdominal strength, lower limb explosive power, sensitivity, and flexibility were significantly improved. This indicates that sports dance training can enhance the students' physical fitness. The effect sizes (Cohen's d) associated with each training modality in improving physical fitness and aesthetic ability also demonstrate substantial practical significance. Notably, rumba training produced very large effect sizes in both lower limb explosive strength ($d = 1.256$) and aesthetic appreciation ($d = 1.242$), indicating that this dance style can induce systematic enhancement in core muscular power and artistic evaluative capacity within a relatively short intervention period, showcasing strong intervention value. From a practical perspective, these effect sizes represent substantial improvements with educational significance. Specifically, rumba training led to an average increase of approximately 8.5 cm in standing long jump performance ($d = 1.256$), which corresponds to a 4.6% improvement over the baseline level of 182.6 cm. This indicates a significant short-term enhancement in lower-body explosive strength, highlighting the clear intervention value of rumba in physical education practice. Similarly, in terms of aesthetic sensibility, the waltz group demonstrated an average improvement of nearly 17.7 points after training ($d = 1.463$), elevating the participants' scores from a baseline of 21.3 to nearly 39. This exceeds the threshold typically considered educationally meaningful, indicating a substantial enhancement in participants' perception of rhythm, spatial composition, and body form aesthetics—far greater than the 5–8 point gains commonly observed in general curricular interventions. Regarding flexibility, yoga training led to an average improvement of about 4.5 cm in the sit-and-reach test ($d = 0.326$), which falls within a moderate-to-high effect range. Given the baseline average of 23.3 cm, this reflects a 19.4% increase, suggesting that even in the absence of expressive dance elements, static stretching can steadily improve body control capacity. Based on differing instructional goals, universities may consider prioritizing rumba in courses aimed at integrating physical and artistic development, employing waltz in aesthetic perception modules, and incorporating yoga into flexibility and mindfulness training sessions, thereby optimizing the differentiation and effectiveness of physical-aesthetic education curricula.

While previous research provided a theoretical foundation for this study, the present research introduces several innovations in terms of experimental design, dance style selection, and variable decomposition, deepening the exploration of sport dance as a pathway to holistic student development. For example, Tunçgenç et al. (2024) found that a 5-week online hip-hop dance program significantly improved social connection and well-being among British adolescents. However, their study focused on standardized pre- and post-intervention comparisons of subjective well-being and social interaction, without differentiating between dance styles. This study not only extended the intervention to 16 weeks but also introduced rumba and waltz as representative styles of Latin and Standard dance, respectively, using a controlled design to systematically compare their differential effects on physical and aesthetic dimensions—enhancing the study's specificity and external validity. Tung et al. (2024) examined the impact of dance interventions on children's cognitive control, focusing on neural and attentional indicators. While valuable in offering a neurological perspective on cognitive performance, their research overlooked the potential of dance as a holistic medium for aesthetic and emotional experiences. In contrast, this study incorporated a tripartite model of aesthetic ability—sensibility, appreciation, and creativity—and developed quantifiable measures to systematically examine how different dance styles influence distinct layers of aesthetic development, thus expanding the scope of sport dance research in educational psychology. Zhang et al. (2025), in their study on the effects of dance interventions on physical balance and cognitive function in older adults, confirmed the multisystemic benefits of dance. However, their participant pool was limited to older individuals, and the training content was based on unified choreography, lacking detailed investigation into how different dance styles affect specific functional domains. By contrast, this study revealed that rumba—with its focus on emotional expression and bodily control—is more effective in enhancing aesthetic appreciation, while waltz—with its rhythmic structure and spatial design—is more beneficial for improving aesthetic sensibility and flexibility. These findings enrich the application of dance intervention strategies in youth educational settings.

Theoretically, this study contributes by comparing the differential effects of various dance styles across physical and aesthetic dimensions, thus enriching the conceptual framework for sport dance-based training. Moreover, by dividing aesthetic ability into three measurable dimensions—sensibility, appreciation, and creativity—it enhances the structural integrity and operational feasibility of aesthetic education research in sport dance. In practice, several recommendations are proposed: First, to achieve instructional goals centered on enhancing students' lower limb explosive power and aesthetic appreciation, rumba training should be designated as a core module within university physical education curricula—particularly in quality development or expressive movement courses. Instructional focus should be placed on knee bends, hip rotations, and rhythmic transitions, supplemented by movement style analysis and imitation-based practice to deepen students' understanding of dance structure, emotional expression, and muscular tension. Classroom demonstrations and peer feedback sessions are also recommended to facilitate the practical translation of aesthetic judgment into observable outcomes. Second, within course frameworks that emphasize the cultivation of aesthetic sensibility and body coordination, waltz is recommended as the primary instructional content. It is particularly suitable for aesthetic-oriented physical education courses or interdisciplinary art-based experiential programs in higher education. Teaching strategies should incorporate multimodal elements such as spatial composition, melodic perception, and audiovisual feedback, guiding students to experience the fluidity of movement and spatial rhythm through the fusion of posture and tempo—thereby stimulating affective cognition and artistic engagement. Third, yoga training may serve as a supplementary module for improving flexibility and bodily control, ideally scheduled in alternating sessions throughout the academic term to support physical recovery and psychological regulation. It is recommended to designate one static training session per week to establish a dynamic-static instructional rhythm. Students should also be encouraged to track and document changes in physical condition, thereby enhancing self-awareness and reflective capacity throughout the training process. Finally, to further improve the educational effectiveness of sport dance curricula, it is advisable to construct a "multi-style–multi-objective–multi-strategy" course system. This approach would involve systematically incorporating pre-post effect size indicators into curricular evaluation and developing dynamic assessment models. In day-to-day instruction, open-ended tasks such as choreography, improvisational performance, and aesthetic critique should be integrated to transition students from passive recipients to active creators—fostering the holistic development of physical-aesthetic literacy.

Despite providing robust evidence of the effects of multi-style sport dance training on students' physical fitness and aesthetic ability, this study has certain limitations. First, the study sample consisted exclusively of third-year female students majoring in physical education at a single university, resulting in high homogeneity in terms of gender, training background, and academic standing. This lack of demographic diversity introduces a degree of population-specific response to the intervention, meaning that the observed effects primarily reflect outcomes within this specific cohort. Consequently, the findings cannot be generalized to male students, underclassmen, or individuals outside of physical education disciplines, thereby limiting the study's external validity. Second, although the aesthetic ability was assessed using a questionnaire instrument that had undergone reliability and validity testing, the self-report nature of this tool inherently depends on participants' subjective judgments. As such, the results are vulnerable to influences from transient emotional states, social desirability biases, and self-perception distortions, which may lead to inflated estimates of training efficacy and constrain the objectivity of aesthetic improvement assessments. Third, the study employed a single post-intervention measurement point, with no follow-up assessments conducted. This design choice precludes the evaluation of effect sustainability, delayed responses, or potential attenuation over time, leaving unanswered questions regarding the temporal stability and cumulative impact of the training. Finally, although participants were instructed to refrain from engaging in other strenuous physical activities during the intervention period, key behavioral covariates—such as dietary patterns, sleep quality, psychological condition, and extracurricular physical activity—were not systematically tracked or controlled. These uncontrolled variables may have influenced the natural fluctuations in physical fitness and aesthetic competence, thereby introducing potential confounds and diminishing the precision of causal attribution regarding the observed training effects.

6 Conclusion

This research integrates questionnaire surveys, experimental approaches, and statistical analysis of data to examine and compare how various sports dance training programs influence university students' overall development, particularly focusing on their physical conditioning and aesthetic skills. Key findings include:

(1) The three physical dance training methods did not substantially enhance students' upper-body strength or speed-related attributes ($p > 0.05$). However, moderate to significant improvements were observed in core strength, leg explosiveness, flexibility, and coordination ($p < 0.05$).
(2) Statistical analysis revealed Rumba demonstrated superior effectiveness to Waltz and Yoga in enhancing students' standing long jump performance (MD = 4.572, $p = 0.031$). Within-group comparisons showed highly significant pre/post-training differences between rumba and waltz ($p < 0.001$), confirming both dance modalities substantially boost lower limb explosive strength.
(3) Statistical analysis showed that waltz training surpassed yoga in increasing seated forward flexion (MD = −3.196, $p = 0.027$). Meanwhile, the control group displayed a highly notable change post-intervention ($p < 0.001$), confirming that yoga also improves flexibility—just not as effectively as waltz.
(4) Statistical analyses confirmed all three training modalities (waltz, rumba, and yoga) effectively improved students' aesthetic capabilities. Waltz demonstrated the most pronounced enhancement of aesthetic perception (MD = −17.660, $p = 0.000$), whereas rumba showed superior efficacy in developing aesthetic evaluation skills (MD = −17.290, $p < 0.001$).

This study highlights the differential impacts of various sport dance styles on students' physical fitness and aesthetic ability. Future research should consider expanding the participant pool to include

more representative populations across gender, academic disciplines, and educational stages, thereby examining the generalizability and specificity of sport dance interventions across diverse groups. Investigating the moderating role of gender in movement receptivity, aesthetic preference, and training feedback could enrich the development of personalized intervention strategies in physical-aesthetic education. Second, given the inherent subjectivity of current questionnaire-based assessments, it is recommended to incorporate more objective evaluation methods. These may include behavioral observation checklists, expert rating systems, and technology-assisted tools such as video-based motion capture and AI-driven recognition systems, which can quantitatively assess changes in movement performance, body tension control, and emotional expressiveness—thus enhancing the measurement validity of non-cognitive domains like aesthetic ability. Third, to more comprehensively capture the dynamic trajectory of training effects, future studies are encouraged to adopt longitudinal designs with distributed follow-up intervals—such as at 1 month, 3 months, and 6 months post-intervention—to examine the persistence, attenuation, or potential rebound of intervention effects across cognitive, behavioral, and emotional dimensions. Such designs would provide theoretical grounding for the long-term optimization and consolidation of intervention strategies. Finally, to mitigate the influence of potential confounding variables in the training environment, future studies may incorporate behavioral control strategies and covariate modeling approaches. By systematically tracking behavioral factors such as daily dietary intake, sleep patterns, psychological states, and exercise logs, and incorporating these variables into statistical analyses as covariates, researchers can enhance the precision of causal attribution regarding intervention effects.

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 the Ethics Committee of Woosuk University on September 11, 2023 [Approval No: (WSU-IRB-2023-056)]. 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

LY: Conceptualization, Data curation, Formal analysis, Writing – original draft. YG: Resources, Visualization, Writing – original draft, Writing – review & editing. LC: Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. JW: Software, Supervision, Validation, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

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.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

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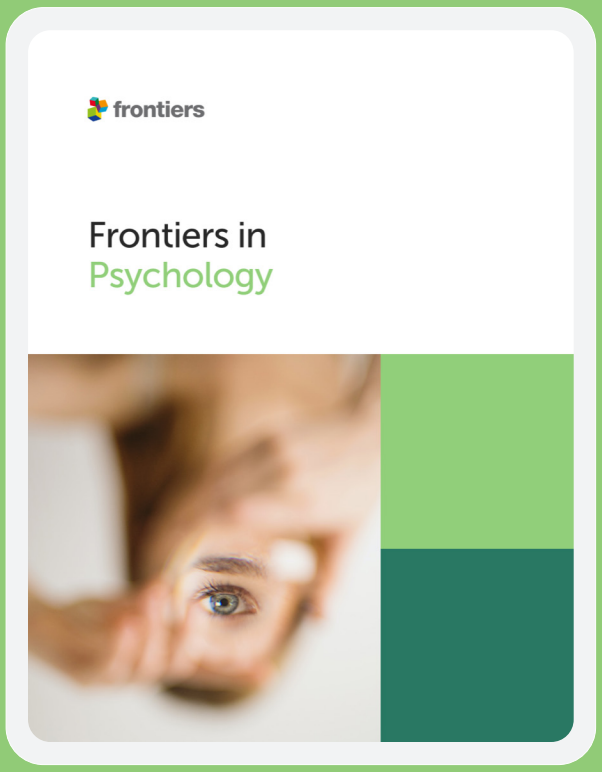

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