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Journal podcasting of health and medical science

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Podcasts are a growing medium of mass communication and are increasingly being produced by academic journals. However, little is known about the specific features of these journal-affiliated podcasts, particularly in the health and medical sciences. This study examines the characteristics and features of journal podcasts through a content analysis of 400 episodes from 10 highly indexed journals. Using a quota sampling method, we analyzed the 40 episodes from each series. A systematic coding approach was employed to assess eight key variables, including host type, guest composition, topic, communication format, complexity, and audio quality. Findings reveal that the majority of episodes focus on research published within the parent journal and are primarily hosted by researchers. The prevalent communication format was scientific, with minimal use of narrative or emotive styles. This study represents an initial investigation into the emerging niche of journal podcasts and identifies opportunities for future research to further understand their role in the media ecosystem and to broaden public engagement with scientific research.

KEYWORDS

podcast, science communication, health, medicine, content analysis, health communication, medical communication

1 Introduction

Podcasts have emerged as a prominent medium of mass communication (Bottomley, 2015). While they have traditionally been associated with popular culture, entertainment, and music, podcasts are increasingly being utilized to disseminate scientific information. A global analysis found that the number of science podcast series published annually grew linearly between 2004 and 2010, before undergoing exponential growth between 2010 to 2018 (MacKenzie, 2019). Most science podcasts are hosted by academics and research scientists who produce audio-only content on behalf of universities and professional organizations, often on a voluntary basis and alongside their existing responsibilities (MacKenzie, 2019). Their motivation for podcasting stems from a recognition of the medium's unprecedented ability to engage large and diverse audiences—an outcome rarely achieved by traditional science communication methods. Compared to other multimedia formats, podcasting is relatively easy to enter, requiring only basic equipment, software, and minimal training, and it allows for free distribution to a broad audience through decentralized platforms (Gomez-Marin, 2023). Perhaps, more so than any other recent technological advancement, podcasts present an unprecedented opportunity for advancing science communication and enhancing public engagement with scientific topics (Fox et al., 2021).

Given these advantages, it is unsurprising that leading academic journal publishers across various disciplines have embraced podcasting. Many top-indexed journals have launched podcast series formally affiliated with and produced by the journals themselves.

These journal podcasts are uniquely positioned to discuss the latest peer-reviewed research and represent a promising development for bridging the gap between technical publications, public engagement, and public understanding (Fox et al., 2021). As tools for scientific outreach, podcasts have demonstrated the capacity to build engaged communities, reduce the disconnect between science and the public, and mitigate the issue of paywall restrictions to journal articles (Figueroa, 2022). Through interactive features such as listener subscriptions, notifications, and opportunities for feedback, podcasts facilitate direct connections between audiences and academics, fostering a deeper appreciation of research and humanizing the researchers behind it (Mollett et al., 2017). Moreover, by presenting complex scientific information in an accessible and conversational format, podcasts have shown the potential to improve both the understanding and retention of scientific concepts (Powell and Mason, 2013; Wolpaw et al., 2022).

The value of journal podcasts is particularly significant in the field of health and medical sciences due to the direct relevance of this research to public life. This is especially true for individuals affected by health conditions, as well as for medical researchers, students, and practitioners. In the context of widespread medical misinformation (Armstrong and Naylor, 2019), commercial biases in other media (Ashai et al., 2023), and growing concerns about misleading health advice (Caramancion, 2022), the expansion of journal podcasts in this field is a promising development. Research on health-related podcasts, including those not directly affiliated with journals, has highlighted their effectiveness in enhancing public health literacy. For instance, podcasts have been shown to improve sexual health literacy (Porter et al., 2022), help parents critically evaluate health treatment claims for their children (Semakula et al., 2017), and foster better understanding and attitudes toward mental health treatments (Nathan, 2018; Caoilte et al., 2023). In addition to their impact on public audiences, health and medical podcasts play a crucial role in facilitating information exchange among expert audiences. Healthcare providers and practitioners frequently turn to health science podcasts for professional education (Cho et al., 2017), to strengthen connections with the broader professional community (Riddell et al., 2020), and to stay up to date on the latest research literature (Malecki et al., 2019). Thus, the growing presence of journal podcasts in health and medical sciences represents a promising avenue for enhancing both public understanding and professional knowledge.

Despite their potential, journal podcasts remain an understudied area in scholarly research. While the global analysis conducted by MacKenzie (2019) provides valuable insights into the broader features of science-based podcasts, relatively little is known about the specific characteristics, features, and practices of journal podcasts. Consequently, there is a limited understanding of the niche that journal podcasts occupy within the media ecosystem or how they complement traditional print journal publications. Understanding who the intended audience is, what type of information is presented, and how accessible this information is to non-expert listeners are critical questions that remain unanswered. Similarly, there is a need to examine the organizational characteristics of journal podcasts, such as host profiles and typical guest speakers, to better understand their role in science communication. By assessing these and other related variables, this study aims to fill the existing knowledge gap and provide a clearer picture of how journal podcasts advance science communication and promote public engagement with scientific research.

To achieve this, we conduct a content analysis of podcast series published by 10 highly indexed academic journals in the field of health and medical sciences. In total, our analysis encompassed 400 distinct podcast episodes (40 from each series), amounting to approximately 103 h of audio content. By systematically listening to the podcasts and applying a quantitative coding scheme across eight key variables, we assessed the general characteristics, features, and practices of these series. Our findings indicate that the majority of podcasts focus on research published within their parent journals, often feature research authors as guests, and generally adopt an interview-style format. While these patterns suggest that journal podcasts may primarily aim to reinforce the visibility and impact of their affiliated journals' research outputs rather than expand public engagement with science, an assessment of the level of information complexity indicates that some episodes do cater to a lay audience. The implications of these findings are discussed in relation to the broader role of journal podcasts within the media ecosystem, including how they compare to science-based podcasts more broadly.

2 Method

This study employed a quantitative content analysis to examine the characteristics and features of podcasts published by highly indexed journals in the field of health and medical science. Our sample consists of 10 distinct journal podcast series, with 40 episodes selected from each series (n = 40), resulting in a total sample size of 400 episodes (N = 400).

2.1 Inclusion criteria

The highest indexed journals in the field of health and medical science were identified using Google Scholar's journal ranking system (Google, 2023). Owing to the shifting nature of rankings overtime, this study used a fixed ranking list produced on February 13, 2023. Working in descending rank order, we identified which of the journals produce an affiliated podcast using a search of known podcast repositories and a search of each respective journal's website. Only podcast series formally affiliated with the peer-reviewed journal were considered for inclusion in the study. Podcast series produced by journal associates, including contributing authors and editors, were not included if the series was not formally affiliated and recognized by the journal. Additionally, inclusion required each podcast series to have a minimum of 40 published episodes (as of February 13, 2023). Using this approach, we identified 10 journal podcast series to analyze. The 10 journals, and their affiliated podcast series name, and google scholar rank, are described in Table 1.

2.2 Procedure and coding criteria

A quota sampling method was used to select 40 episodes from each of the 10-podcast series. To best capture the contemporary features of the podcasts, we sampled the 40 most recent episodes from each series, using February 13, 2022, as the cutoff date for

TABLE 1 Description of the journal series included in the sample.

Journal name (Google Scholar rank)	Podcast series title	Episode release schedule	Average episode length	First episode release date
New England Journal of Medicine (1)	NEJM Interviews	Weekly	10 min 48 s	February 7, 2011
The Lancet (2)	The Lancet in conversation with	Random	17 min 30 s	July 22, 2006
JAMA (4)	JAMA Editors' Summary	Weekly	11 min 16 s	Feb 28, 2006
Proceedings of the National Academy of Sciences (5)	PNAS Science Sessions	Biweekly	12 min 24 s	June 6, 2019
Journal of Clinical Oncology (7)	Journal of Clinical Oncology Podcast	Random	14 min 41 s	March 17, 2011
The Lancet Oncology (8)	The Lancet Oncology in conversation with	Monthly	12 min 28 s	February 25, 2008
Journal of the American College of Cardiology (10)	JACC Podcast	Weekly	13 min 44 s	October 26, 2020
The British Medical Journal (12)	Medicine and Science from The BMJ	Random	43 min 37 s	December 12, 2014
The Lancet Infectious Diseases (15)	The Lancet Infectious Diseases in conversation with	Random	12 min 50 s	September 28, 2006
Cochrane Database of Systematic Reviews (18)	Cochrane Library Podcasts	Random	4 min 58 s	November 5, 2020

inclusion. In this study, individual podcast episodes served as the unit of analysis. To guide systematic and reliable coding of podcast characteristics, we developed a codebook (see Appendix 1). Adapted from a coding scheme by MacKenzie (2019) on the global production and output of science podcasts, our codebook incorporated similar codes for podcast activity, audience type, and host type. However, since MacKenzie (2019) did not specifically examine journal podcasts, we employed data-driven prompts to identify and inductively add additional variables—including podcast guest, topic, communication format, level of information complexity, and audio quality. In total, our analysis encompassed eight variables, detailed in Table 2, with coding conducted by two researchers. Some variables were categorized at multiple levels: primary, secondary, and tertiary. For example, guests were classified based on their order of appearance, with the first guest labeled as primary and the second as secondary. Similarly, the communication format was evaluated across three levels, with the primary level representing the dominant style.

Before data collection, both coders met to establish standardized understanding of the coding approach based on the initial codebook. They then collaboratively coded a set of podcast episodes that were not part of the final sample, engaging in discussions to refine the coding scheme. After this collaborative phase, coders independently coded another set of episodes (also excluded from the final analysis), after which inter-coder reliability (ICR) was calculated. A subsequent team discussion and coding reconciliation meeting further ensured consistency, and because this process yielded high ICR, we proceeded with data collection.

To continuously verify consistency, we estimated ICR to ensure that all coders maintained a shared interpretation of the codebook. Following standard conventions, once initial ICR standards were met, we maintained a 15% overlap in coding across all data. Specifically, we targeted a minimum Gwet's AC score of 0.8. Given that our coding scheme relied heavily on categorical and binary variables, Gwet's AC was the preferred ICR statistic because it overcomes the paradox of high percent agreement paired with lower reliability scores that can occur with other statistics like Krippendorff's Alpha (Gwet, 2008; Ohyama, 2021). In addition to the quantitative codes, coders provided written notes to explain their decision-making process. The codebook is available in Appendix 1.

3 Results

Our study provides a descriptive analysis of the characteristics and features of 10 podcast series published by academic journals. Building on MacKenzie's (2019) approach, our research does not aim to explore relationships between variables or measure their effects on audience engagement. Instead, our goal is to describe the nature of podcast content and offer insights into the emerging niche of academic journal podcasts.

Table 3 presents the combined descriptive analysis across eight key variables. For an explanation of each variable, refer to Appendix 1.

Our analysis reveals several notable patterns. An overwhelming majority (93.75%) of podcast episodes were hosted by researchers, while only 5.25% were hosted by media professionals. Additionally, most episodes did not specify an intended audience, with 97.50% lacking a clear target group.

We found that the overwhelming majority (90.25) of podcast episodes are topically focused on research that has been published within the parent journal. Only 1% of the episodes discussed publications from other journals, while 8.75% were not directly focused on any specific publication(s).

In terms of guest composition, a substantial proportion of primary guests (84.07%) were the authors of the research being discussed. Secondary and tertiary guests also tended to be authors

TABLE 2 Name, definition and Gwets AC score for each variable.

Variable and inter-coder alpha level	Definition	Gwets AC score (% agreement)
Target Audience	The primary listening audience of the podcast, as defined by the podcast itself.	1.0 (100)
Host	The host speaker in the podcast, including description of their qualifications and relationship to the journal.	1.0 (100)
Guest(s) (Primary, Secondary and Tertiary)	The guest speaker in the podcast, including description of their qualifications and relationship to the journal.	1.0 (100)
Topic	Relationship of the podcast topic to the journal, i.e., relation to recent print publication.	1.0 (100)
Format	Description of the podcast speaker organization, such as an interview, conversation, or monologue.	1.0 (100)
Communication Format (Primary, Secondary and Tertiary)	Description of the manner in which information is presented, such using narrative strategies or reliance on data and statistics.	Primary 0.98 (98.36), Secondary 0.98 (98.36), Tertiary 0.96 (96.72)
Podcast Level of Complexity	Description of the level or difficulty of content complexity, related to level of expertise required for comprehension.	0.83 (88.52)
Podcast Audio Quality	The accuracy, fidelity, and intelligibility of audio across all podcast speakers.	0.90 (91.80)

or other experts, with individuals sharing lived experiences (experiential experts) comprising a relatively small portion of guests.

Aligning with the topical focus on published research, we found that the primary communication format centered on scientific information presentation (88.75%), with data-driven content also playing a significant role as a secondary style. However, narrative, emotive, and humorous communication styles were largely absent.

We observed high variation in the complexity of information presented. We found 45.25% of episodes were highly complex, featuring technical jargon and detailed discussions of scientific methodologies. Moderately complex episodes accounted for 24.25% of the sample, while 30.50% of episodes maintained a low complexity level, making them accessible to general audiences. Lastly, our analysis of audio quality showed that the majority of episodes (86.25%) offered high-quality audio. Moderate audio quality was present in 12.50% of episodes, and only 5.00% exhibited low-quality audio.

4 Discussion

Academic journals are increasingly venturing into podcasting. In the field of health and medical science, this development offers listeners a potentially credible source of information in a format often associated with variable content quality, including misinformation and commercial bias. However, as an emerging phenomenon, the role that journal podcasts play within the broader media ecosystem remains poorly understood. Specifically, we lack clarity about who their target audience is, what scope of information they present, who delivers this information, and how accessible it is to non-expert listeners. To address this gap, this study provides a descriptive analysis of the general characteristics, features, and communicative practices of journal podcasts in the field of health and medical science. Using a content analysis of 10 journal-affiliated podcast series, we analyzed several key variables to provide a descriptive assessment of this evolving form of scholarly communication (Appendix 1).

A central finding of our analysis was that an overwhelming majority (90.25%) of podcast episodes focused on research published within their parent journals, with only 1% discussing external publications and 8.75% addressing broader health and medical topics. This result is likely driven by editorial goals to increase engagement with the journal's own content, a conclusion supported by the prominent role of journal editors and staff as podcast hosts. Although this pattern may seem expected, it represents a key contribution of our study: journal podcasts appear to operate as direct extensions of their parent publications. In this capacity, they hold a distinctive position within both the media and scholarly communication ecosystems. Unlike broader science-based podcasts, such as those described by MacKenzie (2019), which tend to explore general scientific themes, journal-affiliated podcasts are narrowly focused on specific studies from their own publications. This finding also indicates that many journals view podcasts as legitimate tools for knowledge dissemination, functioning as complementary outlets alongside traditional print and digital formats. Further supporting this interpretation, we found that most podcast guests were authors of the research being discussed (84.07%), suggesting that these platforms offer researchers an alternative format to discuss their work and elaborate on their findings.

By allowing scholars to directly present their research, podcasts bypass traditional journalistic gatekeepers who historically shaped the public dissemination of scientific information (Shoemaker, 2020). Previous research has shown that journalists base their coverage of science on several criteria, including personal interests, perceived novelty, audience relevance, emotional impact, and narrative potential (Rosen et al., 2016). In contrast, journal podcasts shift this gatekeeping role to the journals themselves, which decide which authors to invite. Once on the podcast, authors have the flexibility to present their research without concerns about being

TABLE 3 Variable, type and count (%) for each variable.

Variable	Type	Count (%)
Podcast Host *N* = 400	Researcher, including academic and clinicians	375 (93.75)
	Media Professional	21 (5.25)
	Unclear	4 (1.00)
Podcast Audience *N* = 400	Experts, such as scientists and clinicians	10 (2.50)
	Students, high school, undergraduate, graduate	0 (0.00)
	General Public	0 (0.00)
	Unspecified	390 (97.50)
Podcast Topic *N* = 400	Publication(s) in their journal	361 (90.25)
	Publication(s) from varied sources	4 (1.00)
	Broader focus not directly linked to any specific publication	35 (8.75)
Podcast Guest (First, by order of appearance) *N* = 295	Author of research under discussion	248 (84.07)
	Expert (excluding author of research under discussion)	38 (12.88)
	Experiential expert	9 (3.05)
Podcast Guest (Second, by order of appearance) *N* = 159	Author of research under discussion	123 (77.36)
	Expert (excluding author of research under discussion)	29 (18.24)
	Experiential expert	7 (4.40)
Podcast Guest (Third, by order of appearance) *N* = 81	Author of research under discussion	62 (76.54)
	Expert (excluding author of research under discussion)	14 (17.28)
	Experiential expert	5 (6.17)
Communication Format (Primary) *N* = 400	Scientific	355 (88.75)
	Data and statistical	37 (9.25)
	Narrative	8 (2.00)
	Emotive	0 (0.00)
	Humor	0 (0.00)
Communication Format (Secondary) *N* = 343	Scientific	81 (23.62)
	Data and statistical	206 (60.06)
	Narrative	44 (12.83)
	Emotive	9 (2.62)
	Humor	3 (0.87)
Communication Format (Tertiary) *N* = 135	Scientific	81 (60.00)
	Data and statistical	8 (5.93)
	Narrative	21 (15.56)
	Emotive	17 (12.59)
	Humor	8 (5.93)
Level of Complexity *N* = 400	Low	122 (30.50)
	Moderate	97 (24.25)
	High	181 (45.25)
Audio Quality *N* = 400	Low	5 (1.25)
	Moderate	50 (12.5)
	High	345 (86.25)

misrepresented or sensationalized by journalists who may lack subject matter expertise (Dempster et al., 2022). In this context, journal podcasts offer a promising alternative for listeners seeking trustworthy, evidence-based information. This is particularly important given ongoing challenges in evaluating podcast content quality. Previous studies have shown that common quality indicators often fail to accurately predict the reliability of podcast content, making it difficult for audiences to distinguish credible information from misinformation (Paterson et al., 2015; Ahn et al., 2016).

Interestingly, we also found that 97.50% of the podcast episodes did not specify a target audience (Appendix 1), either in the audio content or in the metadata, such as the written episode or series descriptions. While this result may seem surprising, it aligns with the broader norms of podcasting, where identifying a target audience is not standard practice. A more useful insight into the target audience may be drawn from our analysis of information complexity (Appendix 1). We found that 45.25% of episodes were highly complex, 24.25% were moderately complex, and 30.50% were of low complexity. Highly complex episodes were often characterized by the detailed discussion of statistical methods and associated inferences, often without accompanying explanation in lay terms. For instance, an episode published in the series *JAMA Editors' Summary*, discusses research examining opioid versus neuromuscular blockers for rapid sequence intubation. A transcription of part of that episode is provided below:

> "The primary outcome was the rate of successful first-attempt tracheal intubation without major complications among adults at risk of aspiration during rapid sequence intubation in the operating room. The study found that remifentanil, when compared with neuromuscular blockers, did not meet the criteria for non-inferiority in achieving this outcome. Although remifentanil was statistically inferior to neuromuscular blockers, the wide confidence intervals around the effect estimate suggest that non-inferiority cannot be definitively ruled out, limiting conclusions about the clinical relevance of the observed difference."

Although the intended audience is not explicitly stated, we suggest that highly complex episodes like this are aimed at expert listeners with both advanced knowledge of statistical terminology and a deep substantive understanding of the topic. Moderately complex podcasts, however, often frame their methodological details with introductory explanations to establish baseline knowledge before diving into technical specifics. For instance, in the *PNAS Science Sessions* episode titled "Racial Disparities in Air Pollution," research author Dr. Gaige Kerr begins by introducing ambient nitrogen dioxide as a pollutant, outlining its broad health impacts, and explaining the study's focus on this specific pollutant—namely, its direct association with vehicle emissions and its regulatory significance under the Clean Air Act. This scientific groundwork sets the stage for the episode's central focus on racial disparities in air pollution exposure, lowering the knowledge barrier and making the content more accessible to a broader audience. While the episode later delves into methodological details, such as sensitivity analyses used to justify the study's temporal scope and the satellite program employed to collect data, this early contextualization allows the content to remain intelligible and engaging for non-expert listeners, even as it offers technical depth for more expert audiences.

Low-complexity podcasts, by contrast, tend to focus on the primary findings of studies, emphasizing the broader implications of the research and its relevance to medicine. For example, an episode from *NEJM Interviews* on cybersecurity threats to patients and the healthcare system explores general categories of cyberattacks—such as data theft, activist-driven attacks, and critical infrastructure disruptions. Dr. Eric Perakslis discusses the potential risks posed by these threats, the frequency of various attack types, and strategies hospitals and medical centers can adopt to mitigate risk. The episode avoids detailed methodological and statistical discussions, instead discussing the topic in language that is easily accessible and relevant to a wide range of medical and healthcare professionals. While our descriptive analysis identifies broad distinctions in levels of information and complexity, it remains unclear whether the communication styles used in each episode are deliberate choices aimed at achieving specific outcomes with particular audiences, or simply reflect individual differences in the communication styles of the hosts and guests. Investigating this further presents a promising avenue for future research.

Consistent with the finding that most episodes focused on published research, the predominant communication format (Appendix 1) was scientific in nature (88.75%). This reflects the intent of these podcasts to present research studies directly, often supported by the use of data and statistics as a secondary presentation style. In contrast, narrative, emotive, and humorous tones were rarely used. When these tones did appear, they were often linked to the less frequently used experiential expertise, featuring individuals with lived experiences of illness or disease. This is exemplified in the *PNAS Science Sessions* episode titled "Treating Cystic Fibrosis," which features Morgan Barrett's lived experience with the condition. The episode discusses her treatment journey, including the regimen she followed as a child, allowing the host to incorporate a personal narrative that complements and humanizes the scientific information presented. Previous research on audio-based health communication has highlighted the value of integrating multiple types of expertise to provide diverse perspectives and create more compelling narratives (Greeves and Ledbetter, 2022). Despite this evidence, narrative was used as the primary communication style in only 2% of episodes, as a secondary style in 12%, and as a tertiary style in 15%. This suggests a missed opportunity for journal-affiliated podcasts to broaden their communication strategies. By incorporating narrative elements and experiential voices more frequently, these podcasts could enhance potential listener engagement and better reach non-expert audiences.

Our finding that the majority of episodes (86.25%) offered high-quality audio, while seemingly straightforward, highlights the accessibility of podcasts as a medium for mass communication. This is particularly relevant for organizations such as academic journals, which often operate within fixed budgets (Fox et al., 2021). Although our analysis did not evaluate production costs, either financially or in terms of time, it is reasonable to infer that podcasting offers a more feasible model for large-scale communication than more resource-intensive formats like video. Only a small proportion of episodes demonstrated issues with audio quality, further reinforcing the viability of podcasting as a practical and scalable communication strategy. In most cases, these issues were linked to individual guests using suboptimal microphone setups. Notably, as many of the sampled episodes were recorded during the COVID-19 pandemic, this finding is not entirely unexpected. The pandemic likely limited some podcast contributors' ability or willingness to access in-person recording setups, which may have contributed to occasional declines in audio quality. Nonetheless, the overall high standard observed across episodes reinforces the potential of podcasts as a practical and cost-effective communication tool for academic journals.

4.1 Limitations

Overall, our findings provide descriptive insights into the nature and characteristics of journal-affiliated podcasting. However, as a descriptive analysis, the scope of inference is limited. Notably, this study did not examine how podcast characteristics influence audience

engagement with the information presented, an important direction for future research. To that end, future studies might consider integrating podcast analytics platforms. For example, Apple Podcasts provides tools for analyzing audience size and demographics, as well as detailed listener behavior metrics such as episode completion rates, drop-off points, and frequently skipped segments (Apple, 2025). These behavioral data could serve as dependent variables in future research, complementing the content-focused variables examined here, which would likely function as independent variables. Importantly, access to such analytics would require collaboration with podcast producers, as this data is only available to publishers.

Additionally, while we found that the majority of podcast episodes centered on publications from their affiliated journals, our analysis did not assess whether these podcasts influenced engagement with the articles themselves. This, too, represents a valuable avenue for future investigation. However, it is likely difficult to disentangle the extent to which reader engagement is driven by the publication itself versus its feature in a podcast. Moreover, we did not include a temporal dimension in our analysis to assess whether communication strategies have changed over time or in response to audience engagement. Similarly, we did not examine whether certain types of content (e.g., research on cancer versus infectious diseases) rely on fundamentally different communication approaches, or whether these strategies are consistent across other research journals. Future research could explore how podcasts produced by journals in other scientific disciplines compared to those in the health and medical sciences analyzed in this study. Such comparative analyses would offer a more comprehensive understanding of the role and impact of journal-affiliated podcasts within the broader landscape of science communication.

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

SG: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. RL: Conceptualization, Investigation, Methodology, Writing – review & editing. RM: Data curation, Formal analysis, Methodology, Writing – review & editing. KW: Data curation, Formal analysis, Methodology, Writing – review & editing.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcomm.2025.1589099/full#supplementary-material

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