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Mapping research trends and knowledge structures of rhythmic gymnastics in early childhood gross motor development: A scopus-based bibliometric analysis (2015–2024)

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Abstract

Background: Research on rhythmic gymnastics and its contribution to early childhood gross motor development has grown considerably over the past decade. However, the scientific landscape, research trends, and knowledge structures within this field remain insufficiently explored.
Aim: This study aimed to map research trends and knowledge structures related to rhythmic gymnastics in early childhood gross motor development through a bibliometric analysis of Scopus-indexed publications.
Methods: A systematic literature review with a bibliometric approach was conducted using the Scopus database. A total of 49 eligible articles published between 2015 and 2024 were analyzed. Bibliometric mapping and visualization were performed using VOSviewer, while descriptive analyses were conducted using Microsoft Excel.
Results: The findings revealed an increasing publication trend, reaching its highest peak in 2022. Keyword analysis identified strong associations between rhythmic gymnastics and motor skills, motor performance, muscle strength, training, and physical education. Tartu Ülikool emerged as the most productive institutional contributor, while Italy and Spain were the leading countries in publication output. Subject-area analysis showed that medicine and health professions accounted for more than two-thirds of the publications, highlighting the predominance of health-oriented perspectives in this field.
Conclusion: The findings demonstrate the growing scientific interest in rhythmic gymnastics as a promising intervention for enhancing early childhood gross motor development. This study provides a comprehensive reference for researchers, educators, and practitioners in developing evidence-based and developmentally appropriate movement programs.

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INTRODUCTION

Early childhood motor development is a fundamental component of children's overall growth because it supports exploration, environmental interaction, and readiness for future learning experiences. Motor competence during the early years is widely recognized as an indicator of healthy growth and developmental progress. The acquisition of motor skills contributes significantly to children's physical abilities, movement coordination, self-confidence, and independence in performing everyday activities (Adatul'aisy et al., 2023). Well-developed motor skills are also associated with broader developmental outcomes, including communication abilities, cognitive

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functioning, creativity, problem-solving skills, and social competence (Capio et al., 2024; Valla et al., 2020). Gross and fine motor skills provide the foundation for children's participation in educational, recreational, and social activities throughout life. Furthermore, motor development is closely linked to the maturation of neurological and psychological functions that influence future learning and behavior. Children with higher levels of motor competence often demonstrate greater engagement in physical and social environments. Evidence also suggests that interventions designed to improve motor development can enhance executive functions, including self-regulation, inhibitory control, and problem-solving abilities (Cassidy & Willoughby, 2025; Willoughby & Hudson, 2023). These findings highlight the multidimensional role of motor development in supporting children's holistic growth. Therefore, promoting motor competence during early childhood remains an important priority for educators, researchers, and health professionals.

Physical activity plays a central role in facilitating motor development during early childhood by providing opportunities for movement practice and skill refinement. Numerous studies have shown that structured physical activities are more effective than unstructured activities in improving both gross and fine motor skills (Dapp et al., 2021; Martinez-Merino & Rico-González, 2024). Structured physical activity programs provide systematic movement experiences that support the development of balance, coordination, agility, muscle strength, and locomotor abilities. Previous research has demonstrated that structured activities, whether implemented independently or combined with free play, produce significant improvements in children's motor competence (Chen et al., 2024; Çolak et al., 2024; McDonough et al., 2020; Panda et al., 2022; Quan et al., 2024a). Such interventions enable children to repeatedly practice movement patterns in developmentally appropriate settings. Participation in structured physical activities also contributes to greater confidence and motivation to engage in active lifestyles. Among the various forms of structured physical activity, rhythmic gymnastics has emerged as a particularly promising approach for enhancing children's motor development. Rhythmic gymnastics combines movement, rhythm, music, and physical exercise in a manner that promotes both physical and psychological engagement. Its structured yet enjoyable characteristics make it suitable for implementation in early childhood education settings. Consequently, rhythmic gymnastics has received increasing attention as a movement-based intervention for supporting children's developmental outcomes.

Rhythmic gymnastics has been shown to provide a wide range of benefits related to children's physical and motor development. Participation in rhythmic gymnastics programs enhances children's ability to follow rhythmic patterns, coordinate upper and lower body movements, and improve movement accuracy and flexibility (Sawitri & Pujiati, 2023; Simamora et al., 2024). The integration of music and synchronized body movements stimulates motor coordination, balance control, and body awareness in young children. Several empirical studies have consistently reported positive effects of rhythmic gymnastics on gross motor skills, including strength, balance, flexibility, and movement coordination (Adatul'aisy et al., 2023; Simamora et al., 2024). Children who regularly participate in rhythmic gymnastics activities demonstrate significant improvements in locomotor skills such as walking, jumping, balancing, and arm movements (Quan et al., 2024a). Beyond its physical benefits, rhythmic gymnastics also promotes enjoyment, creativity, and active participation during learning activities. The flexibility of rhythmic gymnastics enables educators to adapt activities according to children's developmental levels and individual abilities. This adaptability ensures that children with different skill levels can benefit from participation in rhythmic movement activities. As interest in early childhood physical education continues to grow, rhythmic gymnastics has become increasingly recognized as an effective and developmentally appropriate intervention. Consequently, the growing body of research on rhythmic gymnastics warrants a comprehensive examination of how knowledge in this field has evolved over time.

Although research on rhythmic gymnastics, motor skills, and early childhood development has expanded considerably in recent years, the existing literature remains fragmented across multiple disciplinary perspectives. Previous studies have primarily focused on the effectiveness of rhythmic gymnastics in improving physical fitness, motor performance, biomechanical characteristics, injury prevention, and athlete development, while reviews have largely emphasized physiological and performance-related outcomes rather than educational and developmental contexts (Gaspari et al., 2024; Milas et al., 2026; Oliveira et al., 2021). Similarly, a substantial body of literature has examined motor skills and physical activity in children through systematic reviews and meta-analyses, highlighting their importance for physical, cognitive, and psychosocial development (Bolger et al., 2021; Dapp et al., 2021; Jones et al., 2020). Furthermore, bibliometric analyses have been increasingly applied across diverse scientific domains to map research trends, knowledge structures, and emerging themes, demonstrating their value in understanding the evolution of scientific fields (Donthu et al., 2021; Passas, 2024). However, to the best of our knowledge, no previous study has systematically mapped the scientific landscape of rhythmic gymnastics in relation to early childhood gross motor development through a bibliometric approach. Consequently, publication trends, thematic evolution, influential contributors, institutional productivity, international collaboration patterns, and emerging research directions within this field remain insufficiently understood. Addressing this gap is essential for providing a comprehensive understanding of the development of knowledge in this area and for guiding future research, policy, and educational practice.

Therefore, this study employs a bibliometric approach to systematically examine the development of research on rhythmic gymnastics in early childhood gross motor development. Using publications indexed in the Scopus database between 2015 and 2024, this study aims to provide a comprehensive overview of the scientific landscape of this research field. Specifically, the study seeks to analyze publication trends and identify patterns of scientific growth over the last decade. It also aims to examine keyword co-occurrence networks to reveal dominant research themes and emerging topics. Furthermore, the study investigates the knowledge structure of the field through bibliometric mapping and visualization techniques. Author productivity and collaboration patterns are analyzed to identify influential contributors and research networks. Institutional affiliations are examined to determine leading research centers and their contributions to knowledge development. Country-level analysis is conducted to explore global publication patterns and international scientific participation. In addition, the study evaluates subject area distributions to understand the disciplinary perspectives that shape research on rhythmic gymnastics and early childhood motor development. The findings are expected to provide valuable insights into the evolution of this field and offer evidence-based directions for future research, educational practice, and policy development.

LITERATURE REVIEW

Gross motor development refers to the progressive acquisition of movement abilities that involve the coordination of large muscle groups responsible for locomotion, balance, posture, and body control. These skills form the foundation for children's participation in physical activities, social interactions, and learning experiences throughout childhood (Blewitt et al., 2021; Cycyk & Hammer, 2020; O'Connor & Penney, 2021). Gross motor competence is commonly expressed through abilities such as running, jumping, hopping, balancing, throwing, and catching (Gao et al., 2021; Silva, 2025). The development of these skills occurs rapidly during the early childhood period, making it a critical stage for intervention and support. Research has consistently demonstrated that motor competence is associated with children's physical fitness, cognitive functioning, and psychosocial well-being

(Bretz et al., 2026; Salaj & Masnjak, 2022; Visser et al., 2020). Children with higher levels of motor proficiency tend to demonstrate greater confidence in movement-related tasks and are more likely to engage in active lifestyles. Conversely, inadequate motor development may contribute to reduced physical activity participation and lower levels of physical fitness. The acquisition of gross motor skills is influenced by biological, environmental, educational, and social factors. Consequently, educators and researchers have emphasized the importance of providing developmentally appropriate movement experiences during early childhood. Understanding factors that support gross motor development therefore remains an important area of investigation in child development research.

Physical activity has long been recognized as a fundamental contributor to children's motor development and overall health. Participation in regular physical activity provides opportunities for children to practice movement patterns, improve coordination, and strengthen musculoskeletal systems (Almeida et al., 2025; Faienza et al., 2023; Molina-Garcia et al., 2020). Structured physical activities are particularly effective because they provide systematic instruction, repetition, and feedback that facilitate motor learning (Crotti et al., 2022; Mödinger et al., 2022; Veer et al., 2022; Zhou et al., 2021). Such activities allow children to develop movement competence in a supportive and goal-oriented environment. Previous studies have reported positive relationships between structured physical activity participation and improvements in balance, agility, locomotor skills, and object-control abilities (Abusleme-Allimant et al., 2023; T. Fu et al., 2022; Quan et al., 2024b). Furthermore, physical activity contributes to the development of cognitive functions through increased neural stimulation and sensorimotor integration. The benefits of physical activity extend beyond physical outcomes and include social interaction, emotional regulation, and self-confidence. In early childhood education settings, movement-based activities are increasingly incorporated into curricula to support holistic development. The effectiveness of physical activity interventions depends on factors such as intensity, frequency, duration, and developmental appropriateness. Therefore, identifying physical activities that effectively support motor development has become an important focus of educational and health-related research.

Rhythmic gymnastics represents a unique form of physical activity that combines movement, music, rhythm, flexibility, and coordination within a structured learning environment. Unlike conventional exercise programs, rhythmic gymnastics integrates artistic expression with physical performance, creating an engaging experience for young children. The synchronized interaction between music and movement encourages the development of body awareness, timing, rhythm perception, and movement precision. Research has shown that participation in rhythmic gymnastics can improve flexibility, balance, muscle strength, coordination, and overall motor competence (Mandroukas et al., 2023; Skopal et al., 2020; Yu et al., 2025). The activity also promotes creativity and self-expression, which are important components of child-centered learning. Due to its adaptable nature, rhythmic gymnastics can be modified according to children's developmental stages and individual abilities. This flexibility makes it suitable for implementation in preschool and early childhood education programs. In addition to improving motor skills, rhythmic gymnastics may contribute to children's motivation and enjoyment during physical activity participation. The growing recognition of these benefits has resulted in increased academic interest in examining the role of rhythmic gymnastics in child development. Consequently, rhythmic gymnastics has emerged as a promising intervention for supporting gross motor development in early childhood.

Bibliometric analysis is a quantitative research method used to evaluate and visualize the development of scientific knowledge within a particular field. The approach enables researchers to examine publication patterns, citation relationships, collaboration networks, and thematic structures across large collections of academic literature (Y. C. Fu et al., 2022; Ortega, 2021). Bibliometric techniques have become increasingly popular because they provide objective and

systematic insights into the evolution of scientific disciplines. Common bibliometric indicators include publication productivity, citation impact, co-authorship networks, co-citation relationships, and keyword co-occurrence patterns (Klarin, 2024; Kumar, 2025; Schiuma et al., 2023). Advances in bibliometric software, such as VOSviewer, CiteSpace, and Bibliometrix, have facilitated sophisticated visualizations of scientific knowledge structures. These tools enable researchers to identify influential authors, institutions, countries, and research themes. Bibliometric analysis also supports the identification of emerging topics and future research opportunities within rapidly developing fields. Compared with traditional narrative reviews, bibliometric studies offer a more comprehensive and data-driven understanding of scholarly development. As a result, bibliometric approaches have been widely adopted across education, health sciences, social sciences, and sports research. Their ability to reveal intellectual structures and research trajectories makes them particularly valuable for evaluating evolving scientific domains.

Research trends and knowledge structures represent two important dimensions in understanding the development of a scientific field. Research trends describe the temporal evolution of publications, topics, and scholarly attention over time (Balili et al., 2020; Han, 2020; Taylor, 2023). Knowledge structures refer to the relationships among concepts, authors, institutions, and scientific themes that collectively shape the intellectual foundation of a discipline (Hernández-Torrano et al., 2020; Muller, 2023). Through the analysis of publication patterns and thematic networks, researchers can identify dominant research areas as well as underexplored topics. Understanding research trends is essential for recognizing shifts in scientific priorities and emerging areas of inquiry. Similarly, knowledge structure analysis provides insight into how different research communities contribute to the advancement of knowledge. In interdisciplinary fields such as rhythmic gymnastics and early childhood motor development, scientific knowledge is often distributed across multiple domains, including education, health sciences, sports science, and psychology. Mapping these relationships enables researchers to better understand the complexity and evolution of the field. Furthermore, knowledge mapping facilitates evidence-based decision-making regarding future research directions and collaborative opportunities. Therefore, investigating research trends and knowledge structures provides a valuable framework for understanding the scientific development of rhythmic gymnastics in early childhood gross motor development.

METHOD

Research Design

This study employed a quantitative research approach using the Systematic Literature Review (SLR) method integrated with bibliometric analysis. The bibliometric approach was selected because it enables the systematic examination of publication patterns, scientific productivity, collaboration networks, and thematic developments within a specific research domain. The study focused on mapping research trends and knowledge structures related to rhythmic gymnastics in early childhood gross motor development. To ensure the reliability and comprehensiveness of the bibliographic data, publications were retrieved exclusively from the Scopus database, which is widely recognized as one of the largest and most reputable indexing platforms for peer-reviewed scientific literature. Scopus was selected due to its extensive coverage, rigorous indexing standards, and high-quality metadata that facilitate bibliometric analysis. The study covered publications published between 2015 and 2024 to capture the evolution of research during the last decade. Through this design, the study aimed to provide a comprehensive overview of scientific developments, emerging themes, and research directions within the field of rhythmic gymnastics and early childhood motor development.

Participant

In bibliometric studies, the unit of analysis consists of scientific publications rather than human participants. Therefore, the participants in this study were Scopus-indexed journal articles related to rhythmic gymnastics and children. The initial search identified 736 documents from the Scopus database. To ensure relevance and consistency, the retrieved records were screened according to predetermined inclusion and exclusion criteria. Inclusion criteria consisted of: (1) articles published in English, (2) articles with high relevance to rhythmic gymnastics and children, (3) publications issued between 2015 and 2024, (4) articles authored by more than one researcher, (5) articles with full access to bibliographic information, and (6) studies with clearly described and replicable research methods. Exclusion criteria included: (1) non-English publications, (2) articles with low thematic relevance, (3) publications outside the selected time period, (4) single-author articles, and (5) publications with limited access or unclear methodological descriptions. Following the screening process, 49 articles met all eligibility criteria and were included in the final dataset for analysis.

Instrument

The primary instrument used in this study was bibliographic metadata extracted from the Scopus database. Data collection was conducted on June 1, 2025 using the following search query:

(TITLE-ABS-KEY (rhythmic AND gymnastics) AND TITLE-ABS-KEY (children)) AND PUBYEAR > 2014 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "PSYC") OR LIMIT-TO (SUBJAREA, "MULT") OR LIMIT-TO (SUBJAREA, "MEDI") OR LIMIT-TO (SUBJAREA, "NURS")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English"))

The retrieved metadata included publication titles, authors, publication years, affiliations, countries, keywords, abstracts, source titles, and subject categories. Mendeley Reference Manager was employed to organize, verify, and manage bibliographic records throughout the research process. The metadata were subsequently exported in CSV format to facilitate further bibliometric analysis and visualization. Microsoft Excel was used for data management and descriptive statistical analysis, while VOSviewer software was utilized to construct and visualize bibliometric networks. These tools enabled the systematic identification of publication trends, research themes, and collaboration structures within the selected literature.

Research Procedure

The research procedure consisted of five stages. The first stage involved determining the research objectives and developing the bibliometric search strategy. The second stage involved retrieving publications from the Scopus database using predefined keywords and selection criteria. The third stage consisted of screening and filtering records according to the inclusion and exclusion criteria to ensure data relevance and quality. The fourth stage involved exporting the final dataset and conducting bibliometric analyses using Mendeley Reference Manager, Microsoft Excel, and VOSviewer. During this stage, publication trends, keyword networks, author productivity, affiliations, country contributions, and subject area distributions were analyzed and visualized. The fifth stage involved interpreting and synthesizing the findings to identify research trends, thematic developments, collaboration patterns, and emerging directions within the field. Finally, the results were compiled into a comprehensive scientific mapping of research related to rhythmic gymnastics and early childhood gross motor development during the period 2015–2024.

Data Analysis

Data analysis was performed using descriptive bibliometric techniques and science mapping procedures. Descriptive analysis was conducted to identify annual publication trends, leading

authors, productive institutions, contributing countries, and dominant subject areas. Bibliometric mapping was carried out using VOSviewer version 1.6.20 to analyze keyword co-occurrence networks and visualize thematic relationships among research concepts. Network visualization was used to identify major thematic clusters and conceptual connections within the literature. Overlay visualization was employed to examine the temporal evolution of research topics and identify emerging themes over time. Density visualization was used to determine the most influential and frequently occurring concepts in the field. In addition, publication productivity analysis was conducted to evaluate author contributions, institutional performance, and country-level scientific output. The results were interpreted using a knowledge-mapping perspective to reveal the intellectual structure and research development of rhythmic gymnastics in early childhood gross motor development.

RESULTS AND DISCUSSION

Results

The initial data search was conducted on June 1, 2025 using the keyword rhythmic gymnastics without a filter (Figure 1).

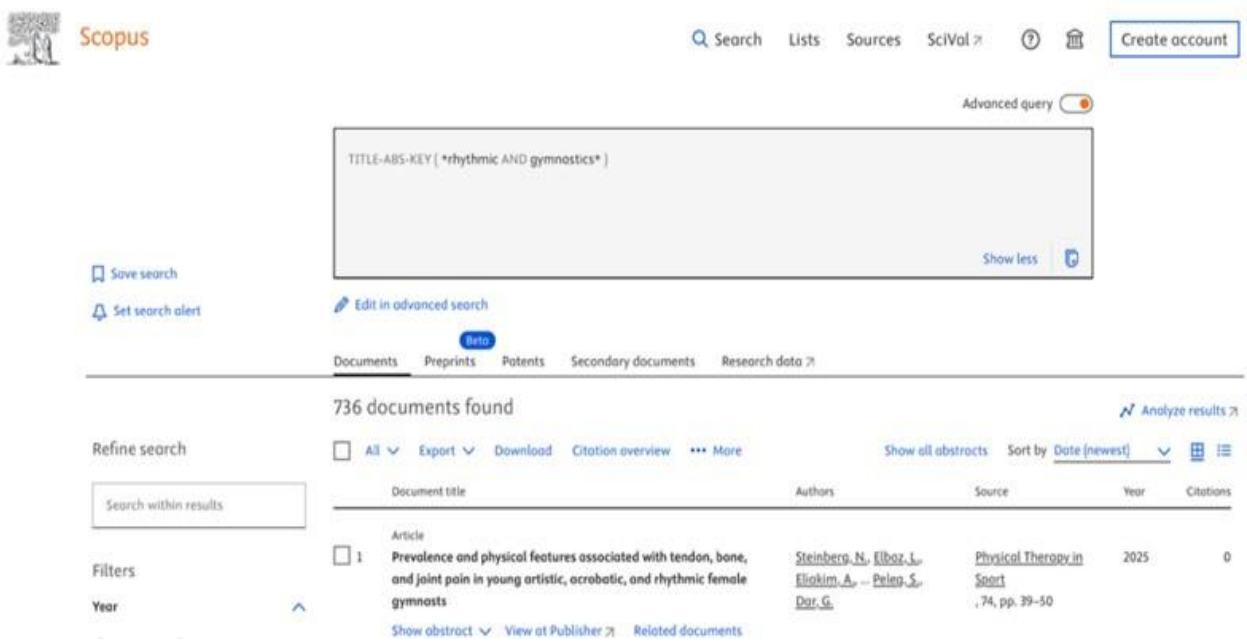

Figure 1. Scopus Database Initial Search

There were 736 Scopus-indexed documents identified using the keyword “rhythmic gymnastics”. The oldest document is titled “Polyrhythmic Gymnastics” by Rath, E in 1930. A total of 8 documents have been published in 2025, but were not included in the research data because there is potential to continue to grow until the end of the year. The results of the next data analysis have used the article selection criteria in Table 1, which consists of 49 articles (Figure 2).

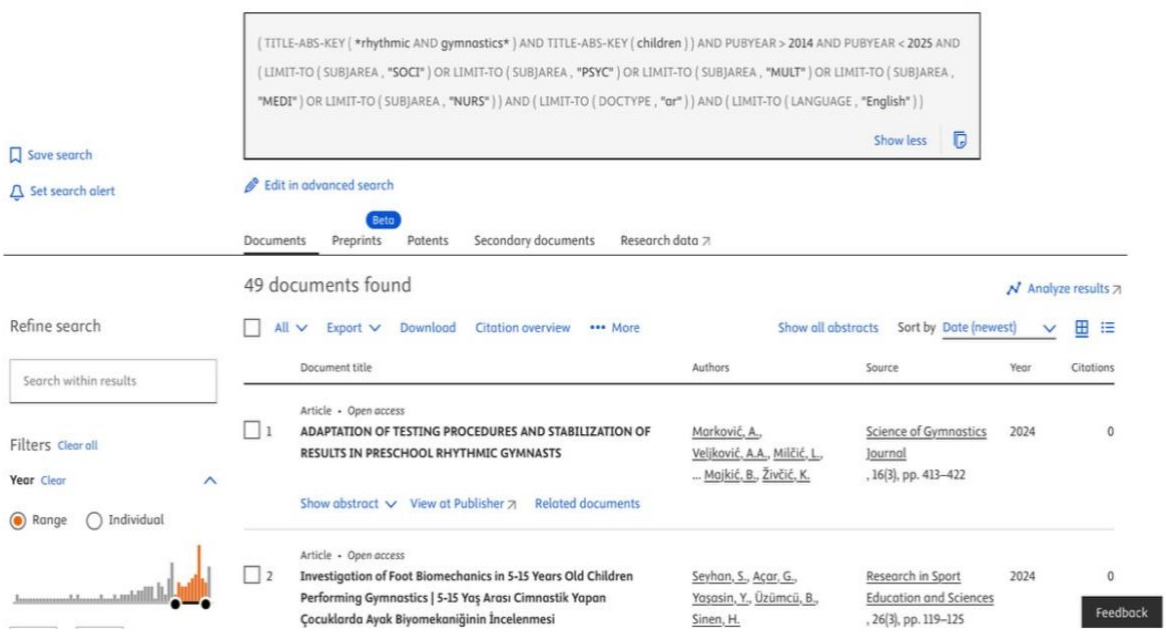

Figure 2. Searching for the Final Database Scopus

Frequency distribution per year

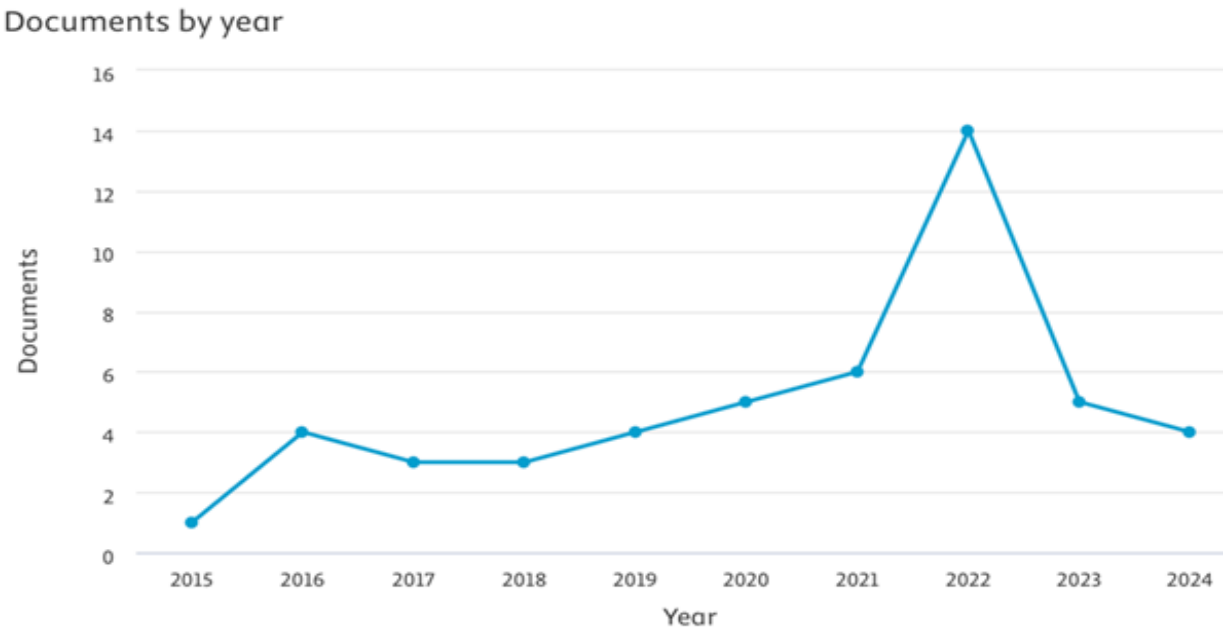

Figure 3. Global Trends in Rhythmic Gymnastics Research in the Last Decade

Figure 2 shows the results of document search analysis in Scopus with the keywords "rhythmic gymnastics" and "children," which are limited to the subjects of social sciences, psychology, medicine, nursing, and others, and English documents from 2015 to 2024. A total of 49 documents were found. The line graph on the right illustrates the number of publications per year, while the table on the left details the number of documents for each year. From the trend analysis, 2022 shows the most significant spike with 14 documents, an increase of 8 articles compared to the previous year (2021), with only 6 documents. Growth is also evident from 2017 to 2022, from 3 to 14 documents (+11). However, after the peak in 2022, there was a sharp drop of -64.3% in 2023 (only 5 documents), and again down to 4 documents in 2024. This pattern indicates increased attention to the topic until 2022, which then declines in the following two years (Table 2).

Table 2. Growth in the Number of Articles

Year	Number	documents Growth from
2016	4	+3
2017	3	-1
2018	3	0
2019	4	+1
2020	5	+1
2021	6	+1
2022	14	+8
2023	5	-9
2024	4	-1

Keyword Analysis, Overlay Visualization, and Density Visualization

The following figure (Figure 3) is a visualization of the keyword network in the research on rhythmic gymnastics generated using VOSviewer software. The main keyword "rhythmic gymnastics" is in the center with the largest size, indicating that this is the main focus in the analyzed literature.

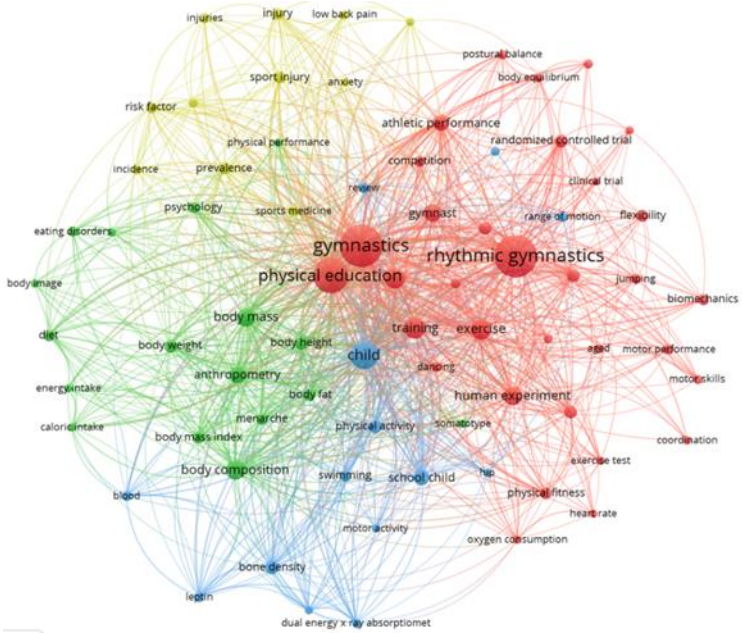

Figure 4. Visualization of keyword network

The terms "rhythmic gymnastics" and "gymnastics" have very strong connections with various other keywords related to physical education, physical performance, and children's motor skills. The red cluster that dominates the center of the network shows that rhythmic gymnastics has close connections with terms such as physical education, training, exercise, motor performance, flexibility, and biomechanics. This indicates that the study of rhythmic gymnastics does not stand alone, but is highly integrated in the context of movement performance and physical capability measurement. The blue and green clusters show the relationship of rhythmic gymnastics themes with anthropometric and body composition studies, such as body mass, body fat, anthropometry, and body composition, as well as with health issues such as diet, body image, and eating disorders. This indicates that the study of rhythmic gymnastics in children also addresses aspects of growth, nutritional health, and psychophysiological balance. Meanwhile, the yellow cluster seems to highlight the dimensions of injury risk and sports performance, with keywords such as injury, risk factors, sports injury, and athletic performance. This shows that in addition to focusing on fostering motor skills and movement aesthetics, the literature on rhythmic gymnastics also pays great attention to the safety and well-

being of children. Overall, this visual map shows that the study of rhythmic gymnastics in early childhood is multidimensional, combining elements of physical education, health, physical performance and child development psychology. This opens up space for interdisciplinary collaboration in developing a more holistic approach to learning and coaching in the future.

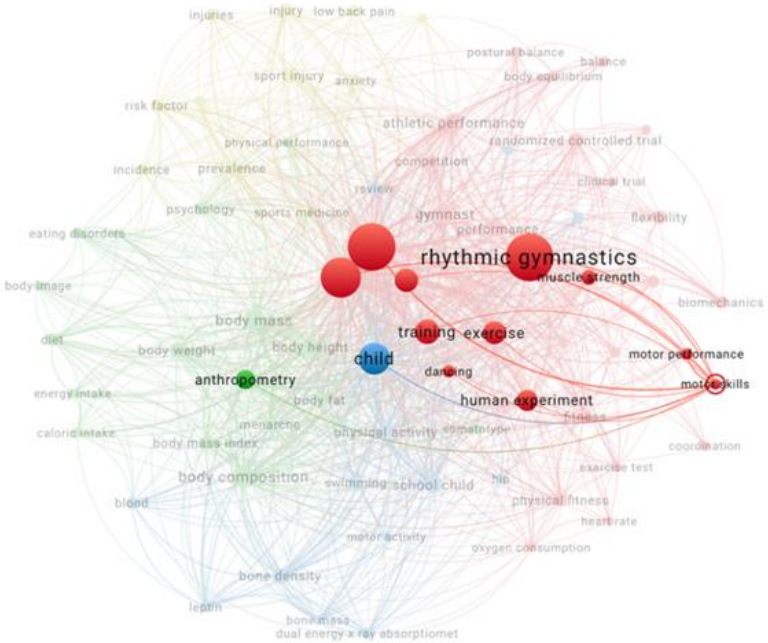

Figure 5. Relationship between Rhythmic Gymnastics and Children's Motor Skills

Rhythmic gymnastics has a very close relationship with several key concepts in physical development, especially in children. Keywords such as “motor skills”, “motor performance”, “muscle strength”, “training”, and “exercise” appear in the same cluster and are strongly interconnected with rhythmic gymnastics, shown by the bold lines indicating a high frequency of association in the literature. This indicates that rhythmic gymnastics is not only understood as an art and sport activity, but also as an effective method of improving fine and gross motor skills, physical performance, and muscle strength.

The keyword “child” in the closest and most directly connected cluster indicates that the child population is the main subject of this study. This indicates that rhythmic gymnastics is mostly researched in early childhood or school-age contexts, where it is thought to contribute positively to children's motor development and physicalfitness. Overall, these keyword relationships underscore the strategic role of rhythmic gymnastics as a holistic approach in supporting children's physical growth and motor skills through a structured exercise program oriented towards muscle strengthening and movement mastery.

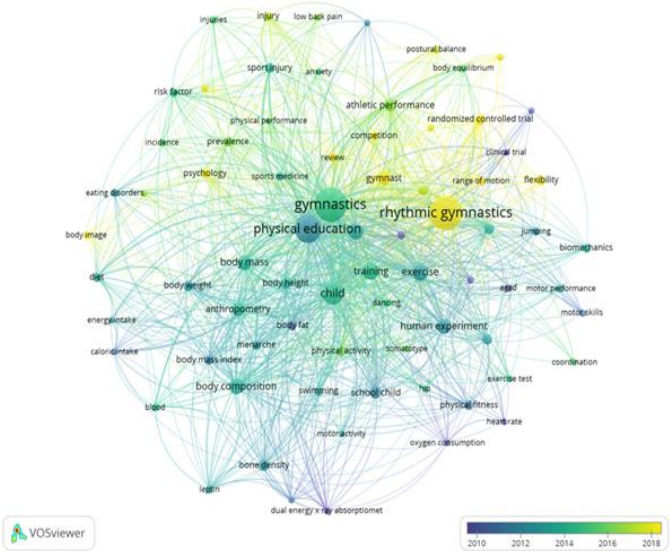

Figure 6. Overlay Visualization

Based on the overlay visualization from VOSviewer, it can be seen that research on rhythmic gymnastics linked to keywords such as “motor skills” and “motor performance” has a dominant yellow color, which represents a relatively more recent publication year (close to 2018). This suggests that the research focus on the role of rhythmic gymnastics in the development of children's motor skills and physical performance has increased in the last decade. In contrast, keywords such as “child”, “physical education”, and “body composition” tend to be blue-green in color, indicating that these studies have evolved earlier, from around 2010 to 2014. Thus, it can be concluded that there is a shift in scientific interest from general issues such as physical education and body composition towards specific approaches such as the use of rhythmic gymnastics as a more targeted training strategy to improve early childhood motor skills and muscle strength. This temporal evolution reflects the academic community's inclination to explore more innovative and movement arts-based interventions to support children's physical development, while opening up opportunities for further research in this area that is increasingly relevant in the modern physical education context.

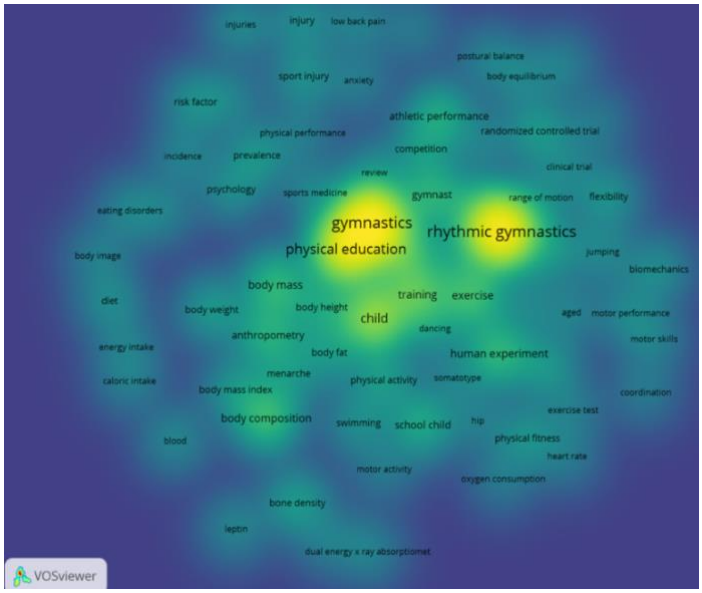

Figure 7. Density Visualization

Based on the density visualization in the figure above, it can be seen that the keywords "gymnastics", "physical education", and "rhythmic gymnastics" are in the high-density region as they have a bright yellow color, indicating a high frequency of occurrence and linkage in the analyzed literature. Other keywords that were also quite dense around this area included "training", "exercise," and "child", indicating that these topics are highly integrated in the research related to rhythmic gymnastics and physical education.

Meanwhile, keywords such as "motor performance", "motor skills", and "muscle strength" are in the medium to low density area (marked green to blue), indicating that although these concepts are relevant, the intensity of discussion is still lower compared to the central topic. However, the close proximity of these words to the core density indicates the potential for strong linkages and promising directions for research development. Thus, this visualization confirms that rhythmic gymnastics has a strategic position in the research landscape related to physical education, especially in the context of children's physical and motor development, and offers opportunities for further exploration in strengthening motor skills and muscle strength through artistic and functional approaches.

Author and Co-Authorship Analysis

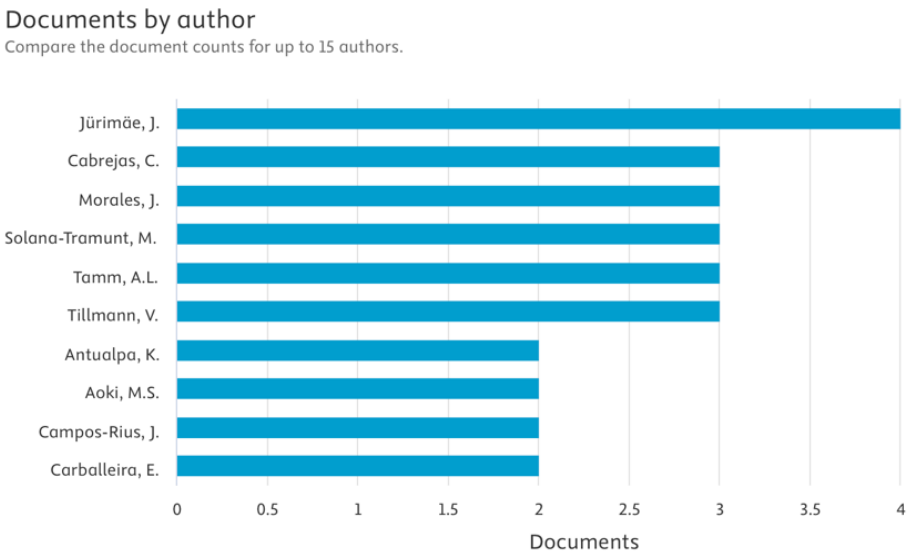

Figure 8. Most Productive Writer

Based on the distribution of documents by author, it can be seen that Jürimäe, J. is the most prolific author in the study of rhythmic gymnastics in children, with a total of four documents. This significant contribution indicates Jürimäe's important role in the development and dissemination of knowledge in the field, as well as possible links to the institution of Tartu Ülikool, which also occupies the top position in the affiliation category. In addition, there are seven other authors with three documents each, namely Cabrejas, C., Morales, J., Solana-Tramunt, M., Tamm, A.L., Tillmann, V., Antualpa, K., and Aoki, M.S.. This balanced number of publications indicates a broad and strong network of author collaborations in this field.

These authors are likely to come from different institutions and countries, reflecting a cross-border approach to the study of children's movement and sport. Other authors, such as Campos-Rius, J., and Carballeira, E. also contributed with two documents each, signifying the continuity and diversity of thought in this study. These data suggest that although rhythmic gymnastics research in children may still be limited on a global scale, it has developed consistently through the contributions of a number of highly productive authors. This consistency is critical to building a strong and deep knowledge base, and opens up opportunities for future multidisciplinary and international

collaborations.

Most Affiliates

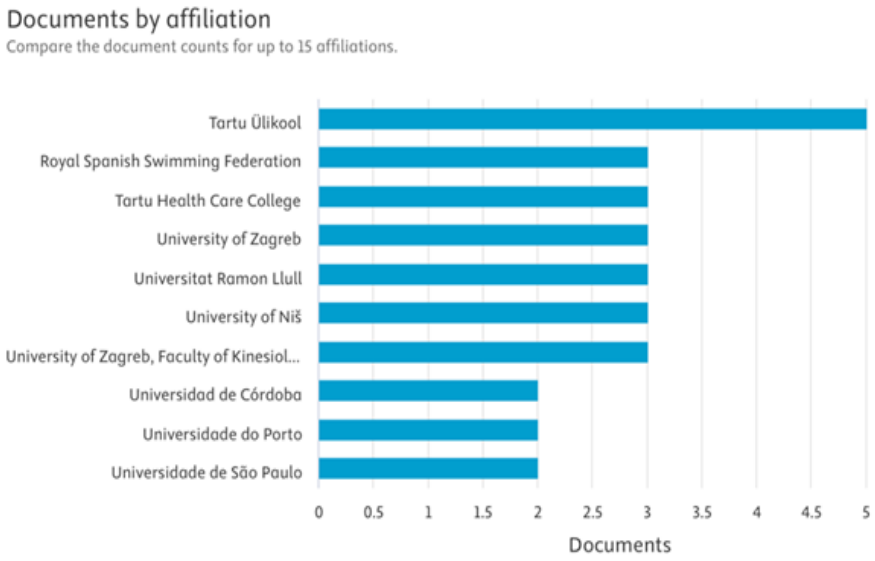

Figure 9. Top 10 Affiliates

Based on the graph of document distribution by institutional affiliation, it can be seen that Tartu Ülikool from Estonia is the most active institution in pediatric rhythmic gymnastics research publications, with a total of five documents. This suggests that there is a center of research excellence in this field in the Baltic region. The Royal Spanish Swimming Federation, Tartu Health Care College, University of Zagreb, Universitat Ramon Llull, University of Niš, and the University of Zagreb, Faculty of Kinesiology, followed by several institutions with three documents. The diversity of affiliations from different countries, such as Spain, Croatia, Serbia, and Estonia, shows that research on rhythmic gymnastics is not only a concern of higher education institutions, but also national sports organizations such as the Spanish swimming federation.

There were also contributions from Latin American institutions such as Universidad de Córdoba, Universidade do Porto, and Universidade de São Paulo, with two documents each. This indicates that there is considerable global interest in this topic, although it is still dominated by European institutions. Interestingly, there is not a single institution from Asia on this list, reflecting the region's potential to develop similar research to enrich the global literature and expand international collaboration in the field of physical education and child development.

Document by Country.

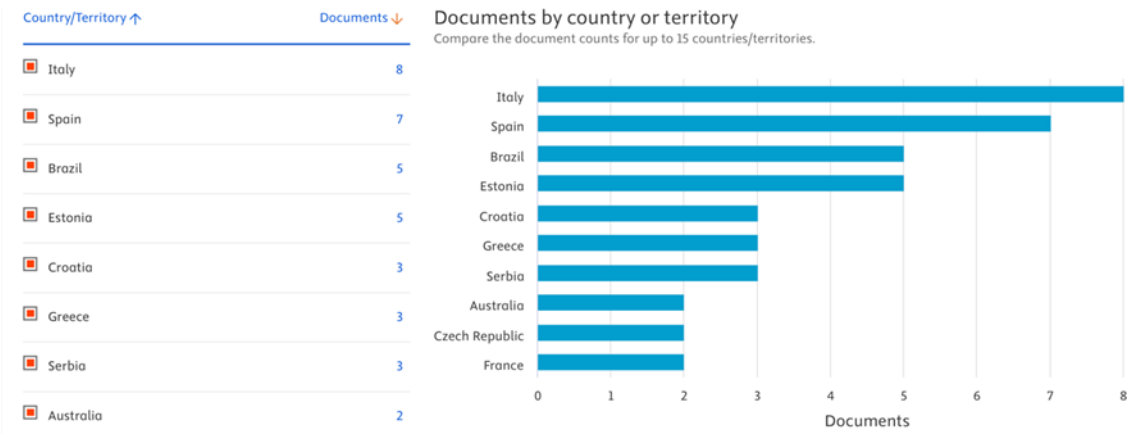

Figure 10. Most Articles By Country

Based on the distribution graph of documents based on the author's country or region of origin, it can be seen that research on rhythmic gymnastics in children is dominated by European countries. Italy is in the top position with a total of 8 documents, followed by Spain with 7 documents. This shows that Southern European countries pay great attention to this field. Furthermore, Brazil and Estonia each contributed 5 documents, indicating active involvement from South America and Eastern Europe. Countries such as Croatia, Greece, and Serbia also showed quite significant participation, each with 3 documents. Australia is the only representative from the Asia-Pacific region included in the top ten list, with a total of 2 documents.

Interestingly, there is no contribution from Asian countries, including Indonesia, in the list. In fact, the Asian region has great potential in developing similar research, especially through the approach of physical education and early childhood health. This opens up great opportunities to develop rhythmic gymnastics studies in regions that are not yet represented, either through independent research or international collaboration. The absence of representation from Asia also reflects the continuing geographical gap in the global academic literature that can be filled by researchers from these regions.

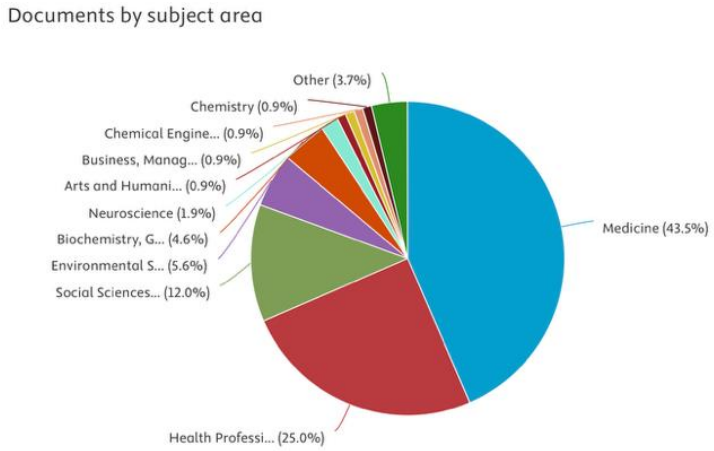

Figure 11. Subject Area

The second figure shows the distribution of the 49 documents analyzed by scientific field. The table and pie chart show that the topic of rhythmic gymnastics in children is most widely researched in the field of medicine, with a total of 47 documents (43.5%), followed by health professions with 27 documents (25.0%), and social sciences with 13 documents (12.0%). Other fields, such as Environmental Science, Biochemistry, Neuroscience, and Arts and Humanities, each contribute a much smaller amount. This distribution shows that the topic of rhythmic gymnastics in early childhood is most predominantly studied from a medical and health perspective, indicating a primary focus on physical aspects, body development, or therapy. Although there are contributions from the social sciences, the proportion is relatively small (12%) compared to the health field, which combined (Medicine + Health Professions, covers more than two-thirds of all publications (68.5%). This indicates that the research approach to this topic is still very medically oriented, and opens up opportunities for expanding studies from a social perspective, child development psychology, and pedagogical approaches in the field of early childhood education.

Discussion

The findings demonstrate that scientific interest in rhythmic gymnastics and early childhood gross motor development has generally increased over the last decade, although fluctuations in publication output were observed across years. The substantial increase in publications between 2017 and 2022 indicates growing recognition of movement-based interventions as an important

component of children's physical and developmental outcomes. The publication peak in 2022 suggests heightened academic attention to physical activity and motor development research following increased global awareness of children's health and physical well-being. Similar publication growth patterns have been reported in bibliometric studies focusing on physical education, motor development, and youth sports, where research productivity increased significantly during the post-pandemic period as concerns regarding children's physical inactivity became more prominent. The decline observed after 2022 should not necessarily be interpreted as a reduction in scientific interest but may reflect publication cycles, indexing delays, and shifting research priorities. Comparable fluctuations have also been reported in bibliometric analyses of physical activity and child development research, where publication outputs tend to vary despite overall long-term growth trends. The sustained presence of publications throughout the study period indicates that rhythmic gymnastics remains a relevant topic within child development and physical education research. Furthermore, the continuous publication of studies suggests that researchers increasingly recognize the potential of rhythmic gymnastics as a structured intervention for promoting motor competence. The observed publication trajectory also reflects the growing integration of sports science, education, and health sciences in understanding children's developmental outcomes. Therefore, the publication trend identified in this study confirms the continuing relevance of rhythmic gymnastics as an interdisciplinary area of scientific inquiry.

Keyword network analysis revealed that rhythmic gymnastics is strongly associated with concepts related to physical education, motor performance, exercise, flexibility, training, and biomechanics. This finding is consistent with previous empirical studies demonstrating that rhythmic gymnastics contributes significantly to improvements in balance, coordination, flexibility, strength, and movement quality among children (Gaspari et al., 2024; Yu et al., 2025). The prominence of keywords related to motor skills and physical performance indicates that the literature continues to emphasize measurable developmental outcomes resulting from participation in rhythmic gymnastics programs. Similar patterns have been observed in systematic reviews examining physical activity interventions for children, where motor competence and physical fitness frequently emerge as dominant research themes (Barnett et al., 2022; Goodyear et al., 2023; Lorås, 2020; Moon et al., 2024). The presence of anthropometry, body composition, and nutritional health within the keyword clusters further suggests that researchers increasingly adopt a holistic perspective when investigating child development. This observation aligns with contemporary developmental theories that emphasize the interaction between physical, biological, and psychosocial factors in shaping children's growth. The appearance of injury-related terms also reflects growing concerns regarding safety and risk management within youth sport participation. Previous studies in sports science have similarly reported increasing attention toward injury prevention and athlete well-being as essential components of long-term athletic development. The multidimensional structure of the keyword network indicates that rhythmic gymnastics research extends beyond motor development alone and encompasses broader health-related and educational outcomes. Consequently, the field appears to be evolving toward a more integrated understanding of child development that combines physical performance, health promotion, and educational practice.

The overlay visualization provides important evidence regarding the temporal evolution of research themes within the field. Earlier studies were primarily associated with broad topics such as physical education, child development, and body composition, whereas more recent publications increasingly focus on motor skills, motor performance, and muscle strength. This shift suggests a gradual movement from general descriptive investigations toward more targeted and outcome-oriented research. Similar thematic transitions have been identified in bibliometric analyses of youth sports and physical activity research, where contemporary studies increasingly emphasize evidence-based interventions and measurable developmental indicators (Y. Ma et al., 2024; Shen & Yang,

2025). The growing prominence of motor skill-related keywords reflects increasing recognition that motor competence serves as a critical predictor of children's long-term physical activity participation and health outcomes. Furthermore, the emergence of performance-related themes suggests a stronger focus on evaluating intervention effectiveness using objective assessment methods. These findings are consistent with recent trends in child development research that prioritize quantifiable indicators of physical and functional development (Jeong et al., 2022; Requejo et al., 2022; Veldman et al., 2021; J.-W. Wang et al., 2023). The overlay analysis also indicates that rhythmic gymnastics is increasingly being examined as a specialized movement-based intervention rather than merely a component of general physical education. Such developments demonstrate the maturation of the research field and the increasing sophistication of methodological approaches used by researchers. Therefore, the temporal evolution identified in this study highlights the growing scientific emphasis on understanding the specific mechanisms through which rhythmic gymnastics influences children's motor development.

The author, affiliation, and country analyses reveal important patterns regarding the global distribution of scientific contributions within this field. The dominance of authors such as Jürimäe and institutions such as Tartu Ülikool suggests the existence of specialized research groups that have consistently advanced knowledge related to rhythmic gymnastics and child development. Similar concentrations of expertise have been reported in other sports science disciplines, where a relatively small number of highly productive scholars and institutions often drive scientific development (Ellemers, 2021; Gleason et al., 2024; L. Ma et al., 2021). The strong representation of European institutions and countries reflects the historical importance of gymnastics within European educational and sporting traditions. Countries such as Italy, Spain, Estonia, Croatia, and Serbia have long-standing traditions in gymnastics participation and athlete development, which may contribute to sustained research productivity. The presence of national sports organizations among the leading affiliations further indicates close collaboration between academic institutions and applied sport sectors. Such collaborations are often associated with greater opportunities for translating research findings into practical programs and policy initiatives. However, the absence of significant representation from Asian countries highlights an important geographical imbalance within the literature. Similar regional disparities have been documented in previous bibliometric studies across education and sports science, where research production remains concentrated in Europe and North America (Hernández-González et al., 2025; Liu et al., 2022; Marginson, 2022; Pérez-Gutiérrez et al., 2023). Expanding research participation from underrepresented regions may contribute to greater cultural diversity and broader applicability of future findings.

The subject area analysis demonstrates that research on rhythmic gymnastics and early childhood motor development is predominantly situated within medicine and health professions, accounting for more than two-thirds of all publications. This finding indicates that researchers have primarily approached the topic from physiological, clinical, and health-oriented perspectives. Similar disciplinary distributions have been reported in bibliometric studies examining children's physical activity, where health sciences frequently dominate the literature (Urbano-Mairena et al., 2023; X. Wang et al., 2026). While this emphasis has contributed substantially to understanding the physical and biological benefits of rhythmic gymnastics, it may also limit the exploration of educational, pedagogical, and psychosocial dimensions. The relatively small proportion of publications originating from social sciences suggests that educational perspectives remain underrepresented within the current knowledge structure. Previous scholars have emphasized the importance of interdisciplinary approaches when investigating children's development because developmental outcomes are influenced by multiple interacting factors (Camerota & Willoughby, 2021; Witherspoon et al., 2023). Greater integration of educational sciences, developmental psychology, and curriculum studies could therefore enrich future research in this area. Such interdisciplinary expansion would

support a more comprehensive understanding of how rhythmic gymnastics contributes not only to physical competence but also to children's social, emotional, and cognitive development. The present findings also indicate substantial opportunities for future research focusing on educational implementation, learning processes, and culturally responsive movement programs. Overall, the dominance of health-related disciplines alongside the limited representation of educational perspectives highlights an important direction for future scientific development in the field.

Implications

The findings of this study provide important implications for researchers, educators, policymakers, and practitioners involved in early childhood development and physical education. The identified growth in scientific publications demonstrates increasing recognition of rhythmic gymnastics as a valuable intervention for supporting children's gross motor development. The strong association between rhythmic gymnastics and motor skills, motor performance, flexibility, and muscle strength suggests that this activity can serve as an effective component of developmentally appropriate movement programs in early childhood settings. The results also highlight the multidisciplinary nature of the field, indicating opportunities for greater collaboration among experts in education, health sciences, sports science, psychology, and child development. From an educational perspective, the findings encourage early childhood educators to integrate rhythmic gymnastics into learning activities to promote both physical competence and active engagement. The dominance of health-related disciplines within the existing literature suggests that future educational research should further explore pedagogical approaches, curriculum integration, and learning outcomes associated with rhythmic gymnastics. The limited contribution from Asian countries indicates a need for broader geographical participation in order to enrich the global evidence base and incorporate diverse cultural perspectives into movement-based educational practices. The identification of leading institutions and productive authors may facilitate the establishment of international research partnerships and knowledge-sharing initiatives. Furthermore, the emerging focus on motor skills and performance outcomes highlights the importance of evidence-based program design and systematic assessment in early childhood physical education. The bibliometric mapping generated in this study can serve as a strategic reference for researchers seeking to identify underexplored topics and promising future research directions. Policymakers may also utilize these findings to support the development of movement-based health promotion programs that address children's physical development needs. Ultimately, this study contributes to a deeper understanding of the scientific landscape surrounding rhythmic gymnastics and provides a foundation for advancing research, educational practice, and policy initiatives aimed at optimizing early childhood motor development.

Limitations and Suggestions for Future Research

This study has several limitations that should be considered when interpreting the findings. First, the analysis was limited exclusively to publications indexed in the Scopus database, which may have excluded relevant studies published in other databases such as Web of Science, Dimensions, PubMed, ERIC, or Google Scholar. Second, only English-language journal articles were included, potentially limiting the representation of research conducted in non-English-speaking countries where rhythmic gymnastics is widely practiced. Third, the study relied on a specific search strategy and keyword combination, which may not have captured all relevant publications associated with rhythmic movement activities, gymnastics-based interventions, or motor development programs. Fourth, the bibliometric approach primarily focuses on publication metadata and citation relationships rather than evaluating the methodological quality or empirical effectiveness of

individual studies. Fifth, the relatively small number of eligible documents identified in this field may limit the generalizability of some thematic patterns and collaboration networks. Sixth, the findings reflect the state of the literature up to 2024 and may not fully represent emerging developments in subsequent years. Future research should expand the scope of analysis by incorporating multiple databases and broader search terms to obtain a more comprehensive representation of the field. Researchers are also encouraged to conduct comparative bibliometric studies across different movement-based interventions to identify unique and shared developmental contributions. Further investigations should integrate citation analysis, co-citation analysis, bibliographic coupling, and thematic evolution techniques to provide deeper insights into the intellectual structure of the field. Future studies may also examine regional research disparities and explore factors contributing to the limited representation of developing countries and Asian institutions. In addition, systematic reviews and meta-analyses are needed to complement bibliometric findings by evaluating the effectiveness of rhythmic gymnastics interventions on specific developmental outcomes. Ultimately, a combination of bibliometric, systematic review, and empirical research approaches will contribute to a more comprehensive understanding of the role of rhythmic gymnastics in supporting early childhood gross motor development.

CONCLUSION

Based on the bibliometric findings and subsequent analysis, this study concludes that rhythmic gymnastics has emerged as an increasingly important research domain in supporting gross motor development during early childhood. The growth of scientific publications over the last decade reflects a rising recognition of rhythmic gymnastics as an effective, engaging, and developmentally appropriate physical activity capable of enhancing coordination, balance, flexibility, muscle strength, and overall motor competence among young children. The keyword, overlay, and density analyses further demonstrate that research attention has progressively shifted toward motor skills, motor performance, and movement-based interventions, highlighting the growing importance of evidence-based approaches in early childhood physical education. The identified knowledge structure confirms that rhythmic gymnastics is closely connected to broader themes of physical education, exercise, health promotion, and child development, reinforcing its multidisciplinary character. Nevertheless, the findings reveal that the existing body of literature remains predominantly concentrated within medicine and health professions, while educational, pedagogical, and developmental perspectives receive comparatively limited attention. The dominance of health-oriented research suggests that current knowledge may not yet fully capture the instructional, curricular, and learning-related dimensions of rhythmic gymnastics implementation in early childhood settings. In addition, the limited contribution from Asian countries highlights a geographical imbalance in scientific production despite the region's rich traditions in movement education, cultural dance practices, and early childhood pedagogy. These gaps indicate the need for a more comprehensive and culturally responsive research agenda capable of integrating health, educational, psychological, and social perspectives. The findings also suggest that the successful implementation of rhythmic gymnastics in early childhood education depends not only on the activity itself but also on the competence of educators in designing child-centered, play-based, and developmentally appropriate learning experiences. Therefore, teacher education institutions, professional development providers, and policymakers should strengthen training opportunities, curriculum support, and evidence-based instructional resources related to rhythmic movement programs. Greater collaboration among researchers, early childhood educators, physical education specialists, and health professionals is also necessary to develop adaptive and contextually relevant intervention models. Ultimately, expanding interdisciplinary and cross-cultural research on

rhythmic gymnastics will contribute to the development of more holistic, inclusive, and scientifically grounded strategies for promoting children's motor development and lifelong physical well-being.

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AUTHOR CONTRIBUTIONS STATEMENT

Lusi Angelia conceptualized the study, designed the research methodology, conducted data collection and bibliometric analysis, interpreted the results, and prepared the original manuscript draft. Imam Muthie contributed to the development of the research framework, supervised the data analysis process, and participated in the interpretation of findings. Lucy Oktavani assisted in data screening, validation of bibliographic records, visualization using VOSviewer, and manuscript editing. Sri Gusti Handayani contributed to the literature review, data interpretation, and critical revision of the manuscript for important intellectual content. Tisna Syafnita supervised the overall research process, provided methodological guidance, reviewed the findings, and critically revised the manuscript prior to submission. All authors contributed substantially to the study, reviewed and approved the final version of the manuscript, and agreed to be accountable for all aspects of the work, ensuring the accuracy and integrity of the research.

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