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UNIVERSITATEA LUCIAN BLAGA DIN SIBIU

CENTRUL DE CERCETARE ÎN ȘTIINȚA SPORTULUI ȘI EDUCAȚIEI FIZICE

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INTERNATIONAL JOURNAL OF Movement Science

TABLE OF CONTENTS

INTERNATIONAL JOURNAL OF MOVEMENT SCIENCE (IJMS), VOL. 1, 2026

TEACHERS' DIGITAL COMPETENCE IN EARLY CHILDHOOD AND PRIMARY EDUCATION: AN ANALYSIS OF THE DIGITAL DIVIDE BASED ON A SYSTEMATIC REVIEW (2021–2025) 1

DYNAMIC BALANCE AND POSTURAL CONTROL ADAPTATIONS AFTER INTEGRATED PROPRIOCEPTIVE TRAINING IN ADOLESCENT LATIN AMERICAN DANCERS 20

METHODOLOGICAL ASPECTS OF SELECTION AND INITIATION IN SPORT DANCE FOR CHILDREN AGED 4–7 YEARS 32

A RANDOMIZED CONTROLLED TRIAL COMPARING MCKENZIE AND WILLIAMS EXERCISES IN PATIENTS WITH ACUTE LOW BACK PAIN 45

PHYSICAL ACTIVITY BEHAVIORS, SPORTS CULTURE AND HEALTH ATTITUDES AMONG MEDICAL STUDENTS: A CROSS-SECTIONAL STUDY..... 57

TEMPO–SPATIAL SYNERGY IN ELITE BASKETBALL PERFORMANCE: A MULTIVARIATE ANALYSIS 72

ENHANCING TENNIS PERFORMANCE IN U16 PLAYERS THROUGH INTEGRATED COGNITIVE–MOTOR TRAINING..... 84

EXPRESSIVITY IN DANCESPORT: A MULTIDISCIPLINARY PERSPECTIVE ON PERFORMANCE, PERCEPTION AND EVALUATION 97

THE ROLE OF PHYSIOTHERAPY IN INCREASING THE QUALITY OF LIFE IN PATIENTS WITH MENISCUS INJURIES..... 114

THE OPINION OF SPORTS DANCE SPECIALISTS REGARDING PHYSICAL TRAINING 128

DEVELOPING UPPER-BODY COORDINATION THROUGH THE USE OF MOBILE APPS IN PHYSICAL EDUCATION CLASSES FOR 8TH-GRADE STUDENTS .
;..... 142

THE IMPORTANCE OF SELF-DEFENSE TECHNIQUES IN THE TRAINING OF MILITARY STUDENTS: A QUESTIONNAIRE-BASED ANALYSIS..... 152

EFFECTS OF REACTIVE AGILITY TRAINING ON PHYSICAL AND GAME PERFORMANCE IN COMPETITIVE PADEL PLAYERS 160

DEVELOPMENT OF MOTOR COORDINATION THROUGH THE FOLK DANCE "BREAZA,, – APPLIED STUDY..... 168

INTRODUCTION OF NEW TECHNOLOGIES IN MEDICAL EDUCATION: APPLICATION OF MERRILL'S INSTRUCTIONAL DESIGN PRINCIPLES IN PEDIATRIC PHYSIOTHERAPY 172

IMPROVING REACTION TIME USING BLAZEPOD TECHNOLOGY IN STUDENTS PRACTISING TRADITIONAL KARATE 191

STUDENTS' BELIEFS ABOUT TALENT AND EFFORT AS PREDICTORS OF PERFORMANCE IN PHYSICAL EDUCATION 202

REALITY OF ENGLISH LINGUISTIC COMPETENCIES OF PHYSICAL EDUCATION TEACHERS IN INTERNATIONAL SCHOOLS ACROSS EGYPT 210

PHYSICAL ACTIVITY IN EUROPE VS ROMANIA: PARTICIPATION 214

EFFECTS OF GREEK FOLK DANCE ON COORDINATION AND PERFORMANCE IN INTERNATIONAL DANCE COMPETITIONS 220

INTEGRATING PHYSICAL AND PSYCHOLOGICAL WELL-BEING IN HIGHER EDUCATION: AN INTERDISCIPLINARY APPROACH TO STUDENT DEVELOPMENT 224

IJMS Journal 2026, Vol. 1, Article 1

Teachers' Digital Competence in Early Childhood and Primary Education: an Analysis of the Digital Divide Based on a Systematic Review (2021–2025)

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Article type	Conference track	Language and length
Systematic review	Movement Science and Human Performance	English, 18 pages

Abstract

Background: This systematic review addresses the growing need to understand how teachers' digital competence influences educational quality in Early Childhood and Primary Education, especially in contexts affected by unequal opportunities for effective technology integration.

Objective: The study aimed to examine recent research on teachers' technological profiles and the teacher digital divide, identifying the digital competence dimensions most frequently addressed and the main forms of inequality reported in the literature.

Results: Following the PRISMA approach, a structured search was conducted in Scopus and Web of Science for journal articles published between 2021 and 2025. After screening and eligibility assessment, 24 studies focused on teachers in Early Childhood and Primary Education were selected for detailed analysis. The findings indicate a clear increase in scientific output during the reviewed period, a predominance of quantitative research designs, and a strong concentration of publications in Europe, particularly in Spain. The literature mainly examines teachers' technological profiles through digital pedagogy, the use and creation of digital resources, and broader digital competence frameworks. The review also shows that the most significant inequalities relate to training and pedagogical use, while access to technology appears less frequently as the main barrier.

Conclusions: These findings suggest that improving digital education in early educational settings requires stronger initial and continuing teacher training, greater institutional support, and a more pedagogically meaningful integration of digital technologies.

Keywords: teacher digital competence; digital divide; early childhood education; primary education; educational technology

1. Introduction

The growing digitalization of society is reshaping educational systems and redefining the professional competences expected of teachers. In this context, the integration of digital technologies in schools can no longer be understood merely as a matter of infrastructure or technical provision, but rather as a pedagogical and professional challenge directly linked to teaching quality and educational innovation. Several studies have shown that the educational value of technology depends largely on teachers' ability to integrate it critically, meaningfully and pedagogically into teaching and learning processes (Barroso, 2013; Cabero, 2020).

The literature consistently highlights that the quality of classroom technology integration is closely associated with teachers' levels of digital competence and with the opportunities they have for both initial and continuing professional development (Barba, 2022; Gutiérrez, 2023). This issue is especially relevant in Early Childhood and Primary Education, as these stages are critical for the development of children's cognitive, social and academic foundations.

At the same time, research indicates that teacher digital competence develops unevenly and is shaped by factors such as educational stage, professional role and access to specialized training. In general, higher levels of digital competence tend to be found among Primary Education teachers and among those involved in technological coordination or educational innovation processes (Vidal, 2025).

The rapid expansion of emerging technologies, particularly artificial intelligence, has further intensified the competence demands placed on teachers and has introduced new challenges for teacher education and professional practice (Holmes, 2019; Area, 2023). In this regard, recent studies suggest that higher levels of teacher digital competence are associated with more favorable attitudes towards the educational integration of artificial intelligence (Galindo, 2024; Tomczyk, 2025).

From an international perspective, the evidence also shows that the teacher digital divide is a multidimensional phenomenon that extends beyond mere access to devices or connectivity. It is also shaped by training conditions, cultural influences and contextual factors that affect both the development of digital competence and its pedagogical application in educational settings (Loureiro, 2024; Masoumi, 2024; Yang et al., 2024).

Against this background, a systematic analysis of the recent scientific literature on teachers' technological profiles and the teacher digital divide is both timely and necessary.

Conceptual Framework for Digital Education

Teacher digital competence is currently understood as a complex professional competence that integrates the knowledge, skills and attitudes required to plan, develop and evaluate technology mediated teaching and learning processes from a critical, safe and pedagogically grounded perspective (Esteve, 2020; Cabero, 2020). From this perspective, teacher digital competence represents a key factor in educational quality, as it guides the pedagogical use of technology in relation to the educational context and the learning needs of students (INTEF, 2022).

One of the most influential frameworks for the conceptualization and assessment of this competence is the European Framework for the Digital Competence of Educators, DigCompEdu. This framework organizes teacher digital competence into six interrelated areas: professional engagement, digital resources, digital pedagogy, technology mediated assessment, empowering learners, and facilitating students' digital competence (Redecker, 2017). Its widespread use in the scientific literature

reflects a broad consensus regarding its value as both a theoretical and methodological reference for the analysis of teachers' competence profiles.

In the Spanish context, this European framework has been adapted through the Reference Framework for Teacher Digital Competence in order to respond to rapid technological change and to the transformations associated with the expansion of digital education, particularly after the COVID-19 pandemic (Ministerio de Educación y Formación Profesional, 2022). This model establishes progressive levels of competence development and offers a common reference point for the training, assessment and accreditation of teachers across different educational stages.

The application of this framework is particularly relevant in Early Childhood and Primary Education. In Early Childhood Education, current legislation emphasizes the importance of introducing technologies through a pedagogical, exploratory and play based approach adapted to pupils' developmental stage (Real Decreto 95/2022). In Primary Education, the literature reports a greater presence of digitally mediated educational practices and relatively higher levels of teacher digital competence, although significant differences linked to training received and to teachers' professional roles remain evident (Vidal, 2025; Loureiro, 2024).

Within this context, the main objective of the present systematic review is to rigorously analyze the recent scientific literature on teachers' technological profiles and the teacher digital divide in the educational domain, with particular attention to Early Childhood and Primary Education.

More specifically, the study aims to: (1) describe the state of scientific output over the past five years; (2) identify the predominant methodological approaches in the analyzed studies; (3) examine the geographical distribution of publications; (4) identify the dimensions of the teacher technological profile most frequently addressed in recent scientific literature; and (5) determine the main types of teacher digital divide, specifically training related, access related and use related, present in the analyzed studies.

Based on these objectives, the review is structured around the following research questions:

Q1. What is the state of scientific output over the past five years?

Q2. What type of methodology predominates in the analyzed studies?

Q3. Which countries and regions concentrate the highest scientific output in this field?

Q4. Which dimensions of the teacher technological profile are most frequently addressed in the recent scientific literature?

Q5. What types of teacher digital divide are primarily identified in the analyzed studies?

2. Methodology

2.1. Study design

This study was designed as a systematic review with a descriptive and interpretive synthesis of the scientific literature. The review aimed to identify and analyze recent publications on teachers' technological profiles and the teacher digital divide in the field of education, with particular attention to Early Childhood and Primary Education. The methodological process was developed in accordance with the PRISMA 2020 guidelines for the identification, screening, eligibility assessment, and inclusion of studies (Page et al., 2021).

Given the heterogeneity of the included studies in terms of aims, methodological designs, and analytical focus, a descriptive synthesis was conducted rather than a meta-analysis. This approach made it possible to examine publication trends, methodological patterns, geographical distribution, dominant conceptual frameworks, and the main forms of teacher digital divide addressed in recent scientific literature.

2.2. Search Strategy

The search process was conducted between January and February 2026 using two internationally recognized academic databases, Scopus and Web of Science Core Collection. These databases were selected because of their broad coverage of high-quality peer reviewed literature and their relevance for educational research.

The search strategy was organized around three main thematic areas: teacher digital competence, educational stage, and digital divide. To identify relevant studies, the following search terms were used: digital teaching competence, teacher digital competence, ICT competence, primary education, early childhood education, digital divide, and digital inequality. These terms were combined using the Boolean operators “AND”, “OR”, and “NOT” in order to refine the search and improve the specificity of the results.

For greater transparency and reproducibility, the search strategy was operationalized through database specific search strings. In Scopus, the search was conducted using the following structure: TITLE-ABS-KEY (“digital teaching competence” OR “teacher digital competence” OR “ICT competence”) AND TITLE-ABS-KEY (“early childhood education” OR “primary education”) AND TITLE-ABS-KEY (“digital divide” OR “digital inequality”). In Web of Science Core Collection, the search was adapted to the Topic field as follows: TS=(“digital teaching competence” OR “teacher digital competence” OR “ICT competence”) AND TS=(“early childhood education” OR “primary education”) AND TS=(“digital divide” OR “digital inequality”). The search strategy was refined iteratively to ensure relevance and coherence with the objectives of the review.

In Scopus, the search was applied to title, abstract, and keywords, whereas in Web of Science it was conducted using the Topic field. The strategy was designed to retrieve studies focusing on teachers in Early Childhood and Primary Education and addressing dimensions related to digital competence, technological profiles, or the digital divide in educational contexts. A total of 847 records were initially identified, including 496 from Scopus and 351 from Web of Science.

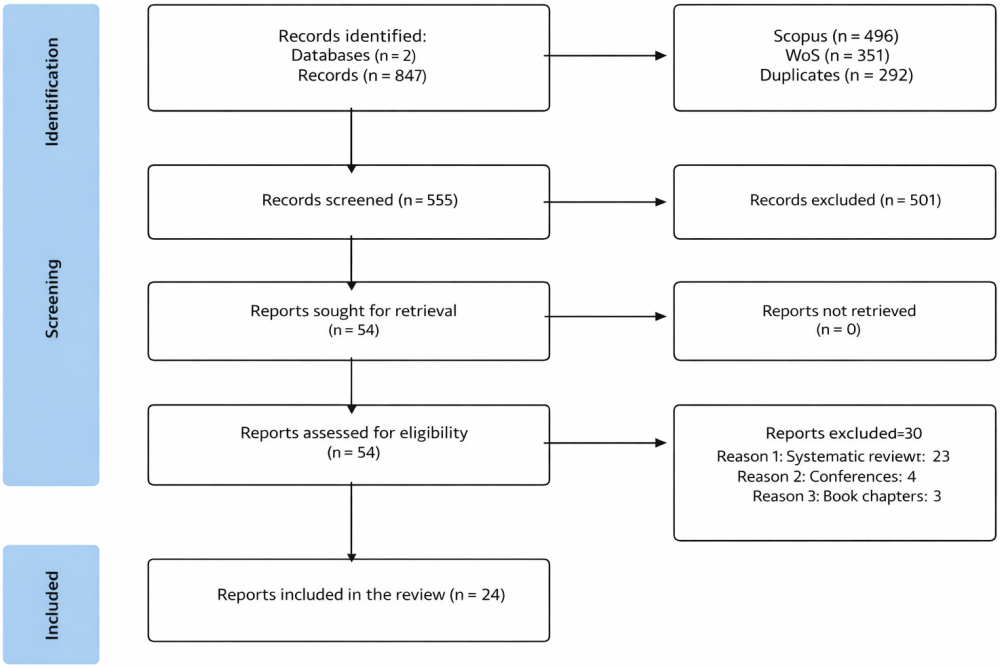


Figure 1. Document selection flow diagram

Note: Adapted from Haddaway et al. (2021), PRISMA2020: R package and Shiny app for producing PRISMA 2020 compliant flow diagrams.

2.3. Inclusion and Exclusion Criteria

The inclusion criteria were defined in advance to ensure consistency in the study selection process. Studies were included if they met the following criteria: (1) publication between 2021 and 2025; (2) journal article format; (3) location within the field of social sciences and education; (4) focus on teachers in Early Childhood Education or Primary Education; (5) explicit relevance to teacher digital competence, teachers' technological profiles, or forms of teacher digital divide; and (6) availability of the full text.

The exclusion criteria were also established prior to screening. Studies were excluded if they corresponded to: (1) systematic reviews, narrative reviews, or other review based publications; (2) conference papers, book chapters, doctoral theses, or non-journal outputs; (3) publications outside the selected time frame; (4) studies not focused on teachers; (5) studies not situated in Early Childhood or Primary Education; or (6) documents with insufficient relevance to the focus of the review.

2.4. Study Selection Process

The study selection process followed the stages recommended by PRISMA 2020. After database searching, duplicate records were identified and removed. Subsequently, the remaining studies were screened on the basis of title and abstract in order to exclude those that did not meet the predefined inclusion criteria. The full texts of the potentially eligible studies were then retrieved and assessed in detail.

Of the 847 records initially identified, 292 duplicate records were removed. The remaining 555 records were screened by title and abstract, resulting in the exclusion of 501 records that did not meet the inclusion criteria. A total of 54 reports were then sought for retrieval, all of which were successfully obtained and assessed for eligibility. After full text review, 30 reports were excluded because they corresponded to publication types outside the scope of the study, including 23 systematic reviews, 4 conference papers, and 3 book chapters. Ultimately, 24 studies were included in the final review.

The entire selection process is presented in Figure 1 through a PRISMA flow diagram.

2.5. Data Extraction and Analysis

Data extraction was conducted systematically using a structured review matrix developed for this study. For each included article, the following information was recorded: author, year of publication, country, educational stage, methodological approach, and principal focus of analysis. In addition, the studies were examined in relation to the dimensions of the teacher technological profile addressed, the conceptual frameworks used, and the types of teacher digital divide identified.

The extracted data were organized in Microsoft Excel to facilitate descriptive analysis and comparison across studies. Frequencies and percentages were calculated in order to identify patterns related to publication year, methodological orientation, geographical distribution, framework adoption, and the predominance of different forms of teacher digital divide. This analytical procedure supported the synthesis of findings in line with the research questions guiding the review.

2.6. Quality Assessment

In order to strengthen the methodological rigor of the review, the quality of the included studies was assessed through a structured appraisal process. Given the diversity of methodological approaches represented in the final sample, the Mixed Methods Appraisal Tool was considered appropriate for evaluating qualitative, quantitative, and mixed methods studies within a single framework.

The quality assessment focused on the clarity of the research aim, the appropriateness of the study design, the adequacy of the sampling and data collection procedures, the coherence between methods and conclusions, and the transparency of the analytical process. This step was incorporated to provide a

more robust basis for interpreting the reviewed evidence and to contextualize the strength of the findings derived from the included studies. The quality appraisal did not lead to the exclusion of additional studies, but it supported a more critical reading of the evidence and contributed to the interpretive synthesis presented in the Results and Discussion sections. Overall, the appraisal suggested moderate methodological quality across the reviewed corpus.

3. Results

In the present systematic review, a total of 24 studies were analyzed, published between 2021 and 2025 and selected in accordance with the established criteria.

3.1. Studies Included in the Review

During this phase of the study, a systematic analysis of the selected literature was carried out. The research was conducted through a systematic literature review following the PRISMA methodology, based on a descriptive analysis of the included studies (see Table 1). Microsoft Excel was used for the processing and analysis of data, enabling the organization of information, the calculation of percentages and the production of graphical representations.

Table 1. Main characteristics of the studies included in the review

No.	Author	Year	Country	Educational stage	Methodology	Main focus
1	Alastor et al.	2024	Spain	Early Childhood and Primary Education	Quantitative	Teacher digital competence
2	Barba-Sánchez et al.	2022	Spain	Primary Education	Quantitative	ICT competence
3	Barragán-Moreno & Lozano-Galindo	2025	Colombia	Basic education	Quantitative	Digital inequality
4	González-Medina et al.	2024	Spain	Primary Education	Quantitative	Teacher digital competence
5	Gutiérrez-Castillo et al.	2023	Spain	Teacher education	Quantitative	Teacher digital competence
6	Hurtado-Mazeyra et al.	2025	Peru	Early Childhood Education	Quantitative	Digital competence gaps
7	Kim & Kwon	2023	South Korea	Primary Education	Mixed methods	Artificial intelligence competencies
8	Loureiro et al.	2024	Portugal	Primary Education	Quantitative	Digital competence
9	Massuh Villavicencio	2025	Ecuador	School education	Quantitative	Technology integration
10	Mellado-Moreno et al.	2023	Spain	Early Childhood Education	Mixed methods	Digital resources
11	Sánchez-Rivas et al.	2024	Spain	Primary Education	Quantitative	Programming and robotics
12	Tarango et al.	2021	Mexico	Basic education	Qualitative	Digital divide in teaching
13	Romero-Tena et al.	2025	Spain	Early Childhood Education	Quantitative	Digital competence
14	Urbina et al.	2022	Spain	Teacher education	Quantitative	Digital competence
15	Valdez & Mendoza	2024	Philippines	Preschool or Early Childhood Education	Quantitative	ICT competence
16	Masoumi & Bourbour	2024	Sweden	Early Childhood Education	Qualitative	Digital competence
17	Galindo-Domínguez et al.	2024	Spain	School education	Quantitative	Digital competence
18	Tomczyk & Majkut	2025	Poland	School education	Quantitative	Generative AI

19	Revuelta-Domínguez et al.	2022	Spain	Primary Education	Quantitative	Pedagogical use of technology
20	Yang et al.	2022	China	Pre service and in service teacher education	Quantitative	Digital competence perception
21	Yang & Hong	2023	China	Early Childhood Education	Qualitative	Educational technology divide
22	Li	2025	China	Primary Education	Quantitative	TPACK and digital divide
23	Pham-Viet et al.	2025	Vietnam	Primary Education	Quantitative	Technology use in teaching practice
24	Esteve et al.	2025	Spain	School education or teacher development	Quantitative	Digital competence assessment

3.2. Quality of the Included Studies

The quality appraisal of the included studies supported a more critical interpretation of the reviewed evidence. Overall, the studies showed acceptable methodological coherence, with clearly stated aims and generally appropriate alignment between research design, data collection procedures, and reported conclusions. The quantitative studies tended to provide structured and comparable evidence, although some offered limited contextual depth. The mixed methods and qualitative studies, while less numerous, contributed valuable interpretive insights into teachers' perceptions and practices. Overall, the appraisal suggested moderate methodological quality across the reviewed corpus. The quality assessment did not result in the exclusion of additional studies, but it helped contextualize the strength and scope of the evidence considered in the review.

3.3. State of Scientific Output over the Past Five Years

With regard to the temporal evolution of scientific output, Figure 2 illustrates the distribution of studies published annually between 2021 and 2025. The analysis reveals a clear upward trend in research on teachers' technological profiles and digital competence over the period under review, indicating growing scholarly interest in this field.

More specifically, the highest volume of publications was recorded in 2025 and 2024, with 8 studies (33.3%) and 7 studies (29.2%), respectively. This increase suggests that the topic has become an increasingly relevant line of inquiry within educational research, particularly in relation to ongoing digitalization processes, the incorporation of emerging technologies, and the need to strengthen teacher digital competence in Early Childhood and Primary Education.

By contrast, 2022 and 2023 showed a moderate and stable level of scientific output, with 4 studies published in each year (16.7%). This pattern may reflect an intermediate phase in which research began to consolidate around two main concerns: the assessment of teachers' digital competence levels and the analysis of the training, pedagogical, and contextual factors associated with its development.

In comparison, 2021 showed the lowest level of scientific output, with only 1 study (4.2%), which may be interpreted as the starting point of the period analyzed. The progressive increase observed from 2022 onwards may be associated with the post pandemic educational context, which intensified attention to the pedagogical integration of digital technologies, teacher professional development, and the reduction of the teacher digital divide.

Taken together, these findings indicate sustained growth in scientific production in recent years and confirm the increasing relevance of teacher digital competence as a prominent area of inquiry in contemporary educational research.

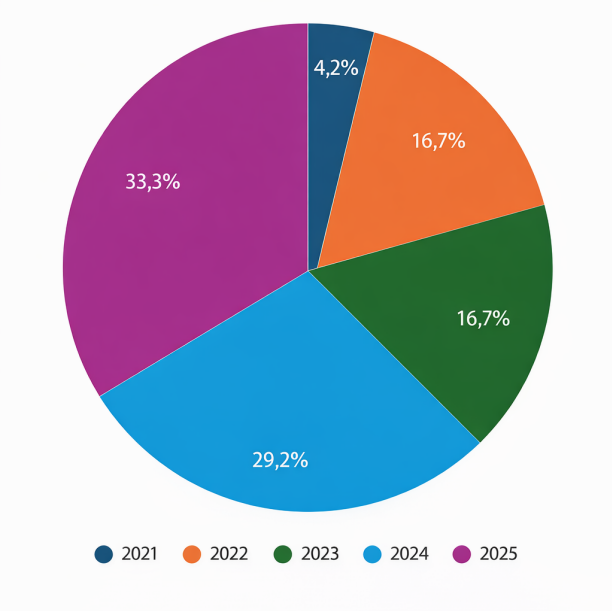


Figure 2. Distribution of studies by year

3.4. Methodology Type of the Studies

The analysis of the studies included in the review reveals a marked predominance of quantitative approaches in research on teachers' technological profiles and digital competence. Specifically, 75.0% of the analyzed studies adopted a quantitative methodology, whereas 12.5% employed mixed methods and 12.5% used qualitative approaches.

The predominance of quantitative designs is consistent with the broader trend observed in recent research on teacher digital competence, where questionnaires and standardized measurement scales are frequently used to assess competence levels and to examine relationships among sociodemographic, pedagogical, and contextual variables in relatively large teacher samples (Revuelta-Domínguez et al., 2022; Sánchez-Rivas et al., 2024; González-Medina et al., 2024). This methodological tendency reflects a strong interest in generating measurable and comparable evidence regarding the development of teacher digital competence across educational contexts.

By comparison, studies using mixed methods represent a smaller proportion of the reviewed literature. These studies combine statistical analysis with qualitative techniques, such as interviews or content analysis, in order to achieve a more nuanced understanding of teachers' perceptions and of the contextual factors influencing the development of digital competence (Mellado-Moreno et al., 2023; Kim & Kwon, 2023). Although less frequent, this approach provides a broader analytical perspective by integrating numerical trends with interpretive insights.

Qualitative studies, in turn, remain limited in the reviewed corpus. Their lower representation suggests that insufficient attention has been given to the in depth exploration of teachers' experiences, meanings, and everyday practices related to the pedagogical use of digital technologies. In this respect, the findings point to the need for future research that incorporates a stronger qualitative or mixed methodological orientation in order to complement the predominance of quantitative evidence and to enrich understanding of the phenomenon under study (Masoumi & Bourbour, 2024; Tarango et al., 2021).

3.5. Geographical Distribution of Studies

Regarding the geographical distribution of the studies included in the review, the results indicate a clear concentration of scientific output within the European context, with Spain accounting for the largest

number of analyzed publications (Table 1). Spain stands out from the other countries represented in the review and emerges as the main national context in research on teachers' technological profiles and digital competence, particularly in Early Childhood and Primary Education.

The prominence of the Spanish context may be interpreted in relation to several structural and normative factors. First, the progressive consolidation of European reference frameworks such as DigCompEdu, together with their adaptation to the national context through the Reference Framework for Teacher Digital Competence, appears to have stimulated the development of specific lines of research focused on both the assessment and improvement of teachers' digital competence. In this regard, several studies conducted in Spain emphasize the relevance of teacher training, the pedagogical integration of digital technologies, and the need to reduce inequalities associated with the digital divide in educational settings (Revuelta-Domínguez et al., 2022; González-Medina et al., 2024; Sánchez-Rivas et al., 2024).

In addition to Spain, contributions were identified from other European countries, including Portugal, Sweden, and Poland, although their representation in the reviewed literature is more limited. Even so, studies conducted in these contexts reflect concerns that are also central within the broader European landscape, particularly those related to initial and continuing teacher education, the pedagogical use of digital technologies, and the development of professional competences aligned with contemporary educational demands (Loureiro et al., 2024; Masoumi & Bourbour, 2024; Tomczyk & Majkut, 2025).

This pattern suggests a shared European interest in strengthening teachers' technological profiles, although with different levels of scientific output depending on each country's educational priorities, regulatory frameworks, and teacher education policies.

From a broader perspective, Figure 4 presents the distribution of studies by continent and shows that Europe accounts for the highest proportion of publications (45.8%), followed by the Americas (33.3%) and Asia (20.8%). These findings confirm Europe's leading position in research on teacher digital competence, while also indicating the increasing relevance of this field in other geographical contexts.

In the Asian context, the presence of studies conducted mainly in China and South Korea reflects growing interest in teacher digital competence within educational systems characterized by rapid technological transformation and the incorporation of emerging technologies into teaching and learning processes (Yang et al., 2023; Li, 2025). These studies tend to focus on teachers' perceptions, the pedagogical use of technology, and the integration of frameworks such as TPACK in highly digitalized educational environments.

Studies from the American continent, particularly from countries such as Peru, Mexico, and Ecuador, reveal significant concern regarding inequalities associated with the teacher digital divide, both in relation to access and to the training and pedagogical use of digital technologies. In these contexts, the literature highlights the structural, institutional, and socioeconomic conditions that shape the development of teachers' digital competence, as well as the need to design contextualized training strategies (Tarango et al., 2021; Hurtado-Mazeyra et al., 2025; Valdez & Mendoza, 2024).

Despite the geographical diversity identified, the results also reveal an uneven distribution of scientific output, with a marked concentration in certain countries and more limited representation in others. This asymmetry, already noted in previous research, may be associated with normative, institutional, and training related factors that influence both the development of educational research and the implementation of policies aimed at strengthening teacher digital competence (Masoumi & Bourbour, 2024).

Taken together, these findings confirm the international scope of interest in teachers' technological profiles and digital competence, while also highlighting the need to expand research in less represented contexts. Greater geographical diversity would contribute to a broader, more contextualized, and more equitable understanding of teacher digital competence in the educational field.

Within this context of geographical diversity and uneven scientific production, it becomes necessary to examine not only where research is being conducted, but also which dimensions of the teacher technological profile are receiving the greatest attention and how different forms of the digital divide are represented in the reviewed literature. The following sections therefore address research questions Q4 and Q5, focusing respectively on the dimensions of the teacher technological profile most frequently examined in recent scientific literature and on the main types of teacher digital divide, namely training related, access related, and use related, identified in the selected studies.

3.6. Dimensions of the Teacher Technological Profile in the Scientific Literature

The analysis of the studies included in the review indicates that recent scientific literature approaches teachers' technological profiles predominantly from a competence based perspective centred on teacher digital competence. This perspective is mainly supported by integrative reference frameworks such as DigCompEdu (Redecker, 2017) and the TPACK model (Mishra and Koehler, 2006), both of which have been widely adopted in educational research. In this regard, Figure 3 shows that a substantial proportion of the analysed studies, 41%, explicitly refer to one or both of these frameworks, underscoring their strong presence and consolidation as dominant theoretical references in the study of teachers' technological profiles.

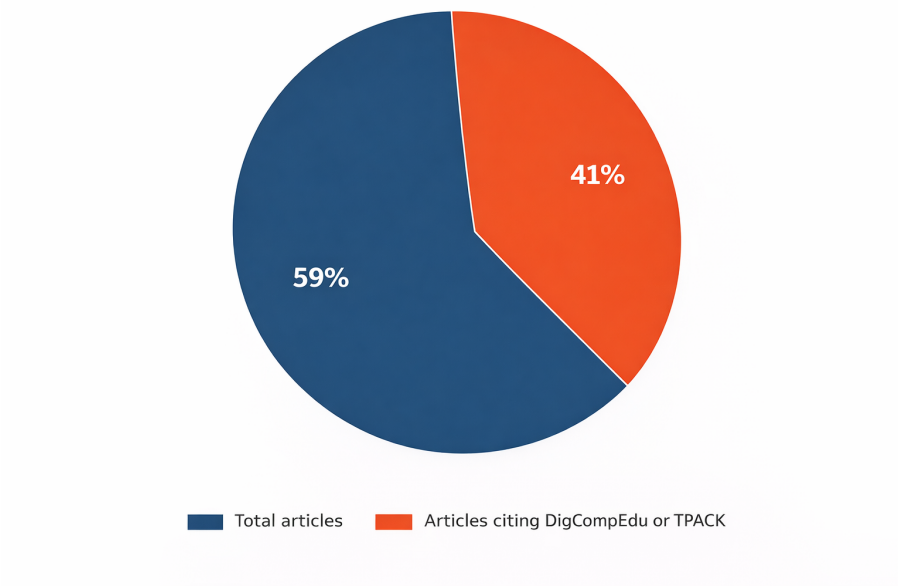


Figure 3. Presence of the DigCompEdu and TPACK frameworks in the analysed studies

These frameworks make it possible to identify the core dimensions that shape teachers' technological profiles, as well as the areas that have received greater or lesser attention in the scientific literature. Within the DigCompEdu framework (Figure 4), teacher digital competence is organised into six interrelated areas, ranging from the pedagogical integration of technology to learner empowerment.

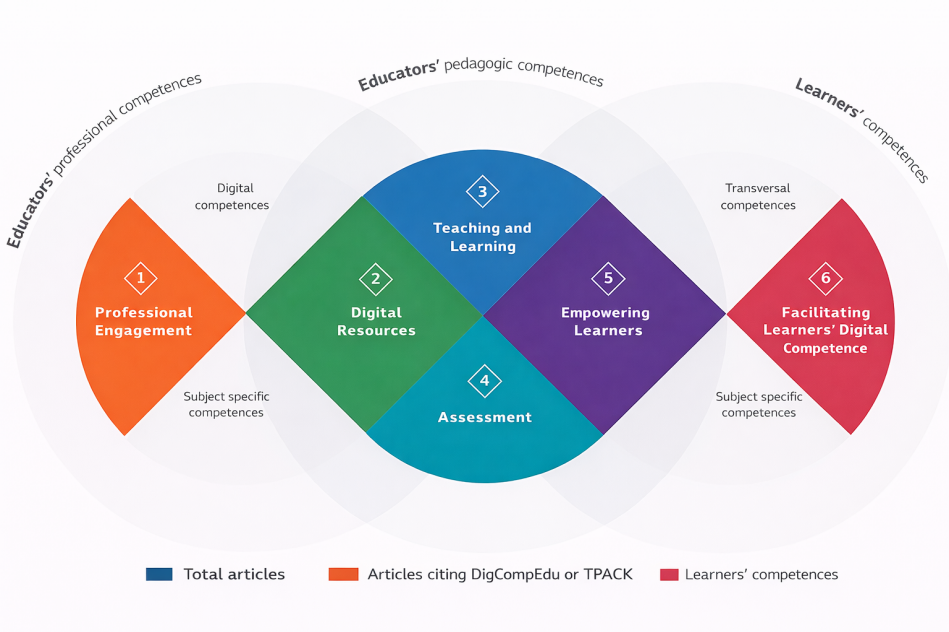


Figure 4. Digital competence framework for educators (adapted from Redecker, 2017)

In a complementary manner, the TPACK model emphasises the need to integrate technological, pedagogical, and content knowledge in a balanced way in order to ensure the effective educational use of digital technologies. Both frameworks converge in identifying digital pedagogy as a central component of the teacher technological profile.

In line with these models, digital pedagogy emerges as one of the most frequently addressed dimensions in the reviewed literature. This dimension refers to teachers' ability to design and implement teaching and learning processes mediated by digital technologies in alignment with curricular objectives and students' characteristics. Within the DigCompEdu framework, this dimension corresponds to the Teaching and Learning area. However, several studies indicate that significant challenges persist in this domain, particularly in the early educational stages. In this regard, Romero-Tena et al. (2025) note that Early Childhood Education teachers encounter greater difficulties in deciding how and for what purposes digital technologies should be used in the classroom, while Hurtado-Mazeyra et al. (2025) identify low levels of competence in areas related to supporting technology mediated learning and fostering pupils' digital competence.

Another dimension widely addressed in the literature concerns digital resources and content creation, including both the selection and adaptation of materials and the production of original resources. Mellado (2023) highlights that, although teachers recognise the pedagogical potential of digital resources, their use does not always lead to substantial methodological change, as traditional practices are often maintained. Similarly, Sánchez (2024) identifies shortcomings in competences related to programming, educational robotics, and digital content creation, which limit more advanced forms of pedagogical integration.

In addition, information and data management, together with the critical and ethical use of technology, constitutes a recurring dimension, particularly in studies focusing on emerging technologies. Galindo (2024) points out that higher levels of competence in this area are associated with more favourable attitudes towards the educational integration of artificial intelligence. In the same vein, Kim (2023) underscores the relevance of technological and pedagogical knowledge for the development of competences related to data literacy and ethical reflection on the use of artificial intelligence in educational contexts.

By contrast, the dimension associated with technology mediated assessment and feedback appears less frequently in the reviewed literature. Studies such as those by Esteve (2025) and Urbina (2022) indicate that teachers tend to demonstrate greater proficiency in the instrumental use of digital tools than in their application to the design of formative, personalised assessment processes oriented towards the development of pupils' digital competence.

Overall, the findings suggest that recent scientific literature has focused primarily on dimensions related to the pedagogical integration of technology, the use and creation of digital resources, and digital pedagogy. Other dimensions, such as learner empowerment, advanced digital assessment, and technological ethics, have received more limited attention, although their presence appears to be increasing in more recent studies.

3.7. Types of Teacher Digital Divide Identified in the Analysed Studies

The studies included in the present review indicate that the teacher digital divide constitutes a complex and multidimensional phenomenon that is closely associated with the development of teachers' digital competence. As illustrated in Figure 5, these inequalities are not confined to access to technology, but are manifested more prominently in the areas of training and the pedagogical use of digital resources. In this context, the literature consistently suggests that the mere availability of technological resources does not, in itself, ensure effective educational integration. Rather, such integration depends to a large extent on teachers' preparation and on their ability to use technology within a clear and pedagogically grounded framework.

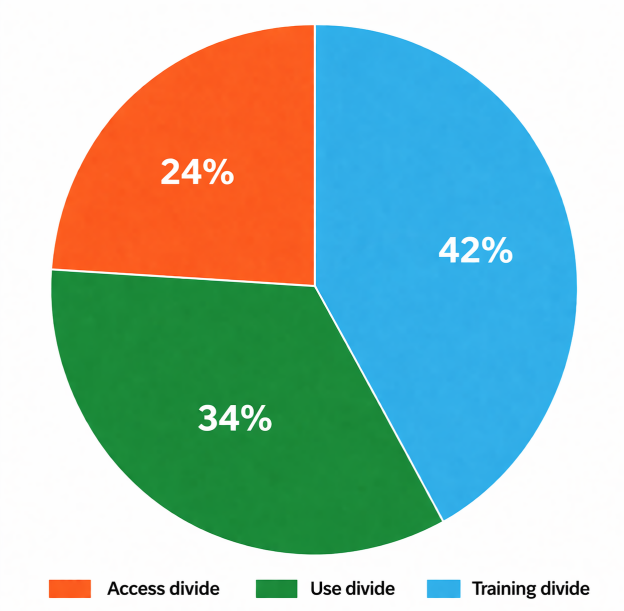


Figure 5. Predominance of types of teacher digital divide in the reviewed research

Specifically, the training related divide emerges as the most frequently identified form of teacher digital divide in the analysed studies, appearing in 42% of the reviewed documents. The literature points to significant shortcomings in both initial and continuing teacher education in relation to digital competence. Several studies identify the absence of systematic training pathways adapted to different levels of competence as one of the main barriers to the effective pedagogical integration of digital technologies

(Tarango, 2021; Gutiérrez, 2023). This issue is particularly evident in research focused on initial teacher education, which stresses the need to coherently integrate technological, pedagogical, and contextual components into the preparation of future teachers (Alastor, 2024; Pham, 2025).

The use related divide represents the second most frequent type, being identified in 34% of the analysed studies. This form of divide becomes evident when teachers, despite having access to technological resources, are unable to integrate them into their teaching practice in a didactically meaningful way. Numerous studies indicate that the use of digital technologies often remains at an instrumental or traditional level, without leading to substantial methodological transformation (Mellado, 2023; Yang et al., 2023). In addition, recent research shows that the incorporation of emerging technologies, such as artificial intelligence, remains limited and depends to a great extent on teachers' level of digital competence (Tomczyk, 2025).

Finally, the access related divide appears less frequently in the reviewed literature, being identified in 24% of the analysed documents. This form of inequality is mainly associated with contextual and territorial factors, such as the availability of devices, connectivity, and access to professional development opportunities. Some studies indicate that these inequalities are particularly acute in rural or socioeconomically disadvantaged settings, where material conditions restrict equitable access to technological resources (Li, 2025; Hurtado-Mazeyra, 2025; Barragán, 2025).

Taken together, these results indicate that the teacher digital divide described in recent scientific literature is concentrated primarily in the domains of training and use, whereas the access related divide, although still present, occupies a secondary position. These findings reinforce the need to address the development of teachers' technological profiles from a holistic perspective that combines robust training, institutional support, and pedagogical reflection aimed at improving technology mediated educational practices.

4. Discussion and Conclusions

The present systematic review aimed to provide a rigorous analysis of recent scientific literature on teachers' technological profiles and the teacher digital divide in the educational field, with particular attention to Early Childhood and Primary Education. Based on the analysis of the 24 selected studies and in line with the five research questions formulated (Q1 to Q5), this section discusses the principal findings in relation to previous research and presents the main conclusions derived from the review.

Regarding the state of scientific output over the past five years (Q1), the findings reveal a progressive and sustained increase in the number of publications, with a particularly marked rise from 2022 onwards and a peak in 2024 and 2025. This temporal pattern is consistent with previous research highlighting the impact of the post pandemic context on the acceleration of educational digitalisation and on the need to redefine teachers' professional roles within technology mediated environments (Barba-Sánchez et al., 2022; Area-Moreira, 2023). From this perspective, the increase in scientific output may be interpreted as an academic response to the challenges generated by the intensified incorporation of digital and emerging technologies into teaching and learning processes, especially at the early educational stages. At the same time, this growth suggests the progressive consolidation of teacher digital competence as a priority field of inquiry within contemporary educational research.

With respect to the predominant methodological approach in the analysed studies (Q2), the results show a clear predominance of quantitative designs, followed at a considerable distance by mixed and qualitative approaches. This methodological pattern is consistent with the broader literature, which has documented the widespread use of questionnaires, standardised scales, and statistical models to assess teacher digital competence and to examine its relationship with sociodemographic, training related, and

contextual variables (Revuelta-Domínguez et al., 2022; González-Medina et al., 2024; Sánchez-Rivas et al., 2024). However, the limited presence of qualitative research constrains a deeper understanding of teaching practices, professional beliefs, and pedagogical decision making processes. In this regard, the findings point to the need for future studies incorporating more interpretive or mixed methodological designs, particularly in Early Childhood Education, where the pedagogical use of technology is strongly shaped by contextual and developmental factors.

Concerning the geographical distribution of scientific output (Q3), the results indicate a marked concentration of studies within the European context, particularly in Spain. This prominence may be explained by the strong implementation of European reference frameworks such as DigCompEdu and their adaptation to the national context through the Reference Framework for Teacher Digital Competence, which has fostered the development of research focused on the assessment, diagnosis, and improvement of teachers' digital competence (INTEF, 2022; Revuelta-Domínguez et al., 2022). At the same time, the presence of studies from Asia and Latin America confirms the international scope of interest in teacher digital competence, while also revealing an uneven geographical distribution of scientific production across regions (Masoumi & Bourbour, 2024). This imbalance suggests that current knowledge has been generated mainly in specific policy and research environments, which may limit the broader transferability of findings to other educational systems.

In relation to the dimensions of the teacher technological profile most frequently addressed in the literature (Q4), the analysed studies consistently conceptualise teacher digital competence as a complex and multidimensional professional competence, examined predominantly through integrative frameworks such as DigCompEdu and the TPACK model (Redecker, 2017; Mishra & Koehler, 2006). The reviewed literature focuses primarily on dimensions associated with the pedagogical integration of technology, the use and creation of digital resources, communication and collaboration in digital environments, and initial and continuing teacher education. Nevertheless, the findings also indicate that, despite widespread recognition of the educational potential of digital technologies, significant difficulties persist in their didactically meaningful integration, particularly in Early Childhood and Primary Education (Romero-Tena et al., 2025; Hurtado-Mazeyra et al., 2025). In addition, dimensions such as advanced digital assessment, learner empowerment, and ethical reflection on the use of emerging technologies remain less developed, although they appear to be receiving increasing attention in more recent studies related to artificial intelligence (Galindo-Domínguez et al., 2024; Tomczyk & Majkut, 2025). Taken together, these findings suggest that the literature remains more strongly oriented towards the pedagogical and instrumental dimensions of technology integration than towards its critical, ethical, and transformative implications.

As regards the types of teacher digital divide identified in the analysed studies (Q5), the results confirm that the principal inequalities are concentrated in the domains of training and the pedagogical use of technology rather than in access to resources. This finding is consistent with previous research showing that the availability of devices and connectivity does not by itself ensure effective educational integration, which depends fundamentally on teachers' level of digital competence and on the quality of the training opportunities available to them (Tarango et al., 2021; Gutiérrez-Castillo et al., 2023). In this regard, the training related divide emerges as a central issue, particularly in diverse educational contexts and at the early educational stages, where insufficient specific preparation conditions the pedagogical use of digital technologies and limits their transformative potential. Likewise, the prominence of the use related divide indicates that access alone is insufficient when teachers remain confined to instrumental, routine, or methodologically traditional uses of digital technologies.

Taken together, the findings of this review show that teachers' technological profiles and the teacher digital divide have become well established and expanding lines of inquiry within the educational field. More specifically, the review confirms the consolidation of teacher digital competence as a priority

area of research in contemporary educational scholarship, especially from 2022 onwards, when a sustained increase in publications associated with post pandemic digitalisation processes can be observed. This growth reflects not only increased scientific production, but also a broader reconfiguration of academic debate concerning teachers' roles in technology mediated educational settings.

The review also positions teacher digital competence as a structural component of the professional profile. Rather than being understood as a purely technical ability linked to the use of digital tools, it should be regarded as a complex competence that shapes the pedagogical integration of technology, didactic planning, classroom decision making, and the capacity to respond to educational environments characterised by rapid technological change. In this sense, teacher digital competence operates not only as a functional skill set, but also as a professional condition for educational quality in digitally mediated contexts.

Similarly, the findings reinforce the view that the main manifestations of the teacher digital divide are concentrated in the dimensions of training and use. In other words, inequality lies not primarily in the mere availability of technological resources, but in teachers' preparation and in their ability to integrate technology in a pedagogically meaningful manner. This interpretation broadens the understanding of digital inequality by shifting the focus from material access to professional capability and pedagogical enactment.

From both theoretical and applied perspectives, these conclusions are especially relevant in Early Childhood and Primary Education, where teachers play a central mediating role in students' educational engagement with technology. Strengthening teachers' technological profiles at these stages requires ensuring that digital integration is guided by sound pedagogical and didactic criteria and does not remain restricted to instrumental or superficial uses. In this regard, the review supports the need for coherent initial and continuing teacher education, stronger institutional support, and a broader conception of digital competence as a multidimensional professional construct linked to equity, quality, and educational transformation.

5. Implications

The present systematic review provides relevant implications for strengthening teachers' technological profiles and reducing the teacher digital divide within the broader context of educational digital transformation.

First, the findings underscore the need to reinforce initial teacher education by integrating teacher digital competence as a structural component of the professional profile and by ensuring a coherent articulation of technological, pedagogical, and disciplinary knowledge, particularly in Early Childhood and Primary Education. This implies that teacher preparation programmes should move beyond purely instrumental approaches and promote a more comprehensive understanding of digital competence as an essential dimension of professional practice.

Second, continuing professional development should be conceived as an ongoing process that enables teachers to update and expand their competences in response to the rapid evolution of digital technologies. This requires the promotion of progressive professional learning pathways, together with sustained opportunities for pedagogical reflection, collaborative learning, and practice based development. In this sense, professional development should not be treated as an isolated or occasional intervention, but as a continuous dimension of teachers' professional growth.

Furthermore, the results indicate that digital transformation policies should not be limited to the provision of technological infrastructure alone, but should give priority to teacher professional development and to the pedagogically meaningful use of technology in educational practice. The review suggests that effective digital transformation depends not only on access to devices and connectivity, but

also on the capacity of teachers to integrate these resources in ways that are educationally relevant and contextually appropriate.

Finally, the effective integration of technology also depends on organisational and cultural conditions within schools, including pedagogical leadership, institutional culture, and support structures. In this regard, strengthening teacher digital competence represents a key condition for advancing towards a more equitable educational system that is better aligned with the demands of digital society. More broadly, these implications point to the need for a systemic approach in which teacher education, school support, and educational policy operate in a coordinated manner to reduce digital inequalities and improve the quality of digitally mediated teaching and learning.

6. Limitations

Despite the contributions of this study, several limitations related to the adopted methodological design should be acknowledged in order to appropriately contextualise the findings. Recognising these limitations does not undermine the validity of the review, but rather situates its conclusions within the analytical framework in which they were produced.

First, the review was limited to two internationally recognised databases, Scopus and Web of Science. Although this decision ensures scientific quality and editorial rigour in the selection of studies, it may also have resulted in the exclusion of relevant research published in other specialised databases, regional repositories, or non indexed literature. Consequently, the analysed corpus reflects primarily consolidated scientific production and may not fully capture the breadth of scholarship available on the topic.

Second, the temporal scope of the review, restricted to the period from 2021 to 2025, provides an updated perspective on the phenomenon, particularly in a context shaped by the acceleration of educational digitalisation in the post pandemic period. However, this delimitation limits the possibility of examining the longer term evolution of teachers' technological profiles and the teacher digital divide, as well as potential continuities or shifts preceding this period.

In addition, the geographical distribution of the included studies reveals certain asymmetries, with a marked concentration in specific national contexts. This may reduce the generalisability of the findings to educational systems operating under different normative, institutional, and cultural conditions. Future research could address this limitation by expanding the geographical scope of analysis and incorporating a stronger comparative perspective across diverse educational settings.

From a methodological perspective, the reviewed literature is characterised by a predominance of quantitative approaches. Although such studies provide valuable diagnostic overviews of teacher digital competence, the limited presence of qualitative and mixed methods research constrains the in depth exploration of teaching practices, professional meanings, and technology integration processes in specific educational contexts. As a result, some dimensions of the phenomenon may remain insufficiently captured in the current evidence base.

Finally, as with any systematic review, the present study is fundamentally descriptive and analytical in nature. Although it allows for the identification of major trends, recurring themes, and dominant conceptual frameworks in the scientific literature, it does not permit the establishment of causal relationships or the direct evaluation of the effects of specific training interventions. Future empirical and longitudinal studies could therefore make an important contribution to advancing understanding of teacher digital competence development and of the processes involved in reducing the digital divide across different educational contexts.

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Dynamic Balance and Postural Control Adaptations After Integrated Proprioceptive Training in Adolescent Latin American Dancers

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Abstract

Background: Adolescent Latin American dancers require high levels of dynamic balance, postural control, and neuromotor stability to meet the technical demands of the discipline. During adolescence, these capacities may be influenced by maturational changes affecting coordination, movement regulation, and functional symmetry.

Objective: This study aimed to evaluate the effects of an integrated proprioceptive training program on dynamic balance, anticipatory postural control, and post landing stability in female adolescent Latin American dancers. Methods: A total of 124 female dancers aged 13 to 15 years were allocated to an experimental group, n = 62, or a control group, n = 62. Over 10 weeks, the experimental group performed an integrated proprioceptive training program twice weekly for 25 to 30 minutes in addition to regular technical practice, whereas the control group continued standard dance training only. Outcomes were assessed at baseline and post intervention using the Y Balance Test, Pediatric Reach Test, and Single Leg Landing Stability Test. Repeated measures ANOVA was used to examine group by time interaction effects.

Results: Significant group by time effects favored the experimental group for all selected outcomes. The largest effects were observed for Y Balance Test composite scores of the right limb, $\eta p^2 = 0.263$, and left limb, $\eta p^2 = 0.175$. The intervention was also associated with reduced inter limb asymmetry, improved Pediatric Reach Test performance in the anterior and lateral conditions, and lower time to stabilization in the Single Leg Landing Stability Test. These findings indicate enhanced dynamic balance, anticipatory postural control, and post landing neuromotor stability after the intervention.

Conclusions: A 10-week integrated proprioceptive training program produced significant functional improvements in female adolescent Latin American dancers. The findings support the inclusion of structured proprioceptive exercises in youth dance training programs to optimize balance, postural regulation, and functional stability.

Keywords: proprioceptive training; dynamic balance; postural control; neuromotor stability; adolescent dancers; Latin American dance.

1. Introduction

Dynamic balance and postural control are fundamental components of movement efficiency, technical execution quality, and injury prevention in both sport and performance settings (Pollock et al., 2000; Hrysomallis, 2011). In dance, these capacities become particularly important because motor performance requires continuous postural adjustments, rapid weight transfers, single leg control, and stabilization under conditions of high coordinative demand. In Latin American dance, frequent changes of direction, rotations, single leg support, rapid rhythmic sequences, and continuous postural transitions impose especially high neuromotor demands (Bojanowska et al., 2021; Kılıç & Nalbant, 2022; Liu et al., 2022; Chilom et al., 2024). Recent evidence has shown that Latin dancers may demonstrate superior gait symmetry and balance ability compared with non dancers, suggesting that this discipline strongly engages the sensorimotor and neuromuscular mechanisms involved in postural regulation (Liu et al., 2022). Additional findings also indicate that Latin dancers tend to show better balance, flexibility, and proprioceptive performance than sedentary controls, further supporting the functional relevance of targeted balance related training in this population (Erdaş et al., 2025).

During adolescence, these demands interact with maturational processes that may temporarily affect intersegmental coordination, functional symmetry, and movement control. For this reason, adolescence represents a particularly sensitive period for the optimization of postural control and dynamic stability (Steinberg et al., 2017). This issue is especially relevant in dance, where technical repetition, high training loads, and rapid physical development may increase vulnerability to movement deficits and overuse problems. Recent work on adolescent dancers has emphasized the need for structured and developmentally appropriate screening models capable of identifying deficits in balance, movement quality, alignment, and functional control at an early stage (Schultz et al., 2024). In parallel, dance medicine literature has continued to highlight the importance of injury prevention strategies based on conditioning and functional preparation in young dancers exposed to repetitive coordinative and postural demands (Schultz et al., 2024).

Previous literature suggests that specific neuromuscular and proprioceptive training programs may positively influence balance control, movement function, and stability during dynamic tasks, both in sport specific settings and in young athletic populations (Tekin et al., 2018; Kalaycioglu et al., 2020). More recent evidence has strengthened this perspective in dance related contexts. For example, Zhang et al. (2021) reported that a 10-week neuromuscular training program improved postural control in elite youth ballroom dancers, supporting the integration of structured sensorimotor interventions into dance training. In addition, a recent systematic review concluded that neuromuscular based training protocols are among the most promising strategies for improving dancers' balance, especially when programs extend for at least four weeks and are performed two to three times per week (Senger et al., 2024). Complementary evidence from pediatric populations has also shown that dance based interventions can improve postural balance under challenging sensory conditions, suggesting that structured movement training may stimulate adaptive changes in sensorimotor control during development (Jouira et al., 2024).

Recent studies also indicate that postural control in dancers is multifactorial and should not be interpreted solely as the result of dance exposure. Professional dance training appears to affect postural sway characteristics, while postural regulation in dancers may also vary under different visual conditions, suggesting a relevant interaction among proprioceptive, vestibular, and visual inputs in movement stabilization (Błaszczyk & Fredyk, 2024; Hong et al., 2025). These findings reinforce the idea that training approaches should not focus only on general balance ability, but also on anticipatory control, stabilization under dynamic conditions, and lower limb symmetry, all of which are directly relevant to Latin American dance technique. Functional tests such as the Y Balance Test are now widely used to assess dynamic

stability and inter limb asymmetries, particularly when combined with complementary measures of postural control and functional stability (Plisky et al., 2009; Plisky et al., 2021).

Despite increasing interest in postural control and balance related interventions in dance, the available evidence remains limited in several important respects. First, relatively few experimental studies have specifically examined adolescent Latin American dancers, although this population is exposed to high coordinative and postural demands during a sensitive stage of neuromotor development. Second, most previous studies have focused on isolated indicators of balance or on broader dance populations, with less attention given to multidimensional functional assessment strategies integrating dynamic balance, anticipatory postural control, and post landing stability within the same design (Zhang et al., 2021; Senger et al., 2024). Third, the effects of integrated proprioceptive training protocols in this specific context remain insufficiently documented. Moreover, recent screening research in adolescent dancers has shown that movement quality and balance related constructs remain central for early identification of functional deficits, but the evidence base is still insufficient for discipline specific recommendations in Latin dance populations (Schultz et al., 2024). Addressing these gaps may contribute to a more precise understanding of the role of targeted neuromotor interventions in youth dance training.

In light of these considerations, the present study aimed to evaluate the effects of an integrated proprioceptive training program on dynamic balance and neuromotor control in adolescent dancers practicing Latin American dance. To this end, three functional indicators were selected to examine dimensions considered particularly relevant to the discipline, namely dynamic balance, anticipatory postural control, and post landing functional stability. It was hypothesized that the experimental group would show more favorable adaptations than the control group in the main parameters of balance, postural control, and functional stability.

2. Materials and Methods

2.1. Study design

This study adopted a controlled quasi experimental pretest to posttest design with two parallel groups assessed over a 10 week intervention period. The aim was to examine the effects of an integrated proprioceptive training program on dynamic balance and postural control in adolescent Latin American dancers. Participants were allocated to either an experimental group or a control group using a balanced group assignment procedure designed to achieve comparable group size and similar baseline characteristics. All outcome measures were collected at baseline, T0, and after completion of the intervention period, T1. During the study period, the experimental group completed an additional proprioceptive training protocol in conjunction with regular dance practice, whereas the control group continued standard technical training only.

2.2. Participants

A total of 124 female adolescent dancers aged 13 to 15 years were included in the study. All participants were regularly engaged in Latin American dance practice and were assigned to an experimental group, EG, n = 62, or a control group, CG, n = 62. Both groups were assessed at baseline and after the 10 week intervention period.

Baseline anthropometric characteristics were recorded before the intervention. In the experimental group, mean age was 14.5 ± 0.6 years, mean height was 156.17 ± 8.09 cm, mean body mass was 50.50 ± 8.55 kg, and mean body mass index was 20.61 ± 2.67 kg/m^2. In the control group, mean age was 14.7 ± 0.7 years, mean height was 156.50 ± 6.19 cm, mean body mass was 49.75 ± 7.48 kg, and mean body mass index was 20.23 ± 2.18 kg/m^2.

Table 1. Baseline anthropometric characteristics of the participants (T0).

Variable	Experimental Group (EG, n = 62)	Control Group (CG, n = 62)
Age (years)	14.5 ± 0.6	14.7 ± 0.7
Height (cm)	156.17 ± 8.09	156.50 ± 6.19
Body Mass (kg)	50.50 ± 8.55	49.75 ± 7.48
BMI (kg/m^2)	20.61 ± 2.67	20.23 ± 2.18

Note. Data are presented as mean ± standard deviation. EG = experimental group; CG = control group; BMI = body mass index; T0 = baseline.

2.3. Eligibility Criteria

Participants were considered eligible if they met all of the following criteria: at least 2 years of continuous Latin American dance practice, regular attendance in organized training, absence of diagnosed neurological or vestibular disorders, absence of acute musculoskeletal injury at the time of testing, attendance of at least 80% of the scheduled sessions during the intervention period, and written informed consent provided by parents or legal guardians.

Participants were excluded if they presented missing outcome data, irregular participation during the intervention period, or any medical or functional condition likely to interfere with motor performance or compromise the validity of the assessments.

2.4. Training Intervention

The experimental group completed an integrated proprioceptive training program for 10 weeks, with a frequency of 2 sessions per week and a duration of 25 to 30 minutes per session, before regular technical dance training. The control group continued its usual technical training without the additional proprioceptive intervention.

The intervention was designed to target neuromotor functions directly relevant to the technical demands of Latin American dance, particularly dynamic balance, postural control, single leg stability, landing control, and movement regulation under coordinatively demanding conditions. The program included progressive tasks focused on balance on unstable surfaces, unilateral stance control, dynamic stabilization, postural adjustment, and landing mechanics. Training materials included unstable support devices such as balance pads, elastic resistance bands, and partner-based coordination tasks.

The intervention progressed from basic static balance and unilateral control tasks in the initial phase to more demanding dynamic stabilization, reduced visual feedback, and landing control exercises in the middle and final phases of the program. Progressive overload was achieved by increasing task complexity across the intervention period through controlled manipulation of surface instability, visual input, movement variability, and coordinative demand. This progression was intended to provide a structured sensorimotor stimulus while preserving the functional specificity of the training for adolescent dancers.

2.5. Outcome Measures

Three functional measures were selected to examine complementary dimensions of neuromotor performance.

2.5.1. Y Balance Test

The Y Balance Test, YBT, was used to assess dynamic balance and inter limb symmetry. Reach distance was recorded in the anterior, posteromedial, and posterolateral directions and normalized to lower limb length. For each limb, a composite score expressed as a percentage was calculated using the following equation:

$$[(\text{anterior} + \text{posteromedial} + \text{posterolateral}) / (3 \times \text{limb length})] \times 100$$

Three trials were performed for each direction and limb, and the best valid score was retained for analysis. Functional asymmetry was calculated as the signed difference between right and left composite scores, with values closer to zero indicating greater inter limb symmetry.

2.5.2. Pediatric Reach Test

The Pediatric Reach Test, PRT, was used to assess anticipatory postural control. The test was administered in three movement conditions, anterior reach, lateral reach to the right, and lateral reach to the left. Three trials were completed for each condition, and the best valid result, expressed in centimeters, was retained for analysis. Higher values indicated better anticipatory postural control.

2.5.3. Single Leg Landing Stability Test

The Single Leg Landing Stability Test, SLLST, was used to assess post landing stability during dynamic unilateral tasks. Post landing control was quantified through time to stabilization, TTS, derived from data recorded by a triaxial accelerometer positioned at the lumbar level, L4. Lower TTS values indicated better dynamic stabilization after landing. Multiple trials were performed for each limb, and the best valid result was used in the final analysis.

2.6. Testing Procedure

All assessments were conducted in a familiar indoor environment under standardized testing conditions. Participants performed all tests barefoot to ensure consistency between sessions. Before formal data collection, a familiarization session was provided to reduce possible learning effects and to improve procedural consistency across participants.

The same testing sequence was adopted at T0 and T1 for all participants: Y Balance Test, Pediatric Reach Test, and Single Leg Landing Stability Test. All measurements were administered in the same order and under the same procedural conditions at both time points in order to reduce measurement variability.

2.7. Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics, version 25.0, IBM Corp., Armonk, NY, USA. Descriptive data are presented as mean ± standard deviation. Prior to inferential testing, data distribution was examined for normality and the suitability of parametric analysis was confirmed. Repeated measures analysis of variance, ANOVA, was then performed for each dependent variable, with time, T0 versus T1, entered as the within subject factor and group, EG versus CG, entered as the between subject factor.

For each analysis, F values, p values, and partial eta squared, ηp^2, were reported as indicators of statistical significance and effect size. Statistical significance was set at $p < 0.05$ for all analyses.

2.8. Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from the parents or legal guardians of all participants before study inclusion. The study protocol received approval from the Ethics Committee of Pegaso Telematic University, approval code PROT/E 002466, on March 29, 2024.

3. Results

Baseline anthropometric characteristics, presented in Table 1, showed no relevant differences between groups at baseline. Following the 10-week intervention period, the experimental group demonstrated more favorable changes than the control group across the main indicators of dynamic balance, anticipatory postural control, and post landing stability. Repeated measures ANOVA revealed significant group × time interaction effects for all selected functional outcomes. The main statistical results are presented in Table 2, while graphical representations of the principal outcomes are shown in Figures 1 and 2.

Table 2. Effects of the intervention on the main functional outcomes: group × time ANOVA

Variable	F(1,122)	p	ηp^2	Interpretation
YBT Composite Right (%)	43.534	<0.001	0.263	Significant interaction
YBT Composite Left (%)	25.929	<0.001	0.175	Significant interaction
YBT Asymmetry (%)	4.858	0.038	0.038	Significant interaction
PRT Anterior (cm)	19.284	<0.001	0.136	Significant interaction
PRT Lateral Right (cm)	16.357	<0.001	0.118	Significant interaction
PRT Lateral Left (cm)	10.327	0.004	0.078	Significant interaction
SLLST Right (s)	6.190	0.021	0.048	Significant interaction
SLLST Left (s)	5.315	0.031	0.042	Significant interaction

Note. Only the outcomes selected for the present contribution are reported. YBT composite scores were normalized to limb length and expressed as percentages. Higher values indicate better performance for YBT and PRT, whereas lower values indicate better performance for SLLST. For YBT Asymmetry, values closer to zero indicate greater inter-limb symmetry.

Abbreviations. YBT = Y Balance Test; PRT = Pediatric Reach Test; SLLST = Single-Leg Landing Stability Test; ηp^2 = partial eta squared.

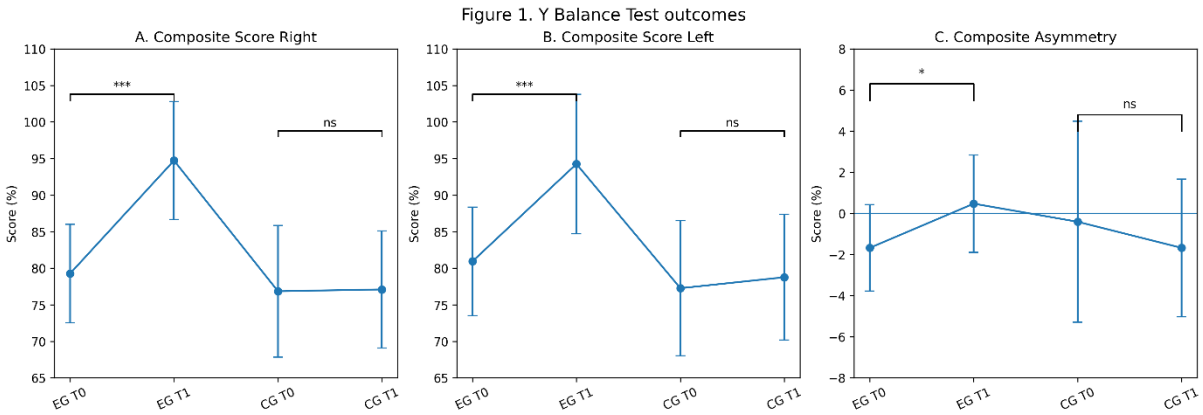


Figure 1. Mean values (± SD) of Y Balance Test outcomes in the experimental and control groups at baseline (T0) and post-intervention (T1). (A) YBT Composite Right (%), (B) YBT Composite Left (%), and (C) YBT

Asymmetry (%). YBT composite scores were normalized to limb length. Values of asymmetry closer to zero indicate greater inter-limb symmetry.

Figure 2. PRT and SLLST outcomes

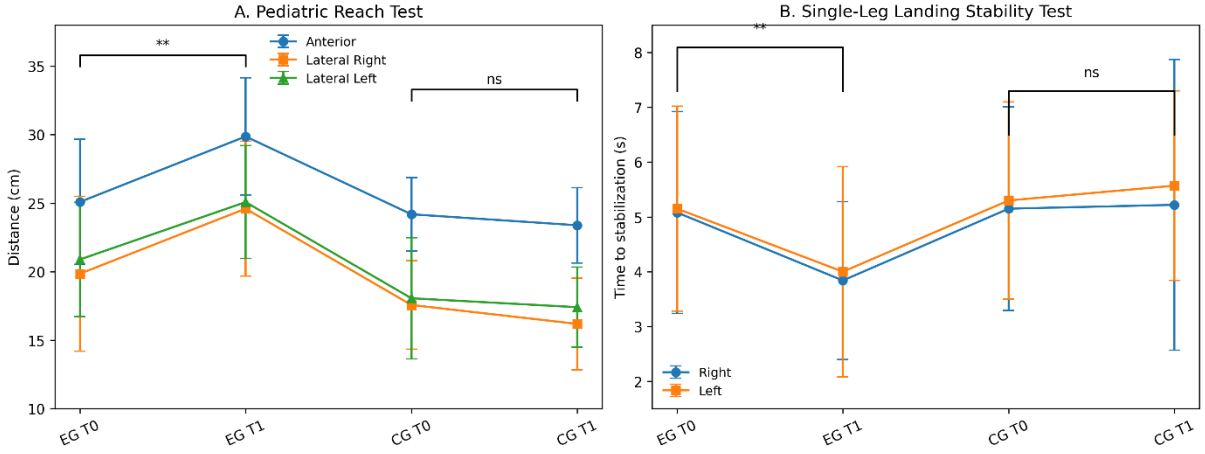


Figure 2. Mean values (± SD) of Pediatric Reach Test and Single-Leg Landing Stability Test outcomes in the experimental and control groups at baseline (T0) and post-intervention (T1). For the Pediatric Reach Test, Anterior (cm), Lateral Right (cm), and Lateral Left (cm) conditions are reported. For the Single-Leg Landing Stability Test, Right (s) and Left (s) values are shown.

3.1. Y Balance Test

Significant group × time interaction effects were observed for all Y Balance Test variables. For YBT Composite Right, the analysis showed a significant interaction, $F(1,122) = 43.534$, $p < 0.001$, $\eta p^2 = 0.263$. For YBT Composite Left, a significant interaction was also found, $F(1,122) = 25.929$, $p < 0.001$, $\eta p^2 = 0.175$. Functional asymmetry also showed a significant group × time interaction, $F(1,122) = 4.858$, $p = 0.038$, $\eta p^2 = 0.038$. As illustrated in Figure 1, the experimental group showed improved composite performance for both limbs together with asymmetry values closer to zero, whereas the control group showed only minor changes.

3.2. Pediatric Reach Test

For the Pediatric Reach Test, significant group × time interaction effects were observed in all testing conditions. In the anterior condition, the analysis revealed a significant interaction, $F(1,122) = 19.284$, $p < 0.001$, $\eta p^2 = 0.136$. Significant interaction effects were also found for lateral right, $F(1,122) = 16.357$, $p < 0.001$, $\eta p^2 = 0.118$, and lateral left, $F(1,122) = 10.327$, $p = 0.004$, $\eta p^2 = 0.078$. As shown in Figure 2, the experimental group demonstrated greater improvements than the control group across all Pediatric Reach Test conditions.

3.3. Single Leg Landing Stability Test

Significant group × time interaction effects were also identified for the Single Leg Landing Stability Test. For the right limb, the analysis showed a significant interaction, $F(1,122) = 6.190$, $p = 0.021$, $\eta p^2 = 0.048$. For the left limb, a significant interaction was also found, $F(1,122) = 5.315$, $p = 0.031$, $\eta p^2 = 0.042$. As shown in Figure 2, the experimental group presented lower time to stabilization values after the intervention, whereas the control group showed only limited variation over time.

3.4. Summary of Main Findings

Taken together, these findings indicate that the integrated proprioceptive training program produced significant improvements in dynamic balance, anticipatory postural control, and post landing stability in adolescent Latin American dancers. The largest effects were observed in Y Balance Test

composite performance, followed by the Pediatric Reach Test outcomes, whereas smaller but still significant effects were identified for YBT asymmetry and Single Leg Landing Stability Test values.

4. Discussion

The present study showed that an integrated proprioceptive training program produced significant improvements in dynamic balance, anticipatory postural control, and post landing stability in adolescent Latin American dancers. Overall, these findings support the initial hypothesis and indicate that the systematic inclusion of proprioceptive exercises may represent an effective strategy for improving neuromotor function in this population. This interpretation is consistent with recent evidence showing that structured neuromuscular training can improve postural control in youth ballroom dancers and that balance focused interventions are among the most effective approaches for enhancing dancers' balance performance across training settings (Zhang et al., 2021; Senger et al., 2024).

The most pronounced effects in the present study were observed in the Y Balance Test, in which the experimental group showed higher composite scores for both limbs together with reduced functional asymmetry. These findings are especially relevant in Latin American dance, where movement execution depends on repeated single leg support, rapid weight transfer, directional changes, and precise control during rotational and transitional actions. In this context, the observed increase in normalized reach performance may reflect better sensorimotor regulation and improved lower limb control during tasks that require stabilization within a reduced base of support. This interpretation is in line with recent studies reporting that Latin dance is associated with superior balance ability and more symmetrical movement behavior, as well as with recent evidence showing that limb symmetry remains an important functional issue in dancers when balance and hop based screening tests are used (Kılıç & Nalbant, 2022; Liu et al., 2022; Wiese et al., 2025).

The reduction in asymmetry observed in the experimental group may also have practical significance. In dance populations, inter limb asymmetry is not only a functional characteristic of repeated unilateral technical work, but may also be relevant for screening and injury risk management. Although the present study did not directly investigate injury incidence, the shift of asymmetry values toward zero suggests a more balanced bilateral motor profile after the intervention. This point deserves attention because recent screening-oriented studies in dancers have emphasized the importance of standardized functional assessment tools and movement competency evaluation for identifying deficits that may affect performance quality and potentially contribute to future musculoskeletal problems (Schultz et al., 2024; Callahan et al., 2024; Wiese et al., 2025).

Another relevant finding was the improvement in the Pediatric Reach Test. This result suggests better anticipatory postural control and may indicate more effective trunk and pelvic stabilization before movement execution. In technical terms, this is particularly important in Latin American dance, where body alignment and segmental coordination must be regulated continuously before and during rapid choreographic transitions. A plausible interpretation is that the proprioceptive protocol enhanced feed forward postural organization and improved the integration of sensory information required for preparatory stabilization. This explanation is consistent with recent literature showing that postural control in dancers depends on the interaction among proprioceptive, visual, and neuromuscular factors, rather than on dance exposure alone. For example, recent work has shown that postural sway characteristics in dancers are influenced by training related adaptations, while visual conditions can substantially modify postural control behavior in trained dancers (Błaszczyk & Fredyk, 2024; Hong et al., 2025).

The improvements found in the Single Leg Landing Stability Test are also noteworthy. The reduction in time to stabilization indicates more efficient post landing control, which is highly relevant in dance due to the frequent presence of jumps, stops, rapid transitions, and controlled landings. From a neuromotor

perspective, this outcome may reflect faster postural reorganization after impact and better regulation of lower limb stiffness and trunk control during unilateral stabilization. Although direct comparisons are limited because few studies have used the same outcome in adolescent Latin American dancers, the present findings are broadly consistent with recent intervention studies showing that balance oriented and combined training protocols can improve dynamic stability and lower extremity control in dancers. In particular, Yan et al. (2025) reported that a 12-week balance plus plyometric program improved dynamic balance and lower extremity stability related indicators in female college dancers, while Zhang et al. (2021) demonstrated significant postural control gains after 10 weeks of neuromuscular training in youth ballroom dancers.

Taken together, the present results reinforce the view that proprioceptive and neuromuscular conditioning should be considered a meaningful complement to technical dance practice, especially during adolescence. This developmental period is characterized by substantial changes in body proportions, coordination, and motor control, which may temporarily reduce movement efficiency and increase the need for targeted functional support. In this regard, recent work on adolescent dancers has underlined the value of pragmatic screening models that include balance, strength, mobility, and dance specific tests in order to establish baseline profiles and guide training decisions (Schultz et al., 2024). The current findings extend that perspective by suggesting that, beyond screening, a structured proprioceptive intervention may generate measurable functional gains in a population exposed to high coordinative and postural demands.

The present findings also fit well within the broader post 2020 literature on dance related adaptations in balance and postural regulation. Recent evidence has shown that different forms of dance-based training can improve postural stability and dynamic balance across different age groups, including older adults and non-clinical populations, although the magnitude and transferability of these effects depend on the specificity, duration, and progression of the intervention (Chen et al., 2024; Senger et al., 2024). In the present study, one strength lies in the fact that the training protocol was implemented in a population with clear sport specific demands and was evaluated through a functionally targeted battery that captured three complementary dimensions of neuromotor performance, namely dynamic balance, anticipatory control, and post landing stability.

From a practical perspective, the findings suggest that dance coaches and conditioning specialists may benefit from integrating short proprioceptive sessions into regular training schedules. The intervention used in this study was relatively time efficient, 2 sessions per week for 10 weeks, yet it produced significant gains in several functional outcomes. This is relevant because recent reviews have noted that many dance intervention studies vary substantially in quality and design, and that more reproducible protocols with validated balance outcomes are needed to support stronger training recommendations (Senger et al., 2024). The present study contributes to that need by providing controlled evidence in a discipline specific adolescent sample.

Several strengths of the study should be highlighted. These include the controlled design, the relatively large sample, the 10-week intervention period, and the use of functional measures closely aligned with the technical demands of Latin American dance. At the same time, some limitations should be acknowledged. First, the study included only female participants, which limits the generalizability of the results to male dancers or mixed cohorts. Second, no follow up assessment was conducted, so it remains unclear whether the observed gains were maintained over time. Third, although the selected test battery was functionally relevant, the study did not include more detailed biomechanical, kinetic, or electromyographic measures that could have provided deeper insight into the mechanisms underlying the observed adaptations. These limitations are important in light of recent work emphasizing the need for

more standardized and multidimensional approaches in dancer assessment and intervention research (Schultz et al., 2024; Callahan and Mangun, 2025; Senger et al., 2024).

Future studies should investigate similar protocols in more heterogeneous dance samples, include male participants, use longitudinal follow up designs, and examine whether improvements in balance and postural control transfer to technical performance and injury related outcomes. It would also be valuable to compare proprioceptive training alone with combined protocols that include plyometric, strength, or movement competency components, as recent work suggests that multimodal approaches may further enhance dynamic balance and lower extremity control in dancers (Yan et al., 2025).

5. Limitations of the Study

Several limitations should be acknowledged when interpreting the findings of the present study. First, the sample included only female adolescent dancers, which limits the generalizability of the results to male dancers or mixed dance populations. Second, no follow up assessment was conducted, so it remains unclear whether the observed improvements were maintained beyond the intervention period. Third, although the selected test battery was functionally relevant and coherent with the technical demands of Latin American dance, the study did not include more detailed biomechanical, kinetic, or electromyographic analyses that could have provided deeper insight into the mechanisms underlying the observed neuromotor adaptations. In addition, the intervention effects were examined through functional performance outcomes only, without direct assessment of transfer to dance specific technical performance or injury related indicators. Future studies should address these aspects in more heterogeneous samples and with longer term monitoring designs.

6. Conclusions

The present study showed that the integration of an additional proprioceptive training program into regular Latin American dance practice can produce significant improvements in dynamic balance, anticipatory postural control, and post landing neuromotor stability in adolescent dancers. The most relevant adaptations were reflected in higher Y Balance Test composite scores, reduced functional asymmetry, better Pediatric Reach Test performance, and lower time to stabilization in the Single Leg Landing Stability Test. Taken together, these findings indicate that targeted proprioceptive training may enhance functional components that are directly related to technical execution and movement control in this discipline.

From an applied perspective, the findings support the inclusion of structured and progressive proprioceptive exercises within youth dance training programs. Even a relatively brief intervention, implemented twice weekly over 10 weeks, was sufficient to induce measurable neuromotor benefits in a population exposed to high coordinative and postural demands. The combined use of the Y Balance Test, Pediatric Reach Test, and Single Leg Landing Stability Test also appears to represent a useful functional assessment approach for monitoring training related adaptations in adolescent dancers.

Overall, the study adds discipline specific evidence to the growing literature on neuromuscular and proprioceptive conditioning in dance and suggests that targeted sensorimotor interventions may be valuable not only for functional development, but also for optimizing movement quality during a sensitive stage of neuromotor maturation.

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Methodological Aspects of Selection and Initiation in Sport Dance for Children Aged 4–7 Years

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Abstract

Background: Sport dance is a complex activity that combines motor, rhythmic, technical, and expressive components, and its early practice may contribute to the development of fundamental psychomotor abilities in young children. The initiation stage is particularly important in children aged 4 to 7 years, as this period is characterized by rapid motor and cognitive development and increased receptivity to coordinated movement and rhythmic learning. A structured methodological approach is therefore necessary to ensure age-appropriate training and effective skill acquisition in beginner dancers.

Objective: The aim of the study was to examine the methodological aspects of selection and initiation in sport dance and to evaluate the effects of a structured initiation program on the development of rhythmic ability and motor-musical skills in children aged 4 to 7 years.

Results: The study was conducted over a period of three months on a sample of 10 beginner children, 5 boys and 5 girls, enrolled in a sport dance club in Bucharest. The intervention program included specific exercises for rhythmicity, musicality, body posture, and motor-musical skills in Slow Waltz and Cha-Cha-Cha. The results showed improvements in all assessed variables between initial and final testing. Mean scores increased from 2.00 to 3.10 for rhythmic ability, from 2.40 to 3.50 for Reverse Turn, from 2.00 to 3.50 for Waltz Structure, from 2.30 to 3.60 for Cross Basic Movement, and from 2.30 to 3.20 for Cha-Cha Structure. The Wilcoxon signed-rank test indicated statistically significant differences for all variables, with p values ranging from 0.0020 to 0.0156. In addition, the reduction in variability coefficients at final testing suggested improved group homogeneity and greater consistency of execution.

Conclusions: The findings indicate that a structured and developmentally adapted initiation program can support the improvement of rhythmic and motor-musical abilities in young beginner dancers. Early training based on progressive and age appropriate methodological means may provide an effective foundation for later technical development and continued participation in sport dance.

Keywords: sport dance, early childhood, rhythmic ability, motor skill development, initiation training, dance education.

1. Introduction

Sport dance represents a complex and highly structured form of physical activity situated at the intersection of sport performance, artistic expression, and motor learning. Beyond its competitive dimension, it functions as a multimodal educational context in which movement, rhythm, posture, coordination, and emotional expressiveness are integrated into a single performance task. As noted in the specialized literature, dance is not only a means of physical exercise, but also a form of nonverbal communication through which individuals express internal states, ideas, and affective experiences through the body (Vișan, 2005). In this sense, sport dance can be understood as both a performance discipline and a pedagogical environment that supports psychomotor, cognitive, and socio emotional development.

From a theoretical perspective, sport dance is defined by the execution of technically regulated movements in close relationship with musical structure, spatial organization, and expressive interpretation. Its dual nature, sportive and artistic, requires the coordinated development of physical, technical, cognitive, and affective capacities, which makes it a particularly demanding activity in the field of sport sciences (Basso et al., 2021; Fitch & Barnstaple, 2024). The specificity of sport dance lies in the continuous integration of balance, rhythm, intersegmental coordination, spatial temporal orientation, and movement precision, often under conditions of synchronization with a partner and with music. Recent research has further emphasized that dance based activities may support not only motor performance, but also broader developmental domains, including executive functioning, body awareness, and self regulation in children and adolescents (Tao et al., 2022; Liu et al., 2025).

Within the broader field of child development, early childhood is considered a particularly sensitive period for the acquisition of fundamental motor patterns and for the shaping of perceptual motor coordination. Children aged 4 to 7 years display high neural plasticity, strong exploratory tendencies, and a natural need for movement, all of which create favorable conditions for structured motor learning when instruction is developmentally appropriate. At this age, training content must be carefully adapted to the child's somatic, cognitive, and emotional characteristics, because the musculoskeletal system is still developing, attention span is limited, and learning is strongly mediated by play, imitation, repetition, and sensory feedback (Șchiopu, 1994; Malina et al., 2015; Payne & Isaacs, 2017). In line with this perspective, motor development literature has consistently shown that early interventions targeting coordination, rhythm, balance, and locomotor competence can positively influence later participation and performance in physical activity (Robinson et al., 2015; Logan et al., 2018; Zhang et al., 2024).

Dance is especially relevant in this developmental window because it combines rhythmic stimulation with purposeful movement and structured bodily control. Previous studies have shown that dance and movement programs can improve various dimensions of child development, including motor creativity, balance, coordination, physical fitness, and psychosocial functioning. A systematic review by Tao et al. (2022) concluded that dance is a feasible and beneficial alternative to traditional physical activity for children and adolescents, with effects extending across physiological and psychological domains. More recent evidence has strengthened this perspective. Thomaidou et al. (2021) found that an eight week creative dance and movement program significantly improved preschoolers' motor creativity, while also highlighting the methodological limitations that still characterize part of this literature. González Devesa et al. (2025), in a systematic review and meta analysis focused specifically on preschool children, reported that dance programs tend to improve fundamental motor skills, particularly body coordination and balance. Likewise, Đošić et al. (2025) showed in a randomized controlled trial that a 12 week dance program improved fine motor competence and balance in preschoolers, while Ito et al. (2024) reported

gains in motor skills and dynamic balance after a short dance based intervention in elementary school children.

The relationship between rhythm based practice and motor learning is particularly important for sport dance. Rhythmic competence supports temporal organization of movement, anticipatory control, movement fluency, and synchronization with external auditory cues, all of which are central to the acquisition of dance technique. Recent work has shown that rhythm oriented training can positively affect motor coordination and facilitate transfer to sport specific skills (Yin et al., 2023). In preschool settings, rhythm and movement interventions have also been associated with improvements in self regulation and executive functioning, suggesting that coordinated music movement practice may have broader developmental value beyond immediate motor outcomes (Williams et al., 2023; Liu et al., 2025). These findings are highly relevant for initiation in sport dance, where the first instructional stages depend not only on the child's ability to reproduce steps, but also on the capacity to organize movement in time, respond to musical cues, and stabilize posture under changing coordination demands.

At the same time, the initiation stage in sport dance cannot be reduced to simple exposure to movement. It requires a methodologically grounded progression through which children gradually acquire postural control, basic locomotor patterns, rhythmic organization, and elementary technical structures specific to the dance styles practiced. In this respect, selection and initiation should be understood as complementary processes. Selection identifies favorable motor and psychomotor predispositions, while initiation provides the structured pedagogical framework through which such predispositions can be observed, stimulated, and refined over time (Moanță, 2011; Abbott & Collins, 2004). This perspective is consistent with contemporary views on talent development, which argue that early potential should not be interpreted rigidly or exclusively as an innate trait, but rather as a dynamic interaction between predispositions, practice conditions, and instructional quality (Ericsson et al., 1993; Baker & Horton, 2004).

Although the general benefits of dance for children are increasingly documented, the literature still shows several limitations when the focus narrows to sport dance initiation in early childhood. First, many studies address creative dance, school based movement, or general dance interventions, but fewer examine structured sport dance contexts involving style specific technical content. Second, much of the available evidence focuses on broader outcomes such as creativity, general motor competence, balance, or cognition, while fewer studies investigate motor musical skills directly linked to dance execution. Third, there remains limited research on children aged 4 to 7 years participating in initiation programs that combine rhythmic training, postural education, and style specific elements from both Standard and Latin dances. Finally, review level evidence also indicates persistent methodological heterogeneity in assessment tools, intervention design, and outcome reporting, which makes it difficult to identify clear pedagogical models for the earliest stages of dance training (Thomaidou et al., 2021; del Barrio & Arús, 2024; González Devesa et al., 2025).

This gap is particularly relevant in the case of sport dance, where early instruction has both formative and selective value. Standardized choreographic disciplines such as Slow Waltz and Cha-Cha require the early organization of body posture, rhythmic timing, weight transfer, movement orientation, and elementary technical accuracy. However, there is still limited empirical guidance regarding how these components should be introduced to very young beginners in a progressive, age appropriate, and pedagogically coherent manner. Existing research supports the educational value of music movement and dance based programs, but less is known about how methodological means specific to sport dance initiation can be structured to support both general motor development and the acquisition of dance related motor musical skills in preschool children (Díaz Pérez et al., 2021; Chilom et al., 2024; Liu et al., 2025).

Therefore, the present study addresses the methodological aspects of selection and initiation in sport dance for children aged 4 to 7 years, with a particular focus on the role of structured training means in the development of rhythmic ability and motor musical skills. The study is grounded in the premise that early sport dance instruction should integrate general developmental principles with the specific technical and musical demands of the discipline. In this context, the purpose of the study was to examine whether a structured initiation program based on exercises for rhythmicity, musicality, body posture, and elementary technical patterns in Slow Waltz and Cha-Cha could improve performance in beginner children aged 4 to 7 years. It was hypothesized that the systematic application of these training means would lead to significant improvements in rhythmic ability and in the execution of fundamental motor musical structures required for sport dance practice.

2. Materials and Methods

2.1. Study design

This study used a one group pretest posttest quasi experimental design to examine the effects of a structured sport dance initiation program on rhythmic ability and motor musical skills in children aged 4 to 7 years. The intervention was implemented over a three month period and focused on the progressive development of basic abilities required for beginner level practice in sport dance. The study was designed as an applied pilot investigation, aiming to explore the methodological value of age adapted training means during the early stage of dance initiation. Given the pilot nature of the study, the findings should be interpreted with appropriate caution.

2.2. Participants

The study was conducted at the Sport Dance Club Stop and Dance, Bucharest, Romania, between March 6, 2025 and May 31, 2025. The sample consisted of 10 children, including 5 boys and 5 girls, aged between 4 and 7 years, all enrolled in beginner level sport dance training programs. Participants were selected using a convenience sampling method based on their availability and regular attendance in the initiation sessions organized by the club.

2.3. Eligibility Criteria

The inclusion criteria were: age between 4 and 7 years, enrollment in a beginner sport dance initiation program, and consistent participation throughout the intervention period. The exclusion criteria were: absence from more than 20% of the training sessions, previous advanced experience in sport dance, and any medical condition limiting safe participation in physical activity. Given the reduced sample size and the exploratory nature of the study, the investigation should be considered a pilot study.

2.4. Ethical Considerations

All procedures were conducted in accordance with the ethical principles for research involving human participants. Informed consent was obtained from the parents or legal guardians of all children prior to participation. Participant anonymity and confidentiality were ensured throughout the study, and all collected data were used exclusively for scientific purposes. The study followed the principles outlined in the Declaration of Helsinki regarding research involving human subjects.

2.5. Procedure

The intervention program was applied over a period of three months within the regular activity schedule of the dance club and included four training sessions per week. The training content was designed to match the psychomotor and cognitive characteristics of children in early childhood and

followed the principles of accessibility, progression, continuity, and individualization. The methodological approach aimed to support the gradual acquisition of rhythmic, postural, and motor musical skills required for the initial stage of sport dance training. The intervention program was conceived and implemented by the instructor responsible for the initiation training process.

The program included three major categories of training means: exercises for the development of rhythmicity and musicality, exercises for the development of body posture, and exercises for the formation of motor musical skills specific to Slow Waltz and Cha-Cha. The training tasks were introduced progressively, beginning with simple coordination patterns and continuing with more structured movement sequences and elementary choreographic combinations. In the initial stages, exercises were performed on verbal counting in order to facilitate understanding of timing and movement organization. This was followed by execution with musical accompaniment in order to strengthen rhythmic integration and improve synchronization between movement and musical structure.

Special attention was given to maintaining a playful and engaging learning environment, appropriate for the developmental characteristics of children aged 4 to 7 years. Exercise dosage was adjusted to avoid fatigue and to maintain concentration and motivation. The alternation of rhythmic, postural, and technical tasks allowed balanced stimulation of multiple motor components while reducing monotony during practice.

2.6. Session Structure

Each training session followed a consistent methodological progression. The first component targeted rhythmicity and musicality and lasted approximately 8 to 10 minutes per session, with 4 to 6 cycles per exercise and a progression from execution on verbal counting to execution with musical accompaniment. The second component focused on body posture and lasted approximately 10 to 12 minutes per session, with 2 to 3 sets of 8 counts per exercise performed at a slow to moderate tempo, synchronized especially with Slow Waltz music. The third component addressed dance specific motor musical skills and lasted approximately 10 to 12 minutes per session, with 3 to 5 cycles for Slow Waltz exercises and 4 to 6 cycles for Cha-Cha movement patterns, progressing from isolated elements to combined sequences and choreographic fragments.

This organization allowed a balanced alternation of rhythmic, postural, and technical tasks and was intended to reduce monotony, avoid fatigue, and maintain concentration and motivation. Exercises were initially performed on counting to ensure correct understanding, followed by execution on music in order to develop rhythmic integration. Special attention was given to maintaining a playful and engaging learning environment adapted to early childhood.

2.7. Training content

Rhythmicity and Musicality Training

Exercises for rhythmicity and musicality were designed to develop temporal coordination, rhythmic perception, and the ability to synchronize movement with external auditory cues. In the case of Slow Waltz, activities were structured according to a three-beat pattern and included clapping, finger snapping, and lower limb movements coordinated with counting and music. In the case of Cha-Cha, exercises followed a four-beat pattern with syncopated elements and focused on dynamic coordination, timing accuracy, and quick movement responses. The duration allocated to this component was approximately 8 to 10 minutes per session, with 4 to 6 repetitions of each exercise pattern.

Postural Training

Exercises for body posture were intended to develop alignment, balance, controlled movement, and aesthetic awareness. These means were inspired by basic elements of classical dance and included turned out foot positions, controlled leg extensions, coordinated arm positions, demi plié, relevé, and circular leg movements. The duration allocated to postural training was approximately 10 to 12 minutes per session, with 2 to 3 sets of 8 counts for each exercise, performed at a slow to moderate tempo. The emphasis was placed on precision, body control, and correct alignment.

Dance Specific Motor Musical Training

The third component of the program targeted the acquisition of elementary motor musical structures specific to the two dance styles included in the study. In Slow Waltz, the training focused on basic walking patterns, rise and fall mechanics, directional control, and the progressive learning of choreographic elements such as Natural Turn, Closed Change, and Reverse Turn. In Cha-Cha, the training emphasized weight transfer, lateral stepping, rhythmic precision, chasse actions, and elementary combinations such as Time Step, Open Basic Movement, Cross Basic Movement, and Three Cha-Cha. These tasks represented the transition from general motor preparation to dance specific execution. The duration allocated to this component was approximately 10 to 12 minutes per session, with progressive progression from isolated elements to combined sequences and short choreographic fragments.

2.8. Assessment Instruments

Participants were evaluated before and after the intervention using two performance based assessment instruments designed to measure rhythmic ability and motor musical skills relevant to beginner sport dance practice. All assessments were conducted under standardized conditions using the same evaluation criteria at both testing moments. The rhythmic pattern used for assessment was selected and, when necessary, repeated by the coach, indicating that the assessment procedure was administered directly within the instructional context of the program.

Assessment of Rhythmic Ability

Rhythmic ability was assessed through an individual rhythmic reproduction task. Each participant was required to reproduce, by hand clapping, a rhythmic pattern demonstrated by the coach, without prior rehearsal. If the child was unable to reproduce the sequence correctly, the demonstration was repeated once. Performance was scored using a three point ordinal scale: 3, accurate reproduction without errors, 2, correct reproduction after one repetition, and 1, inability to reproduce the rhythmic pattern. This instrument was intended to capture rhythmic perception, retention, and motor reproduction capacity.

Assessment of Motor Musical Skills

Motor musical skills were evaluated through the execution of fundamental dance figures and basic choreographic structures specific to Slow Waltz and Cha-Cha. In Slow Waltz, the assessment focused on the figure Reverse Turn and on the execution of a choreographic sequence composed of Natural Turn, Closed Change from Natural to Reverse, Reverse Turn, and Closed Change from Reverse to Natural. In Cha-Cha, the assessment focused on Cross Basic Movement and on a choreographic sequence including Time Step, Open Basic Movement, Cross Basic Movement, and Three Cha-Cha. Performance was scored on a four point ordinal scale according to the quality and coherence of execution: 4, correct execution without errors, 3, execution with one or two minor errors, 2, execution with three or four errors, and 1, inability to correctly perform the required movement structure. The scoring criteria considered technical correctness, coordination, rhythmic synchronization, and the ability to execute the complete choreographic sequence.

2.9. Statistical Analysis

The collected data were processed using descriptive and inferential statistical methods. For each evaluated variable, the following descriptive indicators were calculated: mean, median, standard deviation, and coefficient of variation. These indicators were used to characterize performance level and group homogeneity at initial and final testing.

To examine differences between pre intervention and post intervention scores, the Wilcoxon signed rank test was applied. This nonparametric test was considered appropriate due to the small sample size and the ordinal nature of the assessment scales. The level of statistical significance was set at $p < 0.05$. The analysis aimed to determine whether the structured initiation program was associated with significant improvements in rhythmic ability and dance specific motor musical performance.

3. Results

Descriptive statistics for the pre intervention and post intervention assessments are presented in Tables 1 and 2. At baseline, participants showed relatively modest performance levels across all evaluated variables, with mean scores ranging from 2.00 to 2.40. The highest initial variability was observed for Cha-Cha Structure, CV = 41.25%, while the lowest was found for Cross Basic Movement, CV = 21.00%, indicating moderate to high heterogeneity in group performance at the beginning of the program.

Table 1. Descriptive statistics for the initial assessment

Variable	Mean	Median	SD	CV (%)
Rhythmic Ability	2.00	2.00	0.67	33.33
Reverse Turn	2.40	2.00	0.52	21.52
Waltz Structure	2.00	2.00	0.67	33.33
Cross Basic Movement	2.30	2.00	0.48	21.00
Cha-Cha Structure	2.30	2.00	0.95	41.25

Following the intervention, all evaluated variables showed higher central tendency values. Mean scores increased from 2.00 to 3.10 for Rhythmic Ability, from 2.40 to 3.50 for Reverse Turn, from 2.00 to 3.50 for Waltz Structure, from 2.30 to 3.60 for Cross Basic Movement, and from 2.30 to 3.20 for Cha-Cha Structure. Median values also increased across all measures. In addition, the coefficients of variation decreased at posttest, ranging from 14.34% to 20.20%, which suggests improved group homogeneity and greater consistency of execution after the training program.

Table 2. Descriptive statistics for the final assessment

Variable	Mean	Median	SD	CV (%)
Rhythmic Ability	3.10	3.00	0.57	18.31
Reverse Turn	3.50	3.50	0.53	15.06
Waltz Structure	3.50	4.00	0.71	20.20
Cross Basic Movement	3.60	4.00	0.52	14.34
Cha-Cha Structure	3.20	3.00	0.63	19.76

To determine whether the observed pre to post changes were statistically significant, the Wilcoxon signed rank test was applied for all evaluated variables. As shown in Table 3, statistically significant differences were found for all assessed measures: Rhythmic Ability, $W = 0.00$, $p = 0.0039$, Reverse Turn, W

= 0.00, p = 0.0078, Waltz Structure, W = 0.00, p = 0.0039, Cross Basic Movement, W = 0.00, p = 0.0020, and Cha-Cha Structure, W = 0.00, p = 0.0156. All W values were equal to 0.00, indicating that posttest scores were consistently higher than pretest scores across participants.

Table 3. Wilcoxon signed rank test results for pre to post intervention comparisons

Variable	W	p-value	Effect direction
Rhythmic Ability	0.00	0.0039	$p < 0.01$
Reverse Turn	0.00	0.0078	$p < 0.01$
Waltz Structure	0.00	0.0039	$p < 0.01$
Cross Basic Movement	0.00	0.0020	$p < 0.01$
Cha-Cha Structure	0.00	0.0156	$p < 0.05$

Taken together, the descriptive and inferential results suggest that the structured initiation program was associated with improvements in rhythmic ability and motor musical performance in children aged 4 to 7 years. The increase in mean and median values, along with the reduction in variability and the statistically significant Wilcoxon results, indicates both individual progress and improved group consistency in the execution of the assessed tasks.

4. Discussion

The present study examined the effects of a structured sport dance initiation program on rhythmic ability and motor-musical skills in children aged 4 to 7 years. The results showed significant improvements in all assessed variables, namely rhythmic ability, Reverse Turn, Waltz Structure, Cross Basic Movement, and Cha-Cha Structure. These findings suggest that a systematically organized initiation program may support the early development of rhythm-based coordination and dance-specific motor execution in young beginner dancers. This interpretation is consistent with the growing literature showing that dance-based interventions can positively affect motor development in childhood (González-Devesa et al., 2025; Ito et al., 2024; Jouira et al., 2024).

One of the most important findings of the present study was the improvement in rhythmic ability. This result is particularly relevant because rhythmic processing plays a central role in the temporal organization of movement, synchronization with music, and the acquisition of dance technique. In children, rhythm-based training has been linked not only to better movement coordination, but also to broader developmental benefits. For example, Shen et al. (2020) reported that 8 weeks of street-dance training improved executive function in preschool children, while Wang et al. (2024) found that rhythmic-movement intervention had beneficial effects on hot executive function in 5 to 6-year-old children. Although our study did not assess executive function directly, the improvement in rhythmic reproduction observed in our sample may reflect a similar strengthening of timing, control, and sensorimotor integration during early training.

The progress recorded in the dance-specific variables also supports the pedagogical value of structured initiation. In our study, the children improved both in the Standard dance component, reflected by Reverse Turn and Waltz Structure, and in the Latin component, reflected by Cross Basic Movement and Cha-Cha Structure. This is important because these two styles impose different motor demands. Slow Waltz requires postural alignment, smooth directional control, and rise-and-fall organization, whereas Cha-Cha-Cha requires faster rhythm decoding, dynamic weight transfer, and more rapid directional changes. The slightly less robust statistical pattern observed for Cha-Cha Structure may therefore be explained by the greater coordinative and rhythmic complexity of this dance for very young beginners. A similar point emerges from the broader intervention literature, where studies indicate that more complex

movement patterns often need longer exposure and more gradual scaffolding in young children (Thomaidou et al., 2021; Guo et al., 2024; Hui et al., 2024).

The decrease in the coefficients of variation at final testing is another meaningful result. It indicates not only that the group improved, but also that performance became more homogeneous. From a methodological perspective, this is highly relevant in initiation programs, because the goal is not limited to isolated individual progress. A successful initiation program should also reduce dispersion in performance and promote more stable execution across participants. This interpretation is compatible with the findings reported by González-Devesa et al. (2025), who concluded in their systematic review and meta-analysis that dance programs improve body coordination and balance in preschool children, and by Jouira et al. (2024), who observed improvements in postural balance after aerobic dance intervention. Ito et al. (2024) similarly reported positive changes in motor skills and balance after a dance program in children, which further supports the view that structured dance training can help stabilize movement behavior.

Our findings also align with a broader body of work emphasizing the relationship between motor competence, structured physical activity, and child development. Chen et al. (2023) reported a bidirectional relationship between fundamental motor skills and physical fitness in preschoolers, suggesting that improvements in one domain may reinforce development in the other. In a related way, Jylänki et al. (2022) showed in a systematic review that motor skill and physical activity interventions can support cognitive and academic development in typically developing children aged 3 to 7 years. Although our study focused specifically on sport dance and did not assess physical fitness or cognition directly, the observed gains in rhythm and technical execution are coherent with the idea that early structured movement experiences can generate broad developmental benefits.

The present results are also in line with recent evidence specifically related to DanceSport. Liu et al. (2025), in a randomized controlled trial with preschoolers, found that an early childhood DanceSport intervention improved executive functions after an 8-week program delivered twice weekly. Although the main outcomes in that study were cognitive rather than technical, the findings reinforce the idea that DanceSport is a developmentally meaningful activity in early childhood. In a similar applied direction, Lin et al. (2025) compared a Creative Dance Curriculum with a DanceSport Curriculum in 4 to 6-year-old children, showing that structured dance formats can be implemented successfully in preschool educational settings. These studies strengthen the relevance of our results by showing that dance-based interventions, including DanceSport-oriented ones, can be effective when adapted to children's developmental characteristics.

At the same time, our study differs from much of the recent literature in an important way. Many studies published after 2020 have focused on creative dance, school-based movement education, rhythm-and-movement programs, or general motor competence interventions, rather than on the early acquisition of technical elements from specific sport dance styles. For example, Thomaidou et al. (2021) showed that an eight-week creative dance and movement program improved motor creativity in preschoolers, but also noted that this type of program may not be sufficient to develop a broader range of motor skills. Likewise, Lin et al. (2025) emphasized the educational benefits of creative dance, and Wang et al. (2024) highlighted the developmental role of rhythm-and-movement programs. In contrast, the present study focused on the initiation of concrete motor-musical structures from Slow Waltz and Cha-Cha-Cha, which gives it a more directly applied relevance for coaches and instructors working in beginner DanceSport settings.

Another aspect that supports the interpretation of our results is the structured design of the intervention itself. The program combined rhythmicity and musicality exercises, postural training, and dance-specific technical work. Recent evidence suggests that structured interventions are generally more effective than unstructured ones for improving fundamental motor skills in preschool children (Chen et al., 2024). In addition, Hui et al. (2024) reported in a systematic review and meta-analysis that gross movement

interventions have positive effects on physical fitness in children aged 3 to 10 years, especially when dosage and progression are clearly organized. Even though our weekly frequency was higher and the intervention was centered on dance-specific content, our data support the same broader principle, namely that planned, repeated, and progressive movement experiences are developmentally beneficial in childhood.

Recent experimental studies also suggest that dance-based activity may influence domains beyond motor execution alone. He et al. (2025) showed that rhythm-enhanced digital sports dance acutely affected children's motor abilities, cognitive performance, and neuromuscular synchronization, while Shen et al. (2020) and Liu et al. (2025) both reported executive-function-related benefits in preschool children exposed to dance-based interventions. These findings do not allow direct causal extension to our study, because our outcome measures were different, but they do help position our results within a wider developmental framework in which dance training appears to support integrated motor and cognitive functioning.

From a practical perspective, the present findings suggest that initiation programs in sport dance for children aged 4 to 7 years should prioritize rhythmic education, postural control, and progressive exposure to simplified choreographic structures. The improvement observed in both Waltz and Cha-Cha-Cha variables indicates that very young children are capable of acquiring elementary technical content when this content is methodologically adapted to their age and taught through repetition, counting, and musical accompaniment. This pedagogical implication is coherent with the broader evidence showing that structured dance and movement programs can improve coordination, balance, and motor competence in children when they are age-appropriate and consistently applied (González-Devesa et al., 2025; Ito et al., 2024; Jouira et al., 2024; Guo et al., 2024).

Several limitations must also be acknowledged. First, the sample was small, which limits generalizability. Second, the one-group pretest-posttest design did not include a control group, so the observed improvements cannot be attributed with the same strength as in randomized controlled trials. Third, the assessments were conducted within the instructional context of the intervention, which may have increased the risk of evaluator-related bias. These limitations are important, especially when the present findings are compared with stronger designs such as those used by Liu et al. (2025), Jouira et al. (2024), and other recent intervention studies. Even so, the current study still provides useful pilot evidence and a practical methodological model for future research on sport dance initiation in early childhood.

Overall, the present study adds to the recent literature indicating that dance-based activity can support meaningful development during early childhood. More specifically, it suggests that a structured sport dance initiation program may improve rhythmic ability and elementary motor-musical execution in beginner children aged 4 to 7 years. Its main contribution lies in the applied field of DanceSport pedagogy, where empirical studies focused on early technical initiation remain relatively limited compared with the larger body of research on creative dance or general movement education.

5. Conclusions

The findings of the present study indicate that a structured sport dance initiation program may support significant improvements in rhythmic ability and motor-musical skills in children aged 4 to 7 years. The observed progress in rhythmic reproduction, Reverse Turn, Waltz Structure, Cross Basic Movement, and Cha-Cha Structure suggests that age-adapted training can facilitate the acquisition of essential motor and technical components required for beginner level sport dance practice.

The study also showed a reduction in group variability at posttest, which suggests greater consistency in performance and a more homogeneous level of execution among participants. From a

methodological perspective, these findings support the value of combining rhythmicity and musicality exercises, postural training, and dance-specific motor tasks within a progressive and structured initiation program.

Although the study has clear limitations, particularly the small sample size, the absence of a control group, and the pilot nature of the design, it provides useful applied evidence regarding the pedagogical relevance of early DanceSport initiation. The results suggest that systematically organized training, adapted to the developmental characteristics of children aged 4 to 7 years, may represent an effective way to support both psychomotor development and the early acquisition of dance-specific skills.

Future research should investigate these effects using larger samples, controlled designs, longer intervention periods, and more standardized assessment procedures. Such studies may help clarify the extent to which early initiation in sport dance contributes not only to motor learning, but also to broader developmental outcomes in childhood.

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A Randomized Controlled Trial Comparing McKenzie and Williams Exercises in Patients with Acute Low Back Pain

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Abstract

Background: Acute low back pain is a highly prevalent musculoskeletal condition and a major cause of pain related functional limitation. Exercise based rehabilitation is commonly recommended, with the McKenzie and Williams methods being among the most frequently used approaches. However, direct comparative evidence between these two exercise protocols remains limited.

Objective: This study aimed to compare the effectiveness of McKenzie and Williams exercises in reducing pain in patients with acute low back pain during a 30-day intervention period.

Results: A single blind, parallel group randomized controlled trial was conducted on 28 patients with acute low back pain, randomly assigned to a McKenzie group or a Williams group, with 14 participants in each group. Pain intensity was assessed using the Visual Analogue Scale before and after treatment. Both groups showed significant reductions in pain after the intervention. In the McKenzie group, mean pain scores decreased from 8.29 ± 0.91 to 5.43 ± 1.65, whereas in the Williams group they decreased from 8.29 ± 0.83 to 7.07 ± 1.00. The reduction in pain was significantly greater in the McKenzie group.

Conclusions: Both exercise protocols were effective in reducing pain in patients with acute low back pain. However, the McKenzie method produced greater short term pain relief and may represent a more effective rehabilitation strategy in this population.

Keywords: acute low back pain, mechanical diagnosis and therapy, McKenzie method, Williams flexion exercises, exercise therapy.

1. Introduction

Low back pain remains one of the most prevalent musculoskeletal disorders worldwide and one of the leading causes of disability, with a substantial impact on quality of life, work capacity, and healthcare utilization (Hartvigsen et al., 2018; Ferreira et al., 2023). Recent epidemiological evidence confirms that the global burden of low back pain remains high and is expected to increase further in the coming decades, which reinforces the need for effective and accessible conservative interventions. In addition, recent evidence on the clinical course of low back pain shows that, although many patients with acute or subacute symptoms improve within the first weeks, recovery is not uniform and a relevant proportion of individuals continue to experience pain, disability, or recurrence over time (Wallwork et al., 2024).

Exercise based rehabilitation is widely recommended in the conservative management of low back pain and remains a central component of contemporary clinical practice guidelines (Chou et al., 2007; George et al., 2021; Zhou et al., 2024). Recent guideline comparisons emphasize that active strategies such as exercise, education, self management, and the maintenance of usual activity are consistently recommended across countries. However, these guidelines also show considerable heterogeneity and often provide limited specificity regarding the most appropriate type, dosage, frequency, and progression of exercise therapy, particularly in patients with acute presentations (Zhou et al., 2024; Comachio et al., 2024). This lack of specificity remains clinically relevant because recommending exercise in general does not answer the practical question of which exercise approach should be prioritized for a particular patient profile.

Among the specific causes of lumbar pain are lumbar intervertebral disc disorders associated with nerve root irritation, conditions that occur frequently in adults of working age and may contribute to substantial pain and movement limitation (Schoenfeld et al., 2012). The intervertebral disc is composed of the nucleus pulposus, annulus fibrosus, and cartilaginous endplates, and disc displacement beyond the annular boundary may lead to compression of adjacent neural structures, particularly in the lower lumbar segments (Waxenbaum et al., 2023). At the same time, low back pain is a clinically heterogeneous condition, ranging from nonspecific mechanical pain to radicular syndromes and other specific disorders, which complicates treatment selection in routine rehabilitation practice. This heterogeneity supports the need to evaluate structured exercise approaches that rely on different biomechanical and clinical principles.

Two exercise based approaches commonly used in the rehabilitation of lumbar pain are the McKenzie method and the Williams flexion exercise programme. The McKenzie method, also known as Mechanical Diagnosis and Therapy, is based on repeated movement testing, sustained positions, and patient classification into mechanical syndromes according to symptom response and directional preference (McKenzie, 1981; McKenzie & May, 2003; Hefford, 2008; McKenzie Institute International, 2021). A central feature of this approach is that treatment is guided by clinical reassessment and by the patient's symptomatic and mechanical response, rather than by the routine prescription of the same exercise programme to all individuals. Recent evidence suggests that, when applied by credentialed therapists and matched to patients with directional preference, the McKenzie method may provide superior improvements in pain and disability compared with other conservative interventions, although the strongest evidence currently comes from chronic low back pain populations rather than acute cases (Hennemann et al., 2025).

In contrast, the Williams programme is a flexion biased exercise approach designed to reduce lumbar extension loading and encourage posterior pelvic tilt, abdominal and gluteal activation, and flexibility of the hamstrings and hip flexors (Williams, 1937; Dydyk et al., 2025). This method has long been used in clinical practice, particularly in patients whose symptoms appear to respond favorably to flexion

based loading. Nevertheless, compared with classification based strategies such as the McKenzie method, the contemporary comparative evidence supporting Williams exercises remains less extensive and less methodologically developed.

Despite the longstanding clinical use of both methods, direct comparative evidence between them remains limited. Existing studies are relatively few, often involve small samples, and frequently focus on chronic or nonspecific low back pain rather than acute low back pain. Moreover, recent evidence syntheses on exercise therapy for acute nonspecific low back pain indicate that the overall short term effects of exercise are uncertain or modest, while also highlighting important heterogeneity in intervention content and study quality (IJzelenberg et al., 2024). This suggests that the question is no longer whether exercise should be used, but rather which exercise strategy may produce better outcomes in a defined clinical context.

Another important limitation in the current literature is that many studies emphasize broad comparisons between exercise and usual care, sham treatment, or passive modalities, whereas fewer studies directly compare two established but conceptually distinct exercise protocols using patient reported outcomes as the primary endpoint. Pain intensity remains one of the most clinically meaningful outcomes in acute low back pain because it directly reflects the patient's perceived symptom burden and often influences mobility, adherence, and early response to treatment. Therefore, a focused comparison between a mechanically classified directional approach and a standardized flexion based programme may provide information that is directly useful for clinical decision making.

Therefore, the present study aimed to compare the effectiveness of McKenzie and Williams exercises in reducing pain in patients with acute low back pain over a 30 day intervention period. By directly comparing two commonly used rehabilitation strategies within a randomized controlled design, this study seeks to address a relevant gap in the literature and to contribute evidence that may support more targeted exercise prescription in the conservative management of acute low back pain.

2. Materials and Methods

2.1. Study design

This study was designed as a single blind, parallel group randomized controlled trial conducted over a 30 day intervention period in a private physiotherapy clinic. The study compared the effects of two exercise based rehabilitation protocols, the McKenzie method and the Williams flexion exercise programme, on pain intensity in patients with acute low back pain. Blinding was applied at the level of outcome assessment, as the assessor responsible for recording pain scores was unaware of group allocation. Due to the nature of the interventions, neither the participants nor the treating therapists could be blinded to treatment assignment.

2.2. Participants

A total of 28 patients with acute low back pain were recruited from a private physiotherapy clinic and enrolled in the study. Participants were randomly allocated in a 1:1 ratio to either the McKenzie group, with 14 participants, or the Williams group, with 14 participants. Given the exploratory character of the trial, no formal a priori sample size calculation was performed. Therefore, the study sample should be considered a convenience sample.

2.3. Eligibility Criteria

Participants were eligible for inclusion if they were between 30 and 40 years of age, had acute lumbar pain as the primary diagnosis, and were considered generally healthy, with no psychological disorders and no history of cancer or related illnesses. To reduce potential confounding related to symptom

modulation, participants were also required not to use analgesics or other medications that could influence pain perception during the study period.

Patients were excluded if they presented with systemic disease, neurological pathology, or acute traumatic conditions such as fractures or motor vehicle related injuries. Individuals whose lumbar pain was secondary to another medical condition were also excluded from participation.

2.4. Ethical Considerations

The study was approved by the Research Ethics Subcommittee of Babeș Bolyai University of Cluj Napoca under approval number 18.231/10.11.2025. All participants provided written informed consent prior to enrolment in the study. The study procedures were conducted in accordance with ethical principles for research involving human participants.

2.5. Randomization

Participants were assigned to the two study groups using the randomization function available in R Commander, which generated group allocation after participant data had been entered. This procedure was used to ensure an unbiased distribution of participants between the two intervention arms. Baseline pain values were comparable between groups, supporting the success of the random allocation process.

2.6. Outcome Measure

Pain intensity was selected as the primary outcome of the study and was assessed using the Visual Analogue Scale. The scale ranged from 0 to 10, where 0 indicated no pain and 10 indicated the worst imaginable pain. Pain scores were recorded at two time points, at baseline before the beginning of the intervention and again at the end of the 30-day treatment period. This outcome was chosen because pain reduction represented the main therapeutic objective of the intervention and a clinically relevant indicator of short-term treatment response in patients with acute low back pain.

2.7. Intervention Procedures

Both study groups followed a structured 30 day exercise programme. In addition to daily home based exercise, all participants attended the clinic three times per week for supervised rehabilitation sessions. This combined format was selected in order to support treatment adherence while maintaining a self management component within the rehabilitation process.

Participants allocated to the McKenzie group performed extension based exercises consistent with the principles of the McKenzie method, also known as Mechanical Diagnosis and Therapy. This intervention emphasized repeated lumbar movements and active exercise performance according to the McKenzie approach used in clinical rehabilitation.

Participants allocated to the Williams group followed a flexion based exercise programme derived from the Williams method. The exercise programme included posterior pelvic tilt exercises, knee to chest movements, partial curl up exercises, and hamstring and hip flexor stretching. These exercises were performed throughout the intervention period according to the group specific treatment protocol.

2.8. Statistical Analysis

Descriptive statistics were calculated for all study variables. Pain scores were summarized using measures of central tendency and dispersion. Prior to inferential testing, the distribution of difference scores was assessed for normality using the Shapiro Wilk test. Because the assumption of normality was violated in both groups, non-parametric testing was prioritized for the main within group analyses.

Specifically, the Wilcoxon signed rank test was used to examine pre to post intervention changes in pain scores within each group.

For completeness, paired samples t tests were also performed and reported as supplementary parametric analyses. Effect sizes were calculated using Cohen's d for parametric comparisons and rank biserial correlation for non-parametric analyses. To examine whether the magnitude of pain reduction differed between the two intervention groups, between group comparisons of change scores were also conducted. Statistical significance was set at $\alpha = .05$ for all analyses. All statistical analyses were performed using jamovi, version 2.6 (The jamovi project, 2025).

3. Results

3.1. Baseline Characteristics

At baseline, the two groups were comparable in terms of pain intensity. Both the McKenzie group and the Williams group presented an identical mean Visual Analogue Scale score of 8.29, indicating a similar level of pain severity before the intervention. In the McKenzie group, the baseline mean was 8.29 ± 0.91, with a median of 8.00 and a range from 7.00 to 10.00. In the Williams group, the baseline mean was 8.29 ± 0.83, with a median of 8.00 and the same range of 7.00 to 10.00. These findings suggest that randomization produced equivalent groups at study entry.

Table 1. Descriptive statistics

Statistic parameters	McKenzie Before Intervention	McKenzie Post Intervention	Williams Before Intervention	Williams Post Invervention
Valid	14	14	14	14
Missing	0	0	0	0
Mode	8.026	5.422	8.014	7.000
Median	8.000	5.500	8.000	7.000
Mean	8.286	5.429	8.286	7.071
95% CI Mean Lower	7.758	4.475	7.809	6.496
95% CI Mean Upper	8.813	6.382	8.762	7.647
Std. Deviation	0.914	1.651	0.825	0.997
Skewness	0.043	-0.572	0.332	-0.161
Std. Error of Skewness	0.597	0.597	0.597	0.597
Kurtosis	-0.653	0.107	0.164	0.751
Std. Error of Kurtosis	1.154	1.154	1.154	1.154
Shapiro-Wilk	0.889	0.948	0.878	0.913
P-value of Shapiro-Wilk	.079	.536	.055	.174
Minimum	7.000	2.000	7.000	5.000
Maximum	10.00	8.000	10.00	9.000
Sum	116.0	76.00	116.0	99.00

** More than one mode exists. For nominal and ordinal data, the first mode is reported. For continuous data, the mode with the highest density estimate is reported but multiple modes may exist. We recommend visualizing the data to check for multimodality.*

The distributional properties of pain scores were examined using skewness, kurtosis, and the Shapiro-Wilk test. At baseline, both groups exhibited approximately symmetrical distributions. The

McKenzie group showed near-zero skewness (0.043), indicating an almost perfectly symmetrical distribution, while the Williams group displayed a slight positive skew (0.332), suggesting a minor tendency toward lower scores with a tail extending toward higher values. Following the intervention, the McKenzie post-intervention scores became moderately negatively skewed (−0.572), indicating that most participants clustered toward higher pain values with a tail extending toward lower scores, reflecting that some individuals responded particularly well to the treatment. The Williams post-intervention scores remained approximately symmetrical (−0.161).

Regarding kurtosis, the McKenzie baseline scores showed a platykurtic distribution (−0.653), meaning scores were more uniformly spread with lighter tails than a normal distribution. Post-intervention, the McKenzie group shifted to a slightly leptokurtic distribution (0.107), indicating a marginally more peaked concentration around the central value. The Williams baseline scores were near-mesokurtic (0.164), approximating a normal shape, while post-intervention scores became moderately leptokurtic (0.751), suggesting greater concentration of scores around the mean with fewer extreme values.

Despite these minor departures from normality in skewness and kurtosis, the Shapiro-Wilk test indicated that all four individual distributions did not significantly deviate from normality (McKenzie baseline: $W = 0.889$, $p = .079$; McKenzie post: $W = 0.948$, $p = .536$; Williams baseline: $W = 0.878$, $p = .055$; Williams post: $W = 0.913$, $p = .174$). It is important to note that the normality violations reported in the assumption checks for the paired t-tests ($p = .006$ and $p = .022$) refer to the distribution of difference scores rather than the raw scores themselves.

3.2. Within Group Changes in Pain Intensity

Following the 30 day intervention period, both groups showed statistically significant reductions in pain intensity.

In the McKenzie group, mean pain scores decreased from 8.29 ± 0.91 at baseline to 5.43 ± 1.65 after treatment, corresponding to a mean reduction of 2.86 points. The Wilcoxon signed rank test showed that this reduction was statistically significant, $W = 105.00$, $z = 3.296$, $p < .001$. The paired samples t test yielded consistent results, $t(13) = 5.830$, $p < .001$, with a large effect size, Cohen's $d = 1.558$, 95% CI [0.754, 2.336].

In the Williams group, mean pain scores decreased from 8.29 ± 0.83 at baseline to 7.07 ± 1.00 after treatment, corresponding to a mean reduction of 1.21 points. This reduction was also statistically significant according to the Wilcoxon signed rank test, $W = 55.00$, $z = 2.803$, $p = .005$. The paired samples t test supported the same conclusion, $t(13) = 3.823$, $p = .002$, with a large effect size, Cohen's $d = 1.022$, 95% CI [0.357, 1.662].

Table 2. Paired Samples T-Test

Measure 1	Measure 2	t	df	p	Cohen's d	SE Cohen' s d	95% CI for Cohen's d	
							Lower	Upper
McKenzie Before Intervention	McKenzie Before Intervention	5.830	13	< .001	1.558	0.544	0.754	2.336
Williams Before Intervention	Williams Before Intervention	3.823	13	< .002	1.022	0.427	0.357	1.662

3.3. Between Group Comparison of Pain Reduction

Although both exercise protocols were associated with significant pain reduction, the magnitude of improvement differed between groups. The McKenzie group achieved a mean reduction of 2.86 points on the Visual Analogue Scale, whereas the Williams group showed a mean reduction of 1.21 points. Descriptively, pain reduction was therefore greater in the McKenzie group.

This between group difference in change scores was statistically significant. The Mann Whitney U test showed a significant difference between the two interventions, $U = 40.50$, $p = .007$, indicating that the greater reduction observed in the McKenzie group was unlikely to be due to chance. The independent samples t test produced a consistent result, $t(26) = 2.81$, $p = .009$, with a large effect size, Cohen's $d = 1.06$. These findings support the superior short term effectiveness of the McKenzie method over the Williams programme for pain reduction in patients with acute low back pain

Table 3. Test of Normality (Shapiro-Wilk)

Before intervention	Post intervention	W	p
McKenzie Before Intervention	McKenzie Post Intervention	0.805	.006
Williams Before Intervention	Williams Post Intervention	0.849	.022

** Note. Significant results suggest a deviation from normality.*

3.4. Distributional Assessment

The normality of difference scores was assessed using the Shapiro Wilk test. The distribution of change scores deviated significantly from normality in both the McKenzie group, $W = 0.805$, $p = .006$, and the Williams group, $W = 0.849$, $p = .022$. For this reason, non parametric analyses were prioritized as the primary inferential tests, while parametric results were reported as complementary analyses.

Table 4. Independent Samples T-Test

		Statistic	df	p	Cohen's d		Effect size	
Pain change	Student's t	2.81	26.0	.009	1.558	Cohen's d	0.754	2.336
	Mann-Whitney U	40.5		.007	1.022	Rank biserial correlation	0.357	1.662

To determine whether the observed difference in pain reduction between groups was statistically significant, a between-group comparison of change scores was conducted. A Mann-Whitney U test revealed a statistically significant difference between the McKenzie and Williams groups ($U = 40.50$, $p = .007$), indicating that the greater pain reduction observed in the McKenzie group was not attributable to chance. A parametric independent-samples t-test yielded consistent results ($t(26) = 2.81$, $p = .009$). These findings provide inferential support for the descriptive differences reported above, confirming the superior effectiveness of the McKenzie method in reducing pain over the 30-day intervention period.

4. Discussion

Interpretation of Findings

The present study compared the short-term effects of McKenzie and Williams exercises on pain intensity in patients with acute low back pain over a 30-day intervention period. The main finding was that both interventions produced statistically significant reductions in pain, but the magnitude of improvement was greater in the McKenzie group. Pain intensity decreased by 2.86 points on the Visual Analogue Scale in

the McKenzie group, compared with 1.21 points in the Williams group, and the between group comparison of change scores supported the superiority of the McKenzie protocol in this sample.

These findings suggest that both exercise approaches may have therapeutic value in acute low back pain, but they also indicate that a classification oriented and directional response-based intervention may be more effective than a standardized flexion biased programme when short term pain reduction is the primary outcome. This interpretation is consistent with the theoretical rationale of the McKenzie method, which relies on repeated movement testing, directional preference, and continuous reassessment to individualize exercise prescription (McKenzie, 1981; McKenzie & May, 2003; Hefford, 2008). In contrast, the Williams programme follows a more uniform flexion-based structure, which may be beneficial for some patients but may not address the heterogeneity of symptom behavior seen in acute lumbar pain (Williams, 1937; Dydyk et al., 2025).

The greater improvement observed in the McKenzie group may also be clinically relevant. Although the present study was not designed around a formal responder analysis, a mean reduction of nearly 3 points on a 0 to 10 pain scale suggests a more meaningful symptom change than the approximately 1-point reduction observed in the Williams group. This distinction matters in acute rehabilitation, where early pain reduction may influence mobility, treatment adherence, fear of movement, and return to usual activities (IJzelenberg et al., 2024).

Comparison With Previous Literature

The present findings are broadly aligned with the larger body of evidence supporting exercise-based care for low back pain, while also highlighting the unresolved issue of which exercise approach is most effective in specific clinical contexts. In chronic low back pain, exercise therapy has shown small to moderate benefits for pain and function compared with no treatment or usual care, but the literature remains heterogeneous in terms of exercise type, dosage, and patient selection. Hayden et al. (2021) reported moderate certainty evidence that exercise is more effective than no treatment or usual care in chronic low back pain, yet they also concluded that no single exercise category is universally superior across all populations.

This broader uncertainty is also reflected in more recent evidence syntheses. Zhou et al. (2024) showed that exercise is consistently recommended in clinical practice guidelines for low back pain, but guideline documents often provide limited detail regarding the specific mode, intensity, duration, and progression of exercise. Similarly, Comachio et al. (2024) found that many guidelines remain nonspecific about physical activity and exercise therapy recommendations. These observations strengthen the relevance of direct head-to-head comparisons, such as the present trial, because clinicians need more precise information than a generic recommendation to exercise.

When the focus is narrowed to acute low back pain, the evidence becomes even less definitive. IJzelenberg et al. (2024) concluded that exercise therapy for acute nonspecific low back pain may have little or no clinically relevant short-term effect compared with sham, placebo, or no treatment, although the certainty of evidence was low and the interventions were highly heterogeneous. Against this background, the present study is relevant because it does not simply compare exercise with no exercise, but compares two distinct exercise strategies. Our results suggest that even if the average effect of exercise in acute low back pain is modest at the population level, the choice of exercise approach may still matter in a targeted clinical setting.

The direction of the present findings is also consistent with more specific evidence related to the McKenzie method. Hennemann et al. (2025) found that the McKenzie Method, when delivered by credentialed therapists to patients with chronic low back pain and directional preference, was superior to

comparator interventions for pain up to 6 months and for disability up to 12 months, although the certainty of evidence ranged from low to moderate. While that review focused on chronic low back pain, the present findings suggest that a similar advantage may also emerge in the short-term management of acute low back pain, especially when the primary target is pain reduction.

Recent comparative evidence from the broader exercise literature also supports the idea that not all exercise protocols perform equally. Li et al. (2023), Prat Luri et al. (2023), Capel Alcaraz et al. (2023), Patti et al. (2024), Wang et al. (2024), de Roode et al. (2024), and Rizzo et al. (2025) reported that several active exercise strategies, including trunk focused exercise, motor control exercise, stabilization interventions, and Pilates based programmes, may improve pain and disability in low back pain, although comparative rankings vary according to patient selection, intervention dosage, and study quality. These data reinforce the idea that exercise effectiveness depends not only on whether patients exercise, but also on how the intervention is structured and matched to the clinical presentation.

In relation to the Williams programme, the literature is less developed and substantially less contemporary. The method remains clinically familiar and biomechanically plausible in patients who respond favorably to flexion-based loading, but there is comparatively little high quality recent evidence establishing its superiority over other exercise approaches. This imbalance in the literature is important for interpreting the present study. The smaller improvement seen in the Williams group does not imply that flexion-based exercises lack value, but it does suggest that a standardized flexion programme may be less effective than a more responsive, classification-based method in a heterogeneous acute low back pain sample. This interpretation is compatible with the current trend in rehabilitation research toward individualized rather than uniform exercise prescription (Comachio et al., 2024; Zhou et al., 2024).

The present findings can also be interpreted in light of emerging evidence on contextual and delivery related factors. de Roode et al. (2024) reported that contextual effects contribute meaningfully to outcomes in exercise therapy for low back pain. This is relevant because the current study used a mixed delivery model consisting of supervised sessions three times per week combined with daily home exercise. Such a format may enhance adherence, reinforce self-management, and increase patient confidence, all of which may have contributed to the improvements observed in both groups. However, because the same delivery model was used in both arms, the superior outcome in the McKenzie group is more likely to reflect differences in exercise strategy than differences in contact time alone.

Clinical Implications

From a clinical perspective, the present findings support the use of exercise-based rehabilitation in patients with acute low back pain, but they also suggest that the specific design of the exercise programme matters. In this sample, the McKenzie method produced greater short term pain relief than the Williams protocol, which may make it a useful first option when the therapeutic goal is rapid reduction of pain and when the clinical presentation is compatible with directional assessment and repeated movement testing.

At the same time, the results should not be interpreted as evidence that one programme is universally appropriate for all patients with acute low back pain. Current guidelines and reviews increasingly support stratified, patient centered care rather than a one size fits all approach (George et al., 2021; Zhou et al., 2024). For some patients, especially those whose symptoms appear aggravated by extension or relieved by flexion, a flexion biased programme may still be reasonable. Therefore, the main clinical message of the present study is not that every patient should receive the McKenzie method, but that symptom guided and mechanically informed exercise selection may yield better short-term results than a more standardized protocol.

The study also has practical implications for rehabilitation delivery. The combination of supervised clinic sessions and daily home exercise appeared feasible and was associated with significant within group pain reduction in both treatment arms. This supports current rehabilitation models that combine professional guidance with active self-management, an approach that is particularly relevant for common musculoskeletal disorders such as low back pain (Wallwork et al., 2024; Ferreira et al., 2023).

Limitations

Several limitations should be considered when interpreting the present findings. First, the sample size was small, with only 14 participants per group, and no formal a priori sample size calculation was performed. As acknowledged in the original article, the sample should therefore be considered a convenience sample. This limits both statistical precision and external validity, even though a significant between group difference was observed.

5. Conclusions

The findings of the present randomized controlled trial indicate that both the McKenzie method and the Williams exercise programme were effective in reducing pain intensity in patients with acute low back pain after a 30 day intervention period. However, the McKenzie group achieved a greater reduction in pain than the Williams group, suggesting superior short term effectiveness within the conditions of the present study.

These results support the use of exercise based rehabilitation in the conservative management of acute low back pain and suggest that the specific structure of the exercise programme may influence treatment response. In particular, a classification based and directional response oriented approach such as the McKenzie method may provide greater short term pain relief than a standardized flexion based programme in selected patients. This interpretation is consistent with current literature emphasizing the importance of individualized exercise prescription and patient centered rehabilitation strategies (George et al., 2021; Zhou et al., 2024; Hennemann et al., 2025).

At the same time, these findings should be interpreted with caution because of the small sample size, the short follow up period, and the use of pain as the only clinical outcome. Larger trials with broader outcome assessment and longer follow up are needed to confirm whether the observed advantage of the McKenzie method is maintained over time and generalizes to wider clinical populations.

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Physical Activity Behaviors, Sports Culture and Health Attitudes Among Medical Students: A Cross-Sectional Study

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Abstract

Background: Physical activity is essential for health, stress management, and functional capacity during medical training. For medical students, regular exercise may also support the development of healthy habits relevant to their future professional role in health promotion.

Objective: This study aimed to assess pre university sports participation, current physical activity habits, and sport related attitudes among first year medical students.

Results: A cross-sectional survey was conducted among 232 first year students at the “Carol Davila” University of Medicine and Pharmacy, Bucharest, Romania. Data were collected using an original 25 item online questionnaire. The results showed that 54.3% of participants had not practiced any sport outside compulsory physical education classes before university admission. At the time of the survey, 37.5% engaged in physical activity once or twice per week, while 18.1% reported occasional or no participation. The main motivation for exercise was maintaining or improving health, reported by 80.0% of respondents.

Conclusions: Medical students showed good awareness of the health benefits of physical activity, but actual participation remained limited. Universities should develop targeted strategies to promote regular physical activity among future healthcare professionals.

Keywords: medical students, physical activity, health promotion, lifestyle, sports culture, university health, exercise behavior.

1. Introduction

Physical activity is a core determinant of physical health, mental well being, and long term disease prevention across the life course. Current international guidance recommends that adults engage in 150 to 300 minutes of moderate intensity aerobic physical activity per week, or the equivalent amount of vigorous activity, while adolescents should accumulate an average of 60 minutes of moderate to vigorous physical activity per day. Despite the strength of this evidence, insufficient physical activity remains common worldwide, including among adolescents and young adults transitioning into higher education. This transition is particularly important because health related behaviors established during late adolescence and early adulthood often persist into later life and may influence future professional practice and social modeling. (Bull et al., 2020; Guthold et al., 2020; van Sluijs et al., 2021).

Medical students represent a particularly relevant population in this context. Their academic environment is highly demanding and often associated with stress, fatigue, sleep disruption, and reduced time available for self care. At the same time, future physicians are expected to promote healthy lifestyles, including physical activity, in clinical practice. This creates a dual imperative. Medical students need to maintain their own health during training, and they also need to develop the knowledge, attitudes, and credibility required to counsel patients effectively. Recent studies have shown that although medical students generally recognize the importance of physical activity, many report insufficient training in physical activity counseling, limited personal engagement in exercise, and significant barriers related to workload and time constraints. (Sahlqvist et al., 2022; Essa Hadad et al., 2022; Panton et al., 2024; Ip et al., 2024).

The relevance of this issue is reinforced by growing evidence linking physical activity to psychological resilience, lower depressive symptom burden, and better overall well being. A major meta analysis showed that even modest amounts of physical activity are associated with a lower risk of depression, with the greatest gains observed when individuals move from inactivity to some activity. In medical education settings, recent studies from Thailand, Latin America, Germany, Croatia, and broader university populations have shown that low activity levels, sedentary behavior, and poor lifestyle patterns remain common, while regular exercise is associated with better mental well being and lower stress or burnout indicators. Longitudinal evidence also suggests that the physical fitness of medical students may decline during the university years if active behaviors are not maintained. (Pearce et al., 2022; Dhachpramuk et al., 2024; Herreros Irarrázabal et al., 2024; Tang et al., 2024; Liebig et al., 2025; Vidović et al., 2025; Guerriero et al., 2025; Simões de Almeida et al., 2025).

However, the current literature still shows several limitations. First, many studies focus on only one dimension of the problem, such as current activity levels, mental health, counseling knowledge, or sedentary behavior, without integrating students' earlier sports background, present exercise habits, health motivations, and socio cultural engagement with sport in the same analytical framework. Second, most available studies come from Australia, North America, Asia, or selected Latin American settings, while evidence from Eastern Europe and Romania remains scarce. Third, first year students deserve separate attention because the transition into university is a critical stage in which pre university habits may either persist or rapidly deteriorate under academic pressure. These gaps are especially relevant for medical universities, where students' personal health behaviors may later influence their willingness and confidence to support behavior change in patients. (Sahlqvist et al., 2022; Herreros Irarrázabal et al., 2024; Ip et al., 2024; Al Zahrani et al., 2025; Kyriakoulakou et al., 2025; Liebig et al., 2025).

Against this background, the present study addresses an underexplored area by examining not only current physical activity behavior, but also pre university sports participation, family and socio cultural influences, motivations related to health, and students' broader engagement with the sports domain. Focusing on first year students from the "Carol Davila" University of Medicine and Pharmacy, this study offers context specific evidence from a Romanian medical university and contributes to the limited regional literature on the formation of active lifestyles in future healthcare professionals.

The novelty of the study lies in the integrated assessment of behavioral, attitudinal, and socio cultural dimensions of physical activity at the beginning of medical training.

Therefore, the aim of this study was to identify the sports behaviors and habits of students enrolled in academic medical education prior to university admission and to analyze their socio cultural perceptions and attitudes toward physical activity, leisure sport, and performance sport.

2. Materials and Methods

2.1. Study design

This study used a cross sectional observational design based on an online questionnaire survey. The study was conducted during the first weeks of the 2024 to 2025 academic year, in October 2024, at the "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania. The design was chosen to provide a descriptive overview of students' pre university sports participation, current physical activity habits, health related attitudes, and socio cultural engagement with sport at the beginning of medical training. This approach is consistent with reporting standards for cross sectional studies.

2.2. Participants

The study included 232 first year students enrolled in the basic physical education and sport course at the "Carol Davila" University of Medicine and Pharmacy. Of the total sample, 23.3% were male students, n = 54, and 76.7% were female students, n = 178. Regarding academic specialization, 53.4% of participants, n = 124, were enrolled in the Faculty of General Medicine, 29.3%, n = 68, in the Faculty of Pharmacy, and 17.2%, n = 40, in the Faculty of Dentistry. Most students were aged 20 to 21 years, 63.8%, n = 148, followed by those aged 18 to 19 years, 28.4%, n = 66, while 7.8%, n = 18, were older than 22 years.

2.3. Eligibility Criteria

Eligible participants were first year undergraduate students enrolled at the university during the 2024 to 2025 academic year, attending the compulsory physical education and sport course, and willing to complete the online questionnaire voluntarily. Students were included if they provided complete or sufficiently analyzable responses to the questionnaire. Students from other academic years, students not enrolled in the compulsory course, and questionnaires with substantial missing data were excluded from the analysis.

2.4. Ethical Considerations

Participation was voluntary and anonymous. Data were collected through Google Forms, and no personally identifiable information was reported in the database used for statistical processing. Before completing the questionnaire, students were informed about the purpose of the study and the academic use of the collected data. Completion of the questionnaire was considered to indicate informed consent for participation.

2.5. Outcome Measure

Data were collected using an original 25 item questionnaire structured into four sections. The first section included identification and demographic data. The second section assessed sports background prior to university admission, including participation in school physical education, extracurricular sports practice, duration of sports participation, and family involvement in sport. The third section explored attitudes toward physical activity and health, including perceived health benefits, immediate effects of exercise, current frequency of physical activity, motivations for exercise, and perceptions of the role of physical activity in public health. The fourth section examined sports culture and socio-cultural behaviors, including awareness of Romanian athletes and sports results, attendance at competitions, media consumption related to sport, and interest in sports related health information. The main outcome measures were descriptive indicators of pre university sports participation, current physical activity frequency, motivational profile, and sport related socio-cultural engagement.

2.6. Statistical Analysis

The questionnaire data were exported from Google Forms and processed using descriptive statistical methods. Absolute frequencies and percentages were calculated for categorical variables in order to summarize students' sports background, current physical activity habits, health related attitudes, and socio-cultural behaviors. Given the exploratory and descriptive purpose of the study, descriptive statistics were considered appropriate for the primary analysis. For a stronger version of the manuscript, suitable for a journal aiming toward Scopus level visibility, additional inferential analyses could be considered, such as chi square tests for associations between previous sports participation, family sport models, sex, faculty, and current physical activity frequency. STROBE reporting recommendations also encourage clear reporting of outcomes, summary measures, and, where relevant, adjusted estimates with precision.

3. Results

3.1. Participant characteristics

The study included 232 first year students enrolled at the "Carol Davila" University of Medicine and Pharmacy. Female students represented 76.7%, n = 178, and male students 23.3%, n = 54. Regarding faculty distribution, 53.4%, n = 124, were enrolled in General Medicine, 29.3%, n = 68, in Pharmacy, and 17.2%, n = 40, in Dentistry. Most participants were aged 20 to 21 years, 63.8%, n = 148, followed by those aged 18 to 19 years, 28.4%, n = 66, while 7.8%, n = 18, were older than 22 years.

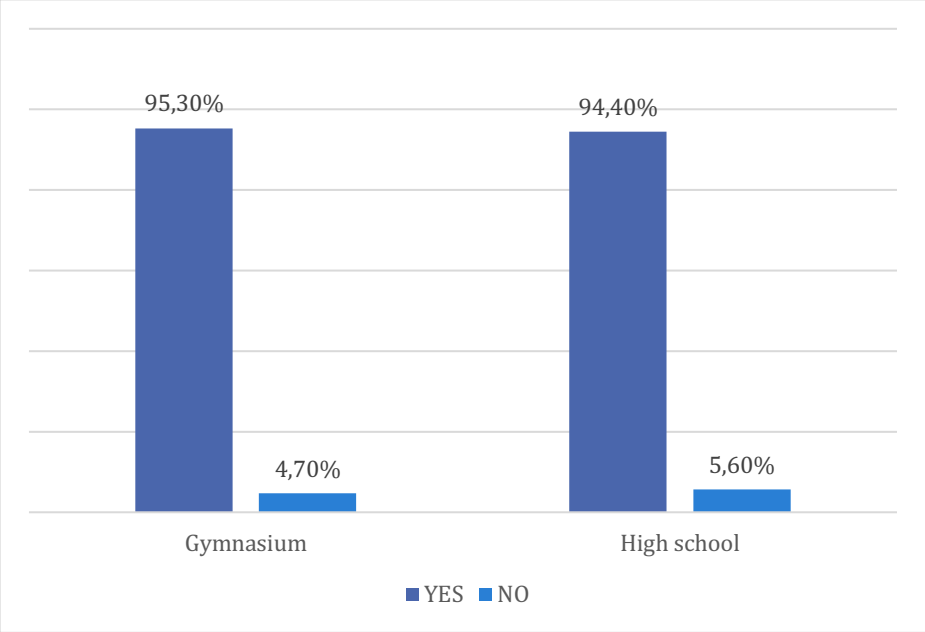


Figure 1. Items II.1 and II.3 - Did you actively participate (being fit for sports) in all the years of secondary school (grades V - VIII)/ (grades IX – XII) in Physical Education and Sports lessons?

II.2. and II.4. Also, in high school education (figure 1), the number of physical education lessons is two lessons per week lasting 50 minutes, thus it is found that 94.4% (n=119) of students attended these lessons being fit for physical activities and only 5.6% (n=13) of them were medically exempted, of the latter, most were exempted in the 12th grade, 84.6% (n=11) (table 1). From the above data, we can note an insignificant increase in the number of medically exempted students from one educational cycle to another (figure 1).

Table 1. Situation of medical exemptions by study class

Items II.2 & II.4.- If you did not participate and were medically exempted, mention in which class/classes?	
Gymnasium	**No. of medical exemptions**
Study class 5	6
Study class 6	5
Study class 7	9
Study class 8	8
High School	**No. of medical exemptions**
Study class 9	9
Study class 10	9
Study class 11	10
Study class 12	11

3.2. Sports background before university admission

Most students reported active participation in compulsory physical education classes during secondary school. In gymnasium, 95.3%, n = 221, attended physical education classes, while 4.7%, n = 11, were medically exempt. In high school, 94.4%, n = 219, participated, whereas 5.6%, n = 13, were medically exempt. Medical exemptions were most frequently reported in grade 7 during gymnasium and in grade 12 during high school.

When asked about sports practice outside compulsory school physical education before university admission, 54.3%, n = 126, reported no extracurricular sports participation, while 45.7%, n = 106, had practiced at least one sport. Among those who reported extracurricular participation, the most common sports were basketball, 21.42%, gymnastics and dance, 17.46%, swimming, 7.93%, contact sports, 7.93%, handball, 7.14%, tennis, 7.14%, volleyball, 6.34%, and football, 3.17%. The reported duration of sports participation ranged from 1 to 13 years, with a mean duration of 4.45 years.

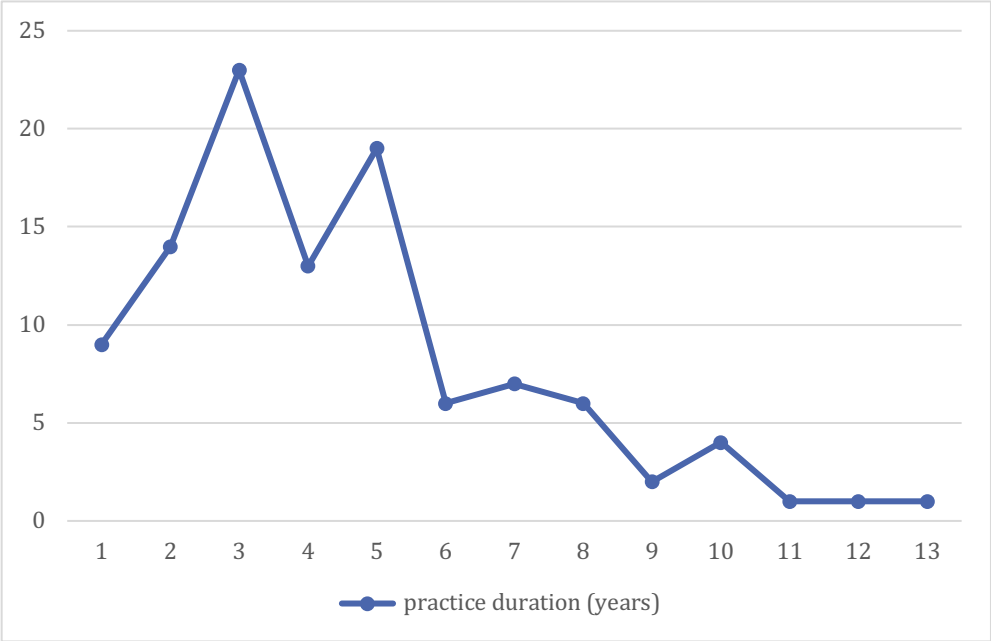


Figure 2. Item II.6.1: Specify for how long?

3.3. Family involvement in physical activity and sport

A total of 38.4%, n = 89, stated that at least one family member regularly practiced leisure time physical activity or sport. Competitive sport involvement in the family environment was reported less frequently, by 16.8% of respondents.

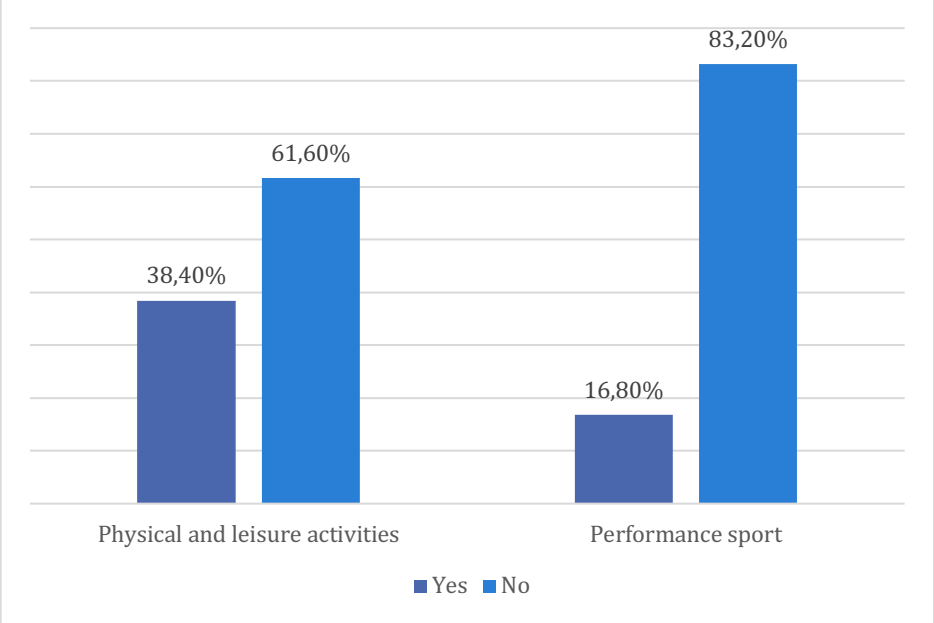


Figure 3. Items II.7 and II.8: Are there people in your family who practiced or are currently practicing sports and leisure activities / performance sports?

3.4. Physical activity, health attitudes, and exercise motivations

When asked to identify health conditions that may be prevented through physical activity, the most frequently mentioned were cardiovascular diseases, 142 mentions, obesity, 137 mentions, diabetes, 72 mentions, and rheumatic or osteoarticular disorders, 19 mentions.

Regarding the immediate effects perceived after exercise, responses included mainly physiological effects, such as increased heart rate, sweating, and fatigue, n = 80, psychological effects, such as well being and positive mood, n = 95, and combined physical and psychological effects, n = 47.

At the time of the survey, 37.5%, n = 87, reported engaging in physical activity outside the university curriculum once or twice per week. A further 19.4%, n = 45, exercised three or more times per week, 19.0%, n = 44, once per week, 6.0%, n = 14, one to three times per month, and 18.1%, n = 42, only occasionally or never.

Table 2. The time allocated to physical activities

Item III.3: Currently, how often do you regularly allocate time in your schedule for physical/sporting and leisure activities outside of the compulsory Sport and Physical Education lessons within the university?		
Frequency of practicing sports	Number of subjects	Percentage (%)
3 times a week or more	45	19.4
once or twice a week	87	37.5
once a week	44	19
once to three times a month	14	6
occasionally / I don't know / never	42	18.1

The main reason for engaging in physical activity was maintaining or improving health, immunity, and longevity, reported by 80.0%, n = 152. Other common motivations were stress reduction and relaxation, 71.6%, n = 136, weight regulation and body image, 71.1%, n = 135, and wellbeing, satisfaction, pleasure, and fun, 60.5%, n = 115. Fewer students selected maintaining or improving physical abilities, 47.9%, n = 91, lifestyle and socialization related reasons, 30.5%, n = 58, or competitiveness, 12.6%, n = 24.

The perceived role of physical activity as a preventive component of public health policy was rated as very important by 67.2%, n = 156, whereas only 2.2%, n = 5, considered it not important at all. Regarding the impact of the COVID 19 pandemic on perceptions of exercise, 25.4%, n = 59, stated that it changed their perspective to a very great extent, 21.6%, n = 50, to some extent, and 24.1%, n = 56, very little.

Table 3. Motivation to practice physical activities

Item III.4: What are the reasons for which you allocate the above time, namely practicing physical activities?		
Response	Number of choices	Percentage (%)
to maintain/improve my health/immunity and extend my life	152	80
maintaining/improving physical abilities	91	47.9
weight regulation, beautiful and harmonious body	135	71.1
reduction of stress factors, relaxation	136	71.6
well-being, satisfaction, pleasure, fun	115	60.5
lifestyle: socializing, new friends, physical exercises are in trend	58	30.5
I like competition, I like to win	24	12.6

3.5. Sports culture and socio-cultural engagement

When asked to identify the Romanian sport with the best recent international results, students most frequently mentioned tennis, 30.17%, n = 70, swimming, 29.74%, n = 69, and gymnastics, 11.63%, n = 27. Other sports were mentioned less often, while 11.20%, n = 26, provided invalid responses.

Regarding Romanian athletes known and appreciated by the respondents, the most frequently mentioned were Simona Halep, 29.74%, n = 69, David Popovici, 26.29%, n = 61, and Nadia Comăneci, 15.09%, n = 35. Other athletes received substantially fewer mentions, and 12.07%, n = 28, of responses were invalid.

Table 4. Sports with the best results

Item IV.1: Currently, in our country, which do you think is the sport with the best performances on the international level (Olympics, WC, EC)?		
Sports	Number of answers	Percentage (%)
Tennis	70	30.17
Swimming	69	29.74
Gymnastics	27	11.63
Handball	14	6.03
Football	13	5.60
Rowing	3	1.29
Basketball	3	1.29
Athletics	3	1.29

Canoe	2	0.86
Fencing	1	0.43
Volley-ball	1	0.43
Invalid answers	26	11.20

Table 5. Athletes with the best results

Item IV.2: Name a Romanian athlete with outstanding sports performances that you know and appreciate.		
Athlete	Number of answers	Percentage (%)
Simona Halep	69	29.74
David Popovici	61	26.29
Nadia Comaneci	35	15.09
Gheorghe Hagi	7	3.02
Cristina Neagu	6	2.59
Larisa Iordache	5	2.16
Ana Maria Branza	4	1.72
Various athletes	17	7.33
Invalid answers	28	12.07

Most students, 75.0%, n = 174, had attended at least one sports competition as spectators, while 25.0%, n = 58, had never done so. Among those who had attended such events, 27.6%, n = 48, had done so within the last month, 10.9%, n = 19, within the previous one to two months, and 62.1%, n = 108, more than two months before questionnaire completion. In addition, 63.4%, n = 147, reported recently watching sports competitions through television, live streaming, or social media.

Table 6. Watching competitions

Item IV.4: Have you physically participated in any sports competition as a spectator?		
Yes	174	75
No	58	25
Item IV.5: When was the last time you were a spectator at a sporting event?		
In the last month	48	27.6
Between one and two months	19	10.9
More than two months	108	62.1
Item IV.6: Have you recently watched sports competitions live on social media?		
Yes	147	63.4
No	85	36.6
Response	**Number of answers**	**Percentage (%)**

Interest in sports related information was also evident. A total of 58.6%, n = 136, reported that they read or followed news related to athletes or sports events, while 81.9%, n = 190, stated that they had noticed or were interested in articles and materials about physical activity as a means of maintaining or improving health.

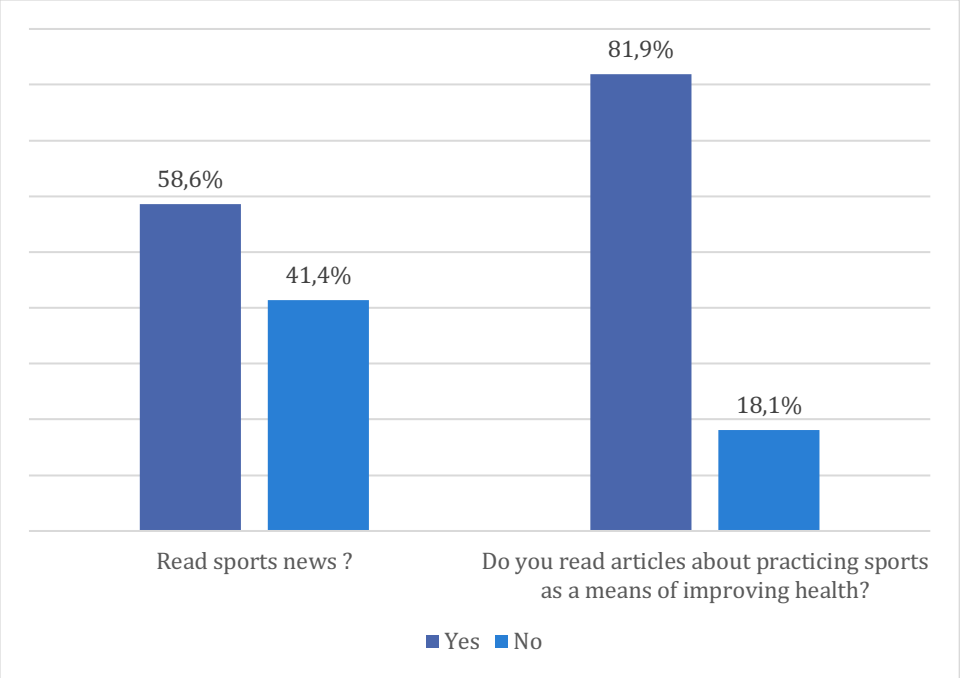


Figure 4. Item IV.7 and IV.8 - Do you read on social media, but not only, news related to the activity of athletes and/or about sports events?/ In social media, but not only, have you noticed or been interested in articles/materials about practicing sports as a means of improving health?

4. Discussion

The present study provides a cross sectional perspective on physical activity behaviors, prior sports experience, and sport related attitudes among first year medical students. The findings suggest a clear contrast between knowledge and behavior. Although most participants demonstrated awareness of the health benefits of physical activity and recognized its preventive value, regular engagement in exercise remained modest. This pattern is consistent with the broader literature showing that health related knowledge alone does not guarantee sustained healthy behavior, even among students preparing for healthcare professions. Recent studies among medical and healthcare students have similarly reported that awareness and positive attitudes toward physical activity often coexist with suboptimal practice, indicating a persistent knowledge behavior gap in this population (Babenko & Mosewich, 2017; Babenko et al., 2020; Sahlqvist et al., 2022; Kandasamy et al., 2024; Al Zahrani et al., 2025).

A central finding of the present study is that more than half of the respondents reported no sports participation outside compulsory school physical education before university admission. This result is important because previous sports involvement may influence both present exercise patterns and broader attitudes toward movement, self discipline, and health maintenance. Earlier work suggested that sports background can shape students' perceptions of the learning environment and support healthier routines during medical school, and our findings are compatible with that view. More recent evidence from Latin America and other university settings also indicates that physical activity and sedentary behavior vary substantially according to demographic and educational factors, while transitions from adolescence to young adulthood often bring a decline in active behavior if these habits are not consolidated earlier (Babenko et al., 2020; Herreros Irarrázabal et al., 2024; van Sluijs et al., 2021).

The high rate of participation in compulsory physical education during secondary school, alongside the relatively low proportion of medical exemptions, suggests that most students had at least a basic level of exposure to organized physical activity before entering university. However, this exposure did not

translate consistently into extracurricular sports participation or regular physical activity in early adulthood. This distinction matters because school based physical education may provide access and minimum exposure, but it does not automatically ensure long term internalization of active lifestyles. The literature increasingly emphasizes that sustainable physical activity in young adults depends on broader ecological influences, including family support, social norms, perceived competence, and the ability to adapt prior habits to new academic environments (Institute of Medicine of the National Academies, 2013; van Sluijs et al., 2021; Cao et al., 2023).

Family influence also appears relevant in our sample. Only a minority of students reported regular leisure time physical activity within the family, and an even smaller proportion reported exposure to competitive sport in the family environment. This supports the idea that family based modeling may contribute to the formation of active behavior, but it may be insufficiently present even in academically high achieving groups such as medical students. Recent research on transitions from adolescence to adulthood has shown that changes in social support are associated with physical activity trajectories, while university students' health behaviors are shaped not only by individual motivation but also by the social context in which those behaviors develop (Rodicio García et al., 2020; Cao et al., 2023; Geantă et al., 2025). The Romanian context may be especially important here, because local university data also indicate variability in physical fitness and the need for targeted programs adapted to student profiles and academic contexts.

Our results also show that students' motivations for physical activity were predominantly health related, followed by stress reduction, body image, and general well being, while competitiveness was selected much less frequently. This motivational pattern is meaningful. It suggests that these students do not primarily perceive exercise through a performance lens, but rather through a preventive and self regulatory one. Similar patterns have been observed in contemporary healthcare student populations, where students often express positive beliefs about the role of exercise for long term health and emotional balance, while reporting lower engagement when activity competes with academic pressures, time constraints, or fatigue (Kandasamy et al., 2024; Al Zahrani et al., 2025; Ip et al., 2024). These results may be useful for universities, because interventions framed around stress reduction, energy management, and health protection may resonate better with medical students than interventions framed around competition or performance.

The discrepancy between students' strong awareness of the preventive role of physical activity and their modest actual practice deserves particular attention. In our sample, many students identified cardiovascular disease, obesity, and diabetes as conditions that can be prevented through physical activity, and most rated the public health importance of exercise highly. Even so, only a minority reported frequent engagement in physical activity. This gap is also reflected in recent literature showing that healthcare students may possess acceptable knowledge and favorable attitudes, yet fail to consistently meet physical activity recommendations. In Saudi Arabia, for example, healthcare students showed good knowledge and positive attitudes, but only part of the sample achieved satisfactory practice levels. A similar pattern appears in wider medical student literature, where adherence is shaped by time burden, competing priorities, and environmental barriers rather than by lack of awareness alone (Kandasamy et al., 2024; Al Zahrani et al., 2025; Ip et al., 2024).

The mental health relevance of these findings should also be emphasized. Medical education is often associated with stress, anxiety, emotional exhaustion, and risk of burnout, and this context makes physical activity especially important. A growing body of evidence after 2020 has shown that physical activity is associated with lower depression, anxiety, and stress symptoms in university populations. A large meta analysis in undergraduate students found that physical activity interventions can reduce symptoms of anxiety, depression, and stress, although the quality of intervention reporting remains uneven. More specific studies in medical students from Thailand, Croatia, and China also indicate that

lower physical activity is associated with poorer mental health outcomes, whereas exercise appears to function as a protective factor (Pearce et al., 2022; Huang et al., 2024; Dhachpramuk et al., 2024; Vidović et al., 2025; Zhang et al., 2025). Our results do not directly test these associations, but the fact that students frequently reported relaxation, stress reduction, and psychological well being among the immediate effects and motivations of exercise is highly consistent with this literature.

Another relevant dimension is the professional role of future physicians. Medical students are not only a population at risk of inactivity under academic pressure, they are also future health promoters. This makes their own relationship with physical activity particularly important. Research published in recent years has highlighted that medical students often receive limited formal education on physical activity counseling, despite recognizing its value. One multi school survey reported that only a small proportion of students had received formal training in physical activity counseling, while many believed that this content should be required in medical education. Systematic review evidence similarly suggests that educational interventions in medical training may improve perceptions and practices related to physical activity counseling and exercise prescription (Panton et al., 2024; Shivgulam et al., 2024; Schlegel et al., 2025). Against this background, our findings support the need for medical schools to promote not only students' own physical activity, but also curricular experiences that connect personal lifestyle habits with future patient counseling competencies.

The sports culture dimension of the present study adds an interesting perspective that is less frequently explored in comparable research. Students showed moderate interest in sports news and events, and many had attended sports competitions as spectators. At the same time, their perceptions of the Romanian sports with the best international results did not always align with official performance data. This suggests that sport related awareness in this group may be shaped more by media visibility and symbolic athletes than by consistent, evidence based knowledge of national sports performance. From a behavioral perspective, this matters because social representation, media exposure, and role model salience may influence the symbolic value of sport even when they do not directly translate into regular personal practice. Our data therefore extend the discussion beyond physical activity frequency alone and suggest that socio cultural engagement with sport may be an important, though indirect, component of active lifestyle formation.

The present study has practical implications for universities. The first year of medical training appears to be a key window for intervention, because students enter university with heterogeneous sports backgrounds and may rapidly consolidate either active or inactive routines. Institutions should consider low threshold, health oriented programs that fit the realities of medical training, including flexible exercise opportunities, peer supported initiatives, curricular links with lifestyle medicine, and campaigns that frame physical activity as a strategy for stress management, self care, and future professional credibility. This direction is consistent with recent evidence supporting lifestyle medicine integration, stronger physical activity education in medical curricula, and interventions tailored to students' daily constraints and motivations (Essa Hadad et al., 2022; Panton et al., 2024; Ip et al., 2024).

This study should also be interpreted in light of several limitations. The findings are based on self reported data from a single medical university and may not be generalizable to all Romanian students or to other academic contexts. The cross sectional design does not allow causal inference, and the use of an original questionnaire limits comparability with studies using internationally standardized instruments. In addition, the sample was predominantly female, and no inferential analysis was conducted to test subgroup differences or predictors of current physical activity. Even so, the study provides useful contextual evidence from an Eastern European medical university and addresses an area that remains insufficiently represented in the international literature, especially when pre university sports background, motivation, and socio cultural engagement are examined together.

Overall, the findings reinforce a conclusion increasingly visible in the literature. Medical students tend to value physical activity and understand its importance, yet this awareness is not always transformed into stable and frequent practice. In this sense, our results support previous observations from both the original references in the manuscript and newer international studies. They also underline the need for universities to move beyond general health messaging and create concrete, context sensitive opportunities that help future healthcare professionals become both active individuals and credible promoters of physical activity in society.

5. Conclusions

This study showed that first year medical students had a generally good level of awareness regarding the health benefits of physical activity, but this awareness was not fully reflected in their actual behavior. Although most participants recognized the preventive role of physical activity and associated exercise with health maintenance, stress reduction, and well being, regular participation in physical activity outside the compulsory university curriculum remained limited.

The findings also suggest that previous exposure to sport, participation in school physical education, family influence, and broader socio cultural engagement with sport may contribute to the development of active lifestyles, but these factors alone do not ensure stable exercise habits during the transition to university. This stage appears to be especially important for medical students, whose academic demands may interfere with the adoption or maintenance of healthy routines.

From an educational and public health perspective, these results are relevant because medical students are future healthcare professionals who will be expected to promote healthy behaviors in the general population. Universities should therefore develop structured and accessible strategies that encourage regular physical activity, support stress management, and strengthen the connection between personal lifestyle practices and future professional responsibilities.

Despite its limitations, including the cross sectional design, self reported data, and single center sample, the study contributes useful evidence on the behavioral, attitudinal, and socio cultural dimensions of physical activity in Romanian medical students at the beginning of their academic training.

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Institutional Review Board Statement: According to the institutional regulations in force at the time of the study, ethical review was not required for this anonymous questionnaire-based survey. The study was conducted in accordance with the Declaration of Helsinki, and participation was voluntary and anonymous.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Participation was voluntary, and completion of the online questionnaire was considered to indicate informed consent.

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Conflicts of Interest: The authors declare no conflict of interest.

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Tempo–Spatial Synergy in Elite Basketball Performance: A Multivariate Analysis

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Abstract

Background: Elite basketball performance has changed substantially in recent years due to the growing importance of game tempo, spatial organization, and data driven tactical models. While traditional indicators such as shooting percentage, rebounds, and turnovers remain relevant, they do not fully capture the dynamic interaction between temporal and spatial factors that shape offensive efficiency in modern basketball.

Objective: This study aimed to examine the individual and combined effects of game pace and spatial efficiency on offensive performance in elite basketball, with a particular focus on their potential synergistic relationship.

Results: A total of 240 games from elite European and international competitions were analyzed using a quantitative observational design. Game pace, spacing index, and offensive rating were included as the main variables. Pearson correlation analysis showed significant positive associations between pace and offensive rating, and between spacing index and offensive performance. Hierarchical multiple regression revealed that both pace and spacing efficiency were significant predictors of offensive rating, with spacing emerging as the stronger predictor. In addition, the interaction term between pace and spacing was statistically significant, indicating that the positive effect of one variable increased when the other was also optimized.

Conclusions: The findings support the concept of tempo spatial synergy and suggest that elite basketball performance is enhanced when teams integrate high tempo with effective spatial organization. These results are relevant for coaching, player development, and applied performance analysis.

Keywords: elite basketball, game pace, spatial organization, spacing index, offensive performance, performance analysis.

1. Introduction

Over the last two decades, elite basketball has undergone a substantial transformation shaped by the expansion of performance analytics, the growing use of player tracking systems, and the tactical reconfiguration of offensive play. While traditional game related statistics such as shooting efficiency,

rebounds, assists, and turnovers remain important, recent scholarship has shown that modern performance analysis increasingly depends on the integration of temporal, spatial, and contextual information. In particular, the growing availability of fine grained tracking and event data has shifted research attention from isolated box score variables toward dynamic models capable of capturing how teams create advantages in real game situations (Sampaio et al., 2015; Ibáñez et al., 2018; Cervone et al., 2014; Rein & Memmert, 2016; Zuccolotto et al., 2021; O'Brien et al., 2023; Chen et al., 2025).

This evolution is especially visible in the study of offensive performance. Recent work has highlighted that successful basketball offenses are not defined only by conversion rates, but also by the quality of possessions, the timing of actions, the organization of line ups, and the spatial conditions under which decisions are made. Research on rotation structures, secondary assists, long term shooting trends, quarter by quarter performance patterns, and expected action value has shown that modern offensive success emerges from coordinated interactions between player positioning, ball movement, possession structure, and decision making under pressure (Kolias et al., 2022; Supola et al., 2022; Zając et al., 2023; Iatropoulos et al., 2025; Jutamulia & Hosoi, 2025).

Within this broader analytical shift, game pace has remained one of the most widely discussed indicators of team style and performance. Traditionally operationalized as possessions per game, pace influences the number of scoring opportunities, the rhythm of tactical execution, and the physical and cognitive demands imposed on players. However, recent evidence suggests that pace should not be treated as a uniform or purely linear variable. More recent studies have shown that game tempo fluctuates within games, interacts with contextual constraints, and may influence success differently depending on possession timing, game state, and offensive structure. Studies on intra game pace dynamics, offensive duration, playoff qualification variables, and late game offensive patterns support the view that tempo is a meaningful but context dependent contributor to performance (Oliver, 2004; Sampaio et al., 2006; Zhang et al., 2025; Amatria Jiménez et al., 2025; Kamitsis & Politis, 2025; Vázquez Estévez et al., 2025).

At the same time, spatial organization has become a central topic in basketball analytics. Advances in spatial statistics, tracking based evaluation, and graph oriented approaches have reinforced the idea that offensive quality is strongly shaped by the way teams occupy the court, stretch defensive structures, and generate open or high value shooting situations. Studies on spatial performance indicators, shot quality, possession outcome patterns, and critical offensive scenarios have demonstrated that space creation, spatial dispersion, and coordinated ball movement are essential for producing efficient offenses in elite competitions (Gudmundsson & Horton, 2017; Zuccolotto et al., 2021; Supola et al., 2022; Jiao et al., 2025; Vázquez Estévez et al., 2024; Vázquez Estévez et al., 2025).

Recent basketball research has also broadened the methodological toolkit used to examine performance. Systematic review evidence indicates that the field is moving toward more complex models that combine event data, tracking data, machine learning, spatial statistics, and contextual analysis, yet also shows that many studies still isolate variables that are likely to interact in competition. Parallel work using markerless motion capture, player performance pattern mining, and game performance load relationships further confirms the growing interest in integrated, multilevel frameworks for understanding performance in basketball settings (Chen et al., 2025; Qiu et al., 2025; Espasa Labrador et al., 2025; Miró et al., 2024; Iatropoulos et al., 2025).

Despite these advances, an important gap remains in the literature. Most basketball studies still examine pace, shot selection, passing behavior, lineup structure, or spatial indicators as relatively separate dimensions of performance. There is still limited evidence on how temporal rhythm and spatial organization operate together within a unified analytical model, especially in elite basketball contexts. This gap is important because high pace without effective spatial distribution may reduce shot quality and decision stability, while good spacing without sufficient tempo may fail to maximize possession value. In

other words, modern offensive efficiency may depend less on the isolated strength of tempo or spacing and more on their interaction. Current research strongly supports the importance of each domain, but provides much less evidence on their combined explanatory power (Zuccolotto et al., 2021; Supola et al., 2022; Chen et al., 2025; Zhang et al., 2025; Jutamulia & Hosoi, 2025; Jiao et al., 2025).

The novelty of the present study lies in its attempt to connect these two dimensions, tempo and spatial efficiency, within the same explanatory framework and to test whether their relationship is additive or synergistic. Rather than treating pace as a standalone stylistic variable or spacing as an isolated tactical descriptor, this study approaches offensive performance as the product of coordinated temporal and spatial organization. This perspective aligns with the current direction of basketball analytics, which increasingly values interaction based and context sensitive models of play, but it remains underdeveloped in the existing basketball literature (Chen et al., 2025; Kamitsis & Politis, 2025; Vázquez Estévez et al., 2024; Vázquez Estévez et al., 2025).

Accordingly, the aim of this study was to examine the individual and combined influence of game pace and spatial efficiency on offensive performance in elite basketball. More specifically, the study sought to analyze the relationship between pace and offensive rating, assess the contribution of spatial organization to scoring efficiency, and test whether a significant interaction exists between these two variables. Based on previous literature, it was hypothesized that both pace and spatial efficiency would positively predict offensive performance, and that teams combining higher tempo with more effective spatial organization would achieve superior offensive outcomes.

2. Materials and Methods

2.1. Study design

This study employed a quantitative, observational, retrospective, and correlational research design to investigate the relationship between game pace, spatial efficiency, and offensive performance in elite basketball. The analysis was based on official game statistics collected from high level European and international competitions across two competitive seasons.

A cross sectional analytical approach was used, with each game representing one observational unit. The study was designed to assess both the individual contribution of temporal and spatial performance indicators and their combined interaction effect on offensive efficiency. In this context, hierarchical multiple regression was selected as the main analytical method, as it allows the examination of incremental explanatory power across successive statistical models.

2.2. Participants

The sample consisted of 240 official elite basketball games selected from European and international male competitions, including top level professional tournaments such as EuroLeague and FIBA events. These competitions were chosen because they represent a high standard of tactical organization, technical execution, and performance consistency.

The unit of analysis was the game. Only matches involving professional senior male teams competing under official regulations were considered. Data were extracted exclusively from publicly available official statistical reports and performance databases. The selected sample was considered appropriate for identifying stable relationships among offensive performance indicators in elite basketball contexts.

2.3. Eligibility Criteria

Games were included in the study if they met all of the following criteria:

- they were played in official elite level basketball competitions,

- complete statistical records were publicly available,
- all variables required for the analysis could be calculated consistently,
- the matches were played under standard competitive conditions.

Games were excluded if they presented incomplete box score data, missing variables relevant to the study, duplicated records, or inconsistencies between official sources. Friendly matches, youth competitions, and non official games were not considered.

2.4. Ethical Considerations

The study was based exclusively on publicly accessible anonymized performance data obtained from official basketball competition records. No direct contact with athletes, coaches, or teams was required, and no personal, medical, or identifiable information was collected.

Because the analysis relied entirely on secondary data from public sources, formal ethical committee approval was not required according to institutional research guidelines for non interventional studies using publicly available datasets. The study was conducted in accordance with the general ethical principles of scientific research, including data accuracy, transparency, and responsible reporting.

2.5. Outcome Measure

The primary outcome measure was Offensive Rating, defined as the number of points scored per 100 possessions. This indicator was selected because it reflects offensive efficiency independently of raw game volume and is widely used in basketball performance analysis.

The main predictor variables were:

- Game Pace, defined as the estimated number of possessions per game.
- Spacing Index, defined as a composite indicator intended to reflect team spatial efficiency during offensive play. In the present study, this index was operationalized using standardized game related variables associated with ball movement and offensive distribution patterns.
- Assist Ratio, defined as the proportion of field goals that were assisted, was also included as a complementary offensive organization indicator.

In addition, an interaction term was created by multiplying the standardized values of game pace and spacing index. This interaction variable was introduced to examine whether the relationship between tempo and offensive performance depended on the level of spatial efficiency.

All variables were calculated from official game statistics and entered into a structured dataset for further analysis.

2.6. Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics, version 26. Descriptive statistics were first calculated for all study variables, including mean values and standard deviations, in order to summarize the distribution of the dataset.

Pearson correlation coefficients were then computed to examine the bivariate associations between game pace, spacing index, assist ratio, and offensive rating. Correlation strength was interpreted according to conventional thresholds.

To assess the predictive contribution of the independent variables, hierarchical multiple regression analysis was conducted with Offensive Rating as the dependent variable. Prior to regression modelling, the predictor variables were standardized using z scores in order to reduce multicollinearity and facilitate the interpretation of the interaction term.

The regression analysis was conducted in three successive models:

- Model 1 included the main predictors, game pace and spacing index.
- Model 2 added assist ratio as an additional offensive organization variable.
- Model 3 introduced the interaction term between pace and spacing index.

This stepwise approach allowed the evaluation of both direct and incremental effects across models. Standardized beta coefficients, coefficients of determination, and significance levels were used to interpret the results. Statistical significance was set at $p < 0.05$.

Before conducting the regression analysis, the assumptions of linearity, normality, independence of errors, and homoscedasticity were examined through residual diagnostics. Multicollinearity was assessed using tolerance and variance inflation factor values. No critical violations were identified, and the data were considered suitable for regression modelling.

Spacing Index was treated as a proxy measure of offensive spatial efficiency, derived from standardized indicators associated with ball circulation and shot distribution rather than direct positional tracking data.

2.7. Variables

Dependent Variable

• Offensive Rating (ORtg): Points scored per 100 possessions (Oliver, 2004).

Independent Variables

• Game Pace: Number of possessions per game.

• Spacing Index: The spacing index was computed as a composite standardized measure combining assist ratio and shot distribution variability across games, serving as a proxy indicator of team spatial organization.

• Assist Ratio: Percentage of field goals assisted.

Interaction Variable

• Pace × Spacing: Product of standardized pace and spacing variables.

3. Results

Descriptive statistics for the main study variables are presented in Table 1. The mean game pace was 72.4 possessions per game, with a standard deviation of 5.8. The average offensive rating was 112.3 points per 100 possessions, while the mean spacing index was 0.68. Assist ratio showed a mean value of 0.59, indicating moderate variability in offensive organization across the analyzed games.

Table 1. Descriptive statistics of Study Variables

Variable	Mean	SD
Game Pace (possessions)	72.4	5.8
Offensive Rating	112.3	8.6
Spacing Index	0.68	0.09
Assist Ratio	0.59	0.07

3.2. Correlation Analysis

Pearson correlation coefficients are presented in Table 2. Game pace was positively correlated with offensive rating, indicating that faster games were associated with higher offensive efficiency. Spacing index showed a stronger positive correlation with offensive rating, suggesting that teams with better spatial organization tended to achieve higher offensive performance. Assist ratio was also positively associated

with offensive rating. In addition, positive associations were observed among the predictor variables, although these did not indicate problematic overlap.

3.3. Hierarchical Multiple Regression

A hierarchical multiple regression analysis was conducted to examine the extent to which game pace, spacing index, assist ratio, and the interaction between pace and spacing predicted offensive rating. The results are shown in Table 3.

In Model 1, game pace and spacing index were entered as main predictors and explained a substantial proportion of variance in offensive rating. In Model 2, the addition of assist ratio produced a small increase in explained variance. In Model 3, the inclusion of the interaction term between pace and spacing further improved the model. The final model explained 58% of the variance in offensive rating and was statistically significant.

In the final model, spacing index emerged as the strongest predictor of offensive rating, followed by game pace. The interaction term was also statistically significant, indicating that the association between pace and offensive performance was stronger when spatial efficiency was higher.

3.4. Graphical Representation of the Main Associations

Figure 1 illustrates the relationship between game pace and offensive rating, showing a moderate positive trend. Figure 2 presents the association between spacing index and offensive rating, revealing a stronger positive relationship. These graphical patterns are consistent with the correlation and regression results.

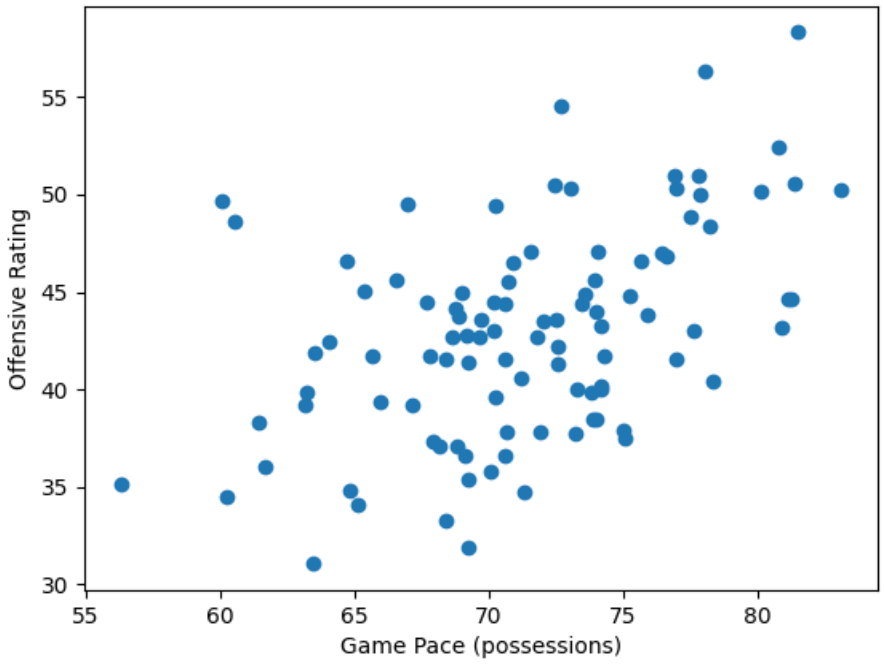


Figure 1. Relationship between game pace and offensive rating

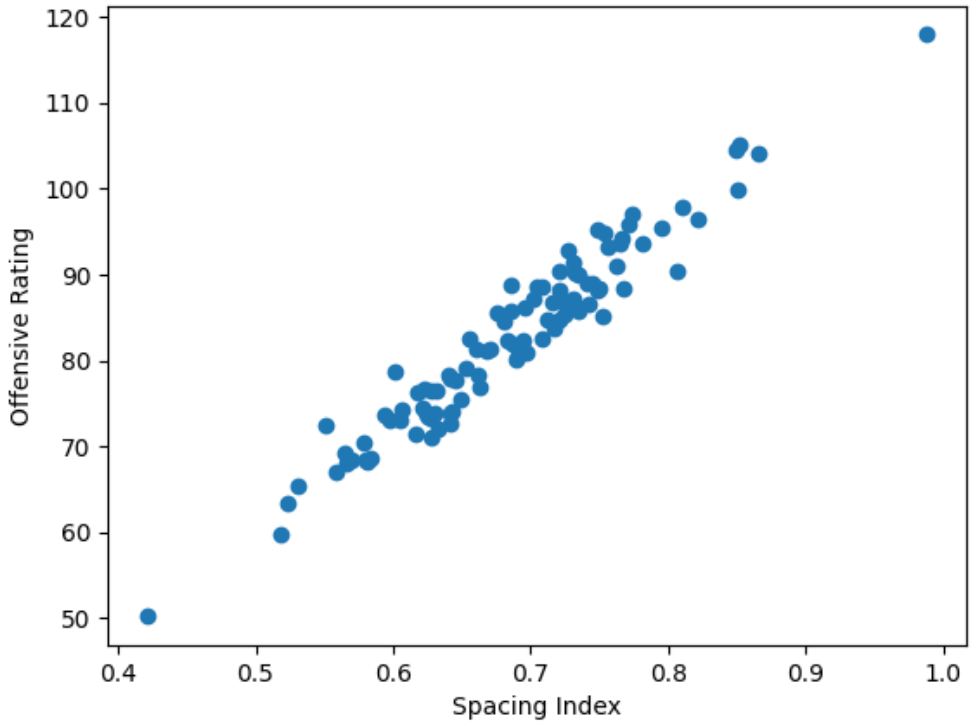


Figure 2. Relationship between spacing index and offensive rating

4. Discussion

The present study examined the individual and combined contribution of game pace and spatial efficiency to offensive performance in elite basketball. The findings showed that both variables were significant predictors of offensive rating, while the interaction term between pace and spacing also reached statistical significance. These results support the central premise of the study, namely that offensive effectiveness in elite basketball is not shaped only by isolated technical indicators, but also by the coordinated relationship between temporal rhythm and spatial organization.

The positive association identified between game pace and offensive performance is consistent with earlier basketball analytics research that has linked a greater number of possessions with increased scoring opportunity and offensive output. In the context of the present study, this relationship suggests that teams capable of sustaining a faster rhythm may create more frequent attacking situations and impose greater tactical stress on the defense. At the same time, recent literature indicates that pace should not be understood as a simple volume indicator. Current studies show that tempo varies within games, depends on contextual constraints, and may have different competitive value depending on possession timing, game state, and tactical execution. This interpretation strengthens the present findings, because it suggests that the positive effect of pace is more meaningful when it is embedded in an efficient offensive structure rather than used as an isolated stylistic feature (Oliver, 2004; Sampaio et al., 2006; Zhang et al., 2025; Amatria Jiménez et al., 2025).

A particularly important result of the current study is that spacing index emerged as the strongest predictor of offensive rating. This finding is in line with recent evidence emphasizing the growing relevance of spatial conditions in offensive success. Contemporary basketball research has shown that the quality of possessions depends heavily on how teams occupy the court, how they move the ball, and how they manipulate defensive spacing to generate higher value shots. Studies based on spatial indicators, technical tactical pattern analysis, and tracking derived variables suggest that offensive efficiency is strongly influenced by coordinated player positioning and the creation of advantageous shooting

conditions. In this regard, the present results reinforce the idea that spatial organization should be treated as a central component of performance analysis rather than a secondary tactical detail (Gudmundsson & Horton, 2017; Zuccolotto et al., 2021; Jiao et al., 2025; Vázquez-Estévez et al., 2025).

The significant interaction between pace and spacing represents the main contribution of this study. This result suggests that the effect of pace on offensive performance becomes stronger when spatial efficiency is also higher, and conversely, that the value of good spacing is amplified when teams are able to play at a higher tempo. This pattern supports the concept of tempo spatial synergy proposed in the article. Recent basketball literature provides indirect support for this interpretation. Studies on offensive patterns in critical moments, one possession scenarios, and applied performance modelling indicate that successful offensive sequences depend on coordinated timing, spacing, and decision making rather than on one isolated variable. Similarly, systematic review evidence shows that the field increasingly recognizes the need for integrated analytical frameworks, especially when fine grained event and tracking data are available. The present study contributes to this developing direction by showing that a combined temporal and spatial perspective can explain offensive output more effectively than a fragmented approach.

From a comparative perspective, the current findings are also consistent with recent studies showing that successful basketball teams are distinguished not only by classical game related statistics, but also by possession quality, offensive organization, shot profile, and adaptive tactical behavior. Research on EuroLeague success indicators, offensive sequences under pressure, and machine learning based performance models has shown that modern offensive success is shaped by multidimensional interactions among technical, tactical, and contextual variables. In this sense, the present study complements this body of work by highlighting that two broad organizing dimensions, tempo and spatial efficiency, may capture part of this complexity in an interpretable and practically useful way.

The practical implications of these findings are relevant for coaching and applied performance analysis. First, coaches should avoid treating pace as a purely stylistic identity marker and should instead connect it with floor balance, spacing discipline, and ball movement quality. Second, offensive training should include constraints that require players to preserve spatial efficiency under higher tempo conditions, because the present findings suggest that offensive success depends on the coexistence of both qualities. Third, analysts may benefit from combining standard game related indicators with spatially informed measures when evaluating offensive systems, especially in elite contexts where small tactical advantages can have meaningful effects on scoring efficiency. These implications are also consistent with recent work stressing the importance of data informed tactical evaluation and more context sensitive modelling in basketball performance analysis.

At the same time, the results should be interpreted within the boundaries of several limitations. The first limitation concerns the operationalization of spatial efficiency. In the present study, the spacing index was derived from proxy indicators rather than from direct positional tracking data. Although this approach allowed the inclusion of a spatially oriented variable using publicly available information, it cannot capture court occupation with the same precision as true tracking based metrics. Recent literature makes clear that many of the most informative spatial variables in basketball, such as inter player distances, defensive pressure angles, and dynamic occupation patterns, are best derived from fine grained spatiotemporal datasets. Therefore, the spacing indicator used here should be interpreted as an indirect estimate of offensive spatial organization rather than a direct measurement of spacing itself.

A second limitation is related to the observational and retrospective nature of the design. Because the study relied on secondary game data, the observed relationships cannot be interpreted as causal. It is therefore not possible to conclude that increasing pace or improving spacing will necessarily produce a direct rise in offensive rating in all contexts. Instead, the findings indicate robust associations within the analyzed sample. This limitation is common in basketball performance analysis and has also been noted

in recent review literature, which highlights the continued dominance of descriptive and correlational designs despite the increasing availability of richer datasets.

A third limitation concerns contextual specificity. The sample included elite level games from high performance competitions, which supports the relevance of the findings for professional basketball but may reduce generalizability to youth, amateur, or women's competitions. The literature suggests that contextual and competitive structures may shape offensive behavior differently across levels of play and competitive scenarios. For this reason, the present findings should be generalized cautiously and preferably within comparable elite male environments.

A further issue that should be acknowledged in a stronger article discussion is model scope. Offensive rating is a meaningful efficiency outcome, but it does not fully represent all dimensions of offensive quality. It summarizes points per 100 possessions, yet it does not directly isolate decision quality, shot quality, lineup interactions, or possession sequence complexity. Recent studies using expected action value, player rotation models, and sequence based analyses suggest that performance can be understood more deeply when offensive output is linked to possession structure and tactical choices. This means that the current model should be viewed as a focused explanatory framework rather than as a complete representation of offensive performance.

Future research should therefore extend the present framework in several ways. The most important step would be to integrate official tracking data in order to compute direct spacing measures and richer spatiotemporal indicators. Another useful direction would be to test whether the tempo spatial interaction remains stable across different competition phases, score margins, or line up structures. In addition, more advanced modelling strategies, including multilevel designs, sequential analysis, or machine learning approaches, could help clarify whether the interaction observed in this study remains robust when a larger contextual set of variables is included. Current research trends in basketball analytics strongly support this movement toward integrated, high resolution, and context aware models.

Overall, the present study contributes to the current evolution of basketball performance analysis by arguing that offensive efficiency in elite basketball should be interpreted through the joint organization of time and space. While previous studies have often focused on either pace or tactical spacing separately, the present findings suggest that their combination may offer a more informative lens for understanding modern offensive success. This adds conceptual value to the literature and provides a foundation for future work that can test the tempo spatial synergy hypothesis using more precise tracking based and context sensitive designs.

5. Conclusions

The present study examined the role of game pace and spatial efficiency in shaping offensive performance in elite basketball. The results showed that both variables were significant predictors of offensive rating, with spatial efficiency emerging as the stronger predictor. In addition, the interaction between pace and spacing was statistically significant, indicating that offensive effectiveness increases when teams combine a higher tempo with more effective spatial organization.

These findings support the idea that offensive success in modern basketball should not be interpreted only through traditional game related statistics, but also through the coordinated relationship between temporal and spatial dimensions of play. In this sense, the study contributes to the current development of basketball performance analysis by proposing an integrated perspective on offensive efficiency.

From an applied perspective, the results suggest that coaches should not approach pace and spacing as separate tactical elements. Instead, offensive systems and training tasks should be designed

to improve the ability of teams to maintain spatial balance and decision making quality under faster game conditions. Likewise, performance analysis models may benefit from incorporating spatially oriented indicators alongside conventional statistics in order to provide a more complete understanding of offensive behavior.

At the same time, the conclusions should be interpreted in light of the study limitations, particularly the use of a proxy indicator for spatial efficiency and the retrospective observational design. Future research should therefore build on this framework by using direct tracking based measures and more advanced analytical models to further clarify how temporal and spatial dynamics interact in elite basketball performance.

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Enhancing Tennis Performance in U16 Players Through Integrated Cognitive-Motor Training

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Abstract

Background: Modern tennis performance depends on both physical abilities and perceptual-cognitive processes, especially in fast and unpredictable game situations. In junior players, the effects of integrated cognitive-motor training on sport-specific performance remain insufficiently documented.

Objective: This study aimed to examine the effects of an integrated cognitive-motor training program on agility, sprint ability, reaction time, decision-making, and tennis-specific performance in U16 competitive players.

Results: Forty junior tennis players were randomly assigned to an experimental group and a control group. Over 8 weeks, the experimental group completed an integrated cognitive-motor training program, while the control group followed traditional tennis training. The experimental group showed significant improvements in all measured variables, with the greatest gains in reaction time, decision-making, and tennis-specific performance. Compared with the control group, post-intervention results were significantly better in agility, sprint performance, reaction time, decision-making accuracy, and tennis-specific performance.

Conclusions: Integrated cognitive-motor training appears to be an effective strategy for improving both physical and perceptual-cognitive performance in U16 tennis players. These findings support the inclusion of representative and cognitively demanding tasks in youth tennis training programs to enhance performance and support long-term athlete development.

Keywords: cognitive-motor training, youth athletes, reaction time, decision-making, agility, perceptual-cognitive performance.

1. Introduction

Modern tennis is a high-speed open-skill sport in which performance emerges from the continuous interaction between technical execution, physical readiness, perceptual attunement, and rapid tactical adaptation. In competitive settings, players must repeatedly accelerate, decelerate, change direction, anticipate ball trajectories, and select appropriate responses under severe temporal pressure. Recent evidence has confirmed that performance in tennis is shaped not only by traditional fitness indicators such as speed, agility, and power, but also by technical and tactical competencies that must be expressed in

dynamic and context-dependent situations (Lambrich & Muehlbauer, 2023; Crespo et al., 2024; Fernández-Fernández et al., 2023; Axman et al., 2025).

This multidimensional profile is especially relevant in youth tennis, where performance development depends on the coordinated progression of physical, motor, technical, and cognitive factors. Longitudinal and cross-sectional studies in young tennis players have shown that physical capacities such as change-of-direction speed, sprint ability, and coordination develop alongside tennis-specific skills and may differentiate competitive level from an early age (Waldziński et al., 2024; Chapelle et al., 2023; Munivrana et al., 2025). At the same time, normative and review-based evidence indicates that agility, speed, and power are central components of youth tennis profiling and training evaluation, yet their interpretation is strengthened when they are linked to game-specific demands rather than assessed as isolated physical outputs (Axman et al., 2025; Lambrich & Muehlbauer, 2023).

Alongside these physical demands, perceptual-cognitive processes play a decisive role in successful tennis performance. Players must identify relevant cues, allocate attention efficiently, update working memory, inhibit ineffective responses, and make fast and accurate decisions while the environment changes from shot to shot. Recent literature has reinforced the importance of perceptual-cognitive expertise and executive functions in interceptive sports, showing that attention, anticipation, cognitive flexibility, and information processing speed are tightly linked to skilled action in time-constrained performance environments (Hodges et al., 2021; DeCouto et al., 2024; Cao et al., 2025). In young tennis players specifically, longer tennis training experience has already been associated with faster reaction times and better executive function profiles, suggesting that tennis participation and cognitive development may be closely intertwined during childhood and adolescence (Xu et al., 2022).

These findings support a growing shift away from isolated and repetitive training models toward more representative and integrated practice designs. Research on perceptual-motor learning, dual-task training, agility development, and representative task design suggests that training becomes more transferable when athletes are exposed to tasks that preserve the informational structure of competition and require simultaneous perception, decision, and action (Bergmann et al., 2021; Moreira et al., 2021; Thieschäfer & Büsch, 2022). In this context, agility should no longer be understood only as a pre-planned change-of-direction capacity, but as a cognitive-motor quality that depends on perception, response selection, and movement execution under uncertainty. This perspective is highly relevant for tennis, where players constantly adapt their movements to opponent behavior, ball speed, spin, depth, and tactical context.

Recent intervention studies in tennis further support this integrated view. In young tennis players, plyometric and agility-based interventions have improved speed, change-of-direction ability, and reactive agility, while more specific training approaches have also shown positive effects on attentional processes and tennis-related functional performance (Sinkovic et al., 2023; Selmi et al., 2024; Messina et al., 2024). In parallel, broader evidence from visual and perceptual-cognitive training has shown that structured vision-based interventions can improve response time, decision-making speed, and sport-specific performance, particularly when the training content is closely aligned with task demands (Lochhead et al., 2024; Wang et al., 2025; Guo et al., 2025). Emerging tennis-specific evidence has also suggested that cognitive interventions delivered through virtual reality or other immersive platforms may positively influence adolescent performance outcomes, further reinforcing the value of integrated training models in racquet sports (Anguera et al., 2025).

The adolescent period is particularly important for this type of intervention. During the U16 stage, players are exposed to increasing tactical complexity, greater competitive pressure, and rapid biological and neuromuscular changes, all of which influence performance adaptation. Recent research on maturity, youth athlete development, and tennis-specific functional change indicates that this stage is characterized

by marked inter-individual variability but also by substantial trainability, especially when training programs are appropriately structured and developmentally aligned (Fernández-Fernández et al., 2023; Waldziński et al., 2024; Bergeron et al., 2024). This makes adolescence a strategically important period for interventions that aim to integrate physical and perceptual-cognitive components rather than develop them separately.

Despite this growing body of literature, important gaps remain. First, much of the recent tennis literature has focused either on physical conditioning, technical-tactical profiling, or isolated perceptual training, with fewer studies examining the combined effects of cognitive-motor training on both physical and tennis-specific outcomes within the same experimental design. Second, although recent studies support the relevance of agility, attention, and cognitive training in youth tennis, the number of randomized controlled investigations in adolescent players remains limited, and transfer to tennis-specific performance is still insufficiently documented. Third, the literature continues to call for ecologically valid training tasks and more integrated models capable of linking decision-making, reaction time, movement execution, and sport-specific performance in real training environments (Crespo et al., 2024; Axman et al., 2025; Anguera et al., 2025; Cassidy et al., 2025).

Therefore, the novelty of the present study lies in examining the effects of an integrated cognitive-motor training program in U16 competitive tennis players through a randomized controlled design that simultaneously targets agility, sprint ability, reaction time, decision-making, and tennis-specific performance. By combining physical and perceptual-cognitive demands within representative training situations, this study aims to extend current evidence on youth tennis development and to provide a more applied model for performance-oriented training. Accordingly, the aim of this study was to investigate the effects of an integrated cognitive-motor training program on agility, reaction time, decision-making, and tennis-specific performance in junior tennis players. It was hypothesized that the experimental group would show significantly greater improvements than the control group following the intervention.

2. Materials and Methods

2.1. Study design

This study used a randomized controlled pretest to posttest design to examine the effects of an integrated cognitive-motor training program on physical and perceptual-cognitive performance in U16 tennis players. The intervention lasted 8 weeks and was conducted during the competitive training season.

Participants were randomly assigned to either an experimental group or a control group in a 1:1 ratio. Both groups completed four training sessions per week and followed the same overall weekly training volume. The only planned difference between groups was the intervention component performed during the final part of each session. The experimental group completed an integrated cognitive-motor training program, whereas the control group followed traditional tennis-specific training.

Each training session lasted approximately 90 minutes and included a standardized structure: warm-up, technical-tactical training, physical conditioning, and group-specific intervention content. Pre-intervention and post-intervention assessments were performed under the same testing conditions, at the same training facility, and by the same evaluators.

2.2. Participants

A total of 40 competitive junior tennis players participated in the study. The mean age of the sample was 15.1 ± 0.6 years. All participants were actively engaged in organized tennis training and regular competition at performance-oriented clubs.

After recruitment and baseline assessment, participants were randomly allocated to one of two groups: an experimental group, n = 20, and a control group, n = 20. Random allocation was performed using

a simple randomization procedure. Group assignment was completed after eligibility screening and before the start of the intervention.

The participants had comparable training backgrounds and similar competitive experience at baseline. No statistically significant differences were observed between groups in the pretest assessment, which supported initial group homogeneity.

2.3. Eligibility Criteria

Participants were included if they met all of the following criteria: at least 4 years of formal tennis training experience, regular attendance in tennis training of at least 4 sessions per week, active participation in official competitions, and medical clearance for full sports participation.

Participants were excluded if they had suffered a musculoskeletal injury within the previous 6 months, presented neurological or visual impairments that could affect performance testing, or missed more than 10% of the training sessions during the intervention period.

These criteria were established to ensure a relatively homogeneous sample in terms of age, training status, and competitive readiness, and to reduce potential confounding effects related to injury or inconsistent participation.

2.4. Ethical Considerations

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki for research involving human participants. Written informed consent was obtained from all participants and from their legal guardians before inclusion in the study.

Participation was voluntary, and all athletes were informed about the study procedures, purpose, potential benefits, and their right to withdraw at any stage without consequences. Confidentiality and anonymity were maintained throughout the study, and no personally identifiable information was disclosed in the reporting of the results.

2.5. Outcome Measure

The primary outcome measure was Offensive Rating, defined as the number of points scored per 100 possessions. This indicator was selected because it reflects offensive efficiency independently of raw game volume and is widely used in basketball performance analysis.

The main predictor variables were:

- Game Pace, defined as the estimated number of possessions per game.
- Spacing Index, defined as a composite indicator intended to reflect team spatial efficiency during offensive play. In the present study, this index was operationalized using standardized game related variables associated with ball movement and offensive distribution patterns.
- Assist Ratio, defined as the proportion of field goals that were assisted, was also included as a complementary offensive organization indicator.

In addition, an interaction term was created by multiplying the standardized values of game pace and spacing index. This interaction variable was introduced to examine whether the relationship between tempo and offensive performance depended on the level of spatial efficiency.

All variables were calculated from official game statistics and entered into a structured dataset for further analysis.

2.6. Statistical Analysis

Performance was assessed before and after the 8-week intervention using standardized field-based and task-specific testing procedures. The selected outcome measures were intended to capture both physical performance and perceptual-cognitive functioning relevant to tennis.

Agility was assessed using the Modified T-Test and recorded in seconds. This test was used to evaluate multidirectional movement ability and change-of-direction speed.

Linear sprint performance was assessed with a 10 m sprint test, also recorded in seconds, to evaluate short-distance acceleration.

Reaction time was measured using a light-based reaction system, with results recorded in milliseconds. The test assessed the speed of motor response to external visual stimuli.

Decision-making ability was assessed through a video-based tennis-specific task. Participants watched simulated match situations and were required to select the most appropriate response as quickly as possible. Two variables were recorded: decision accuracy, expressed as a percentage, and decision time, expressed in milliseconds.

Tennis-specific performance was evaluated using a standardized practical test focused on return efficiency and point-play success in simulated tennis situations. Performance was expressed as a percentage score based on execution accuracy and success during structured task conditions.

All assessments were conducted under standardized environmental conditions and supervised by qualified coaches familiar with the testing procedures. Participants completed the same test battery at baseline and after the intervention.

3. Results

3.1 Descriptive Statistics

Baseline descriptive statistics for all outcome variables are presented in Table 1. No statistically significant differences were observed between the experimental group and the control group at pre-intervention assessment, indicating that the two groups were comparable at baseline across all measured variables.

The pretest values showed similar levels of agility, sprint performance, reaction time, decision-making, and tennis-specific performance in both groups. This baseline homogeneity supported the validity of subsequent between-group comparisons following the intervention.

Table 1. Descriptive statistics of performance variables (Mean ± SD)

Variable	Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)
Agility (s)	EG	10.21 ± 0.42	9.48 ± 0.37
	CG	10.18 ± 0.39	9.95 ± 0.36
Sprint (s)	EG	1.89 ± 0.08	1.78 ± 0.07
	CG	1.88 ± 0.07	1.83 ± 0.06
Reaction Time (ms)	EG	412 ± 25	355 ± 22
	CG	410 ± 27	392 ± 24
Decision-Making (%)	EG	68.5 ± 6.2	81.3 ± 5.4
	CG	69.1 ± 5.9	73.2 ± 5.7
Tennis Performance (%)	EG	62.3 ± 5.8	75.6 ± 5.1
	CG	63.0 ± 6.1	67.8 ± 5.9

3.2. Within-Group Comparisons

Within-group comparisons are presented in Table 2. The experimental group showed statistically significant improvements across all measured variables after the 8-week intervention. Agility time decreased from 10.21 ± 0.42 s to 9.48 ± 0.37 s, while sprint time improved from 1.89 ± 0.08 s to 1.78 ± 0.07 s. Reaction time showed a marked reduction from 412 ± 25 ms to 355 ± 22 ms. Decision-making accuracy increased from 68.5 ± 6.2% to 81.3 ± 5.4%, and tennis-specific performance improved from 62.3 ± 5.8% to 75.6 ± 5.1%.

All within-group changes in the experimental group were statistically significant, with large effect sizes observed for agility, reaction time, decision-making, and tennis-specific performance. The greatest effect was found for reaction time, suggesting a particularly strong response of perceptual-cognitive performance to the integrated cognitive-motor intervention.

In contrast, the control group demonstrated only modest improvements. Small but statistically significant changes were observed for agility, sprint performance, decision-making, and tennis-specific performance, whereas the reduction in reaction time did not reach statistical significance. Overall, the magnitude of improvement was consistently greater in the experimental group.

Table 2. Within-group comparisons (paired t-test)

Variable	Group	t	p	Effect size
Agility (s)	EG	8.72	<0.001	1.75
	CG	2.84	<0.05	0.45
Sprint (s)	EG	6.11	<0.001	1.20
	CG	2.21	<0.05	0.35
Reaction Time (ms)	EG	11.03	<0.001	2.10
	CG	1.72	>0.05	-
Decision-Making (%)	EG	9.54	<0.001	1.90
	CG	2.63	<0.05	0.40
Tennis Performance (%)	EG	9.02	<0.001	1.85
	CG	2.95	<0.05	0.50

3.3. Between-Group Comparisons

Post-intervention comparisons between groups are shown in Table 3. Statistically significant differences were found in all outcome variables in favor of the experimental group.

At post-test, the experimental group outperformed the control group in agility, sprint performance, reaction time, decision-making, and tennis-specific performance. The largest between-group differences were observed for reaction time, decision-making, and tennis-specific performance, indicating that the integrated cognitive-motor training program was particularly effective in enhancing perceptual-cognitive and sport-specific outcomes.

These findings suggest that the addition of representative cognitive-motor tasks to regular tennis training produced superior adaptations compared with traditional training alone.

Table 3. Between-group comparisons (post-test)

Variable	t	p
Agility (s)	−4.21	<0.01
Sprint (s)	−3.12	<0.01
Reaction Time (ms)	−6.85	<0.001
Decision-Making (%)	5.94	<0.001
Tennis Performance (%)	6.22	<0.001

3.4. Percentage Improvements

Percentage changes in performance are summarized in Table 4. The experimental group showed greater relative improvement across all variables compared with the control group. The most substantial gains were observed in reaction time, decision-making, and tennis-specific performance.

Specifically, the experimental group improved by 7.1% in agility, 5.8% in sprint performance, 13.8% in reaction time, 18.7% in decision-making, and 21.3% in tennis-specific performance. In contrast, the control group showed smaller improvements ranging from 2.2% to 7.6%. These results further support the practical relevance of the intervention and its transfer to tennis-related performance.

Table 3. Percentage improvements (%)

Variable	EG (%)	CG (%)
Agility (s)	+7.1	+2.2
Sprint (s)	+5.8	+2.6
Reaction Time (ms)	−13.8	−4.3
Decision-Making (%)	+18.7	+5.9
Tennis Performance (%)	+21.3	+7.6

3.5. Graphical Representation of Post-Intervention Outcomes

The visual comparison of post-test performance between groups is shown in Figure 1. The figure illustrates consistently better outcomes in the experimental group, with the clearest separation observed for reaction time, decision-making, and tennis-specific performance.

Figure 2 presents the post-intervention distribution of reaction time values in both groups. The experimental group demonstrated a visible shift toward lower reaction time scores, indicating faster perceptual-motor responsiveness following the intervention.

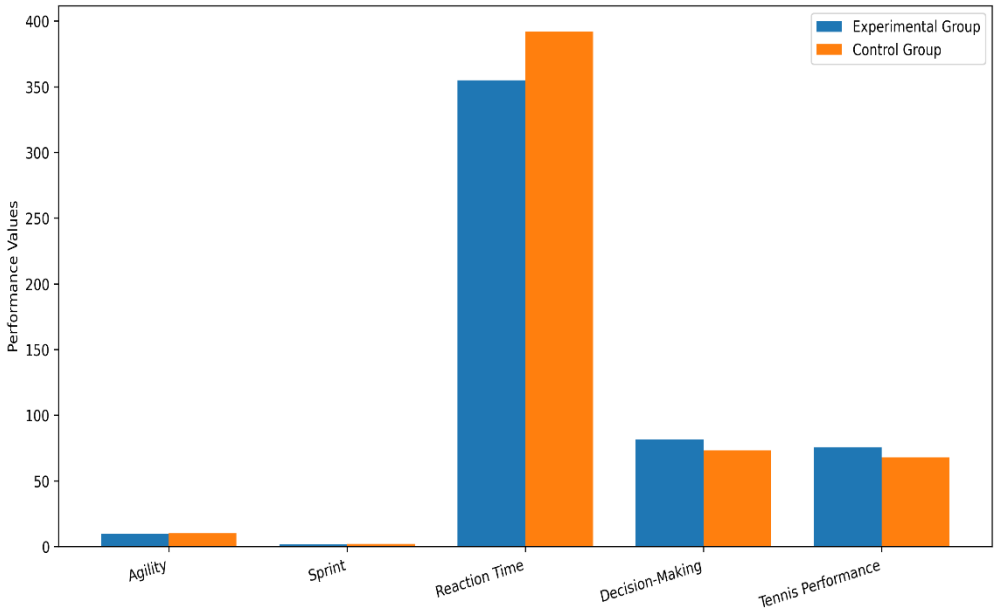


Figure 1. Comparison of post-test performance between experimental and control groups

The experimental group demonstrated superior performance across all variables, with the largest differences observed in reaction time, decision-making, and tennis-specific performance.

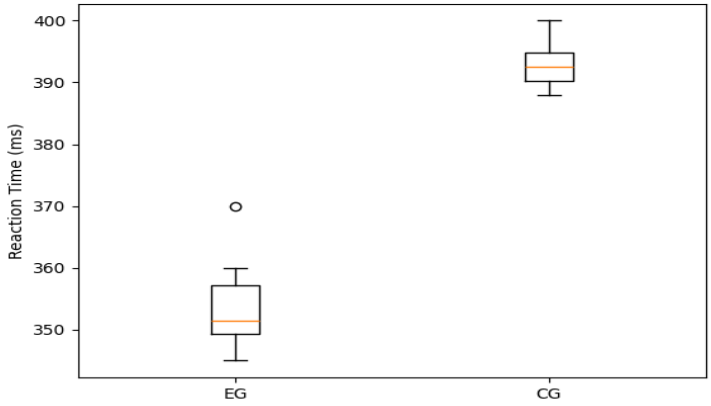


Figure 2. Distribution of reaction time in experimental and control groups after the intervention

The experimental group exhibited a clear shift toward lower reaction time values, indicating improved perceptual-cognitive processing speed compared to the control group.

4. Discussion

The aim of this study was to investigate the effects of an integrated cognitive-motor training program on agility, sprint performance, reaction time, decision-making, and tennis-specific performance in U16 players. The findings strongly support the study hypothesis, as the experimental group showed significantly greater improvements than the control group across all measured variables. These results suggest that combining motor and perceptual-cognitive demands within representative practice tasks can produce broader and more transferable adaptations than traditional tennis training alone.

One of the most important findings was the marked reduction in reaction time in the experimental group. This result is consistent with previous research showing that training environments characterized by uncertainty, visual demands, and rapid motor responses can enhance perceptual speed and

sensorimotor efficiency (Broadbent et al., 2015; Yarrow et al., 2009). Recent literature has further shown that visual and perceptual-cognitive training interventions can improve reaction-related performance and decision-making in athletes, particularly when the training content is task-specific and sustained over time (Wang et al., 2025; Cano et al., 2024). The present findings are in line with these observations and suggest that the integrated training used in our study may have enhanced both visual information processing and response execution speed.

The significant gains observed in decision-making performance further reinforce the importance of perceptual-cognitive training in open-skill sports such as tennis. According to ecological dynamics theory, effective performance depends on the continuous coupling of perception and action under changing environmental constraints (Davids et al., 2008; Pinder et al., 2011). In our study, players in the experimental group were repeatedly exposed to variable stimuli, time pressure, and task uncertainty, which may have improved their ability to identify relevant cues and select more appropriate responses. This interpretation is supported by recent evidence suggesting that adolescent tennis players may benefit from cognitive training approaches that target attention, working memory, and goal management, with positive effects on tennis-related performance (Anguera et al., 2025).

Another relevant result was the large improvement in tennis-specific performance, which suggests an effective transfer from training tasks to game-related execution. This is especially important because one of the major criticisms of isolated cognitive training is the limited transfer to sport-specific outcomes. In the present study, tennis-specific performance improved more strongly than in the control group, indicating that the integration of decision-making, movement execution, and contextual information may have facilitated more meaningful adaptations. This finding is consistent with recent work on youth tennis development, which has highlighted the need to align physical and cognitive training with the informational and tactical structure of the sport (Liu et al., 2024; Crespo et al., 2024; Axman et al., 2025). It also agrees with recent tennis-related intervention studies showing that cognitively enriched or reactive forms of training may improve not only isolated motor outputs but also more applied performance indicators (Selmi et al., 2024; Anguera et al., 2025).

The improvement in agility observed in the experimental group also deserves attention. Although agility has often been assessed as a physical quality, current evidence increasingly supports a broader understanding of agility as a motor-cognitive skill that involves perception, response selection, and movement adaptation in response to external stimuli. The current results support this view, as the group exposed to integrated cognitive-motor drills showed greater gains than the group performing traditional training. This pattern is comparable with findings showing that programs combining change-of-direction and reactive agility training produce meaningful benefits in adolescent tennis players and other open-skill athletes (Selmi et al., 2024; Sheppard & Young, 2006; Moreira et al., 2021; Thieschäfer & Büsch, 2022).

The superiority of the experimental group over the control group across both physical and cognitive outcomes suggests that the benefits of integrated training were not limited to one domain of performance. This is a relevant point for youth athlete development, because training interventions that simultaneously stimulate movement quality, attentional control, anticipation, and decision-making may offer a more efficient pathway for performance enhancement during adolescence. Recent research has indicated that youth tennis players are particularly responsive to appropriately structured, multi-component training, especially during developmental stages marked by high neural and motor plasticity (Xu et al., 2022; Fernández-Fernández et al., 2023; Waldziński et al., 2024). Our findings extend this literature by showing that an 8-week integrated intervention may generate improvements not only in basic motor tasks but also in sport-specific performance indicators.

At the same time, the moderate improvements observed in the control group should not be overlooked. Traditional tennis training still produced some positive changes, particularly in agility, sprint

performance, and tennis-specific execution, which is expected given that regular practice itself promotes adaptation. However, the smaller magnitude of change in the control group indicates that conventional training may be less effective in addressing the perceptual-cognitive demands of contemporary tennis. This point is in line with previous literature arguing that technical repetition and general physical conditioning, although essential, may be insufficient when training does not adequately reflect the uncertainty and decision constraints of real match play (Reid et al., 2013; Pinder et al., 2011). More recent evidence also suggests that perceptual-cognitive training may improve on-court performance, but transfer depends strongly on the representativeness and specificity of the training tasks (Zhu et al., 2024; Wang et al., 2025).

From a practical perspective, the present findings support the inclusion of representative cognitive-motor tasks in junior tennis training programs. Coaches working with U16 players may benefit from integrating reactive agility drills, visual cue-based decision exercises, variable rally constraints, and dual-task situations that require simultaneous movement and cognitive control. Such an approach appears particularly valuable in development settings where the goal is not only to improve isolated physical qualities but also to enhance the athlete's capacity to perceive, decide, and act effectively under competitive conditions.

5. Strengths and Limitations

This study has several strengths. First, the randomized controlled design strengthens the internal validity of the findings. Second, the intervention was implemented within a realistic training context, which increases the ecological relevance of the results. Third, the simultaneous assessment of physical, perceptual-cognitive, and tennis-specific variables allowed for a more comprehensive analysis of training effects. This multidimensional approach is important in tennis, where performance emerges from the interaction of multiple systems rather than from a single isolated capacity.

Several limitations should also be acknowledged. The sample size was relatively small, which may limit the generalizability of the findings. The intervention lasted only 8 weeks, so the long-term persistence of the observed adaptations remains unclear. In addition, although the outcome battery included tennis-specific measures, more advanced assessment tools such as motion tracking, eye-tracking, or notational performance analysis could have provided a more detailed understanding of the underlying mechanisms. Another limitation is that reaction time and decision-making were assessed under controlled conditions rather than during real match play, which may reduce the extent to which these measures capture in-competition behavior. Finally, although the results were clearly in favor of the experimental group, future studies should further examine whether similar effects are observed across different sexes, age categories, and competitive levels.

6. Future Directions

Future research should examine the long-term effects of integrated cognitive-motor training in youth tennis and determine whether performance gains are maintained across longer competitive periods. It would also be valuable to compare the effects of different cognitively enriched training formats, such as video-based anticipation tasks, stroboscopic vision training, reactive agility programs, and immersive virtual reality interventions. Recent studies suggest that these approaches may influence reaction time, attention, decision-making, and sport performance through partially different mechanisms (Selmi et al., 2024; Anguera et al., 2025; Wang et al., 2025).

Further studies should also use larger samples, stronger statistical models, and more detailed performance tracking systems in order to clarify how perceptual-cognitive and motor adaptations interact over time. In particular, future work should investigate whether improvements in reaction time and

decision-making directly mediate changes in tennis-specific performance, and whether training responsiveness differs according to biological maturation, training age, or competitive standard. Such evidence would help refine training design and support more individualized player development models.

7. Conclusions

The present study demonstrated that an integrated cognitive-motor training program can significantly improve both physical and perceptual-cognitive performance in U16 tennis players. Compared with traditional training, the intervention produced superior gains in agility, sprint performance, reaction time, decision-making, and tennis-specific performance.

These findings suggest that tennis performance in adolescent athletes should not be approached exclusively through technical and physical training, but through training models that also integrate perceptual and cognitive demands. The marked improvements observed in reaction time, decision-making, and tennis-specific performance indicate that representative and cognitively enriched practice tasks may enhance the transfer of training effects to sport-relevant situations.

From a practical perspective, the results support the inclusion of reactive agility drills, decision-based tasks, and other integrated training strategies in youth tennis development programs. Such approaches may provide a more effective framework for preparing players to cope with the speed, uncertainty, and tactical complexity of modern tennis.

Overall, integrated cognitive-motor training appears to be a valuable strategy for optimizing junior tennis performance and supporting long-term athlete development. Future research should confirm these findings in larger samples, over longer intervention periods, and across different competitive levels.

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Expressivity in Dancesport: A Multidisciplinary Perspective on Performance, Perception and Evaluation

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Abstract

Background: Dancesport combines athletic execution with artistic performance, making its evaluation more complex than in objectively measured sports. Beyond technical proficiency, expressive movement plays a key role in communicating emotion, shaping aesthetic impact, and influencing both audience engagement and judges' perception. Although expressivity has been widely explored in dance studies, its relevance for dancesport performance remains insufficiently synthesized.

Objective: This study aimed to examine the role of expressivity in dancesport by reviewing recent literature on movement expression, emotional communication, aesthetic evaluation, and performance perception, with the goal of clarifying its contribution to competitive performance and judging.

Results: The reviewed literature indicates that expressivity significantly enhances perceived performance quality, particularly through movement amplitude, rhythm, timing, dynamic variation, and emotional congruence. Studies also suggest that expressive movement increases emotional resonance and observer engagement, while expertise influences sensitivity to expressive cues. Emerging technological approaches, including motion analysis and machine learning, show potential for supporting a more objective assessment of expressive performance.

Conclusions: Expressivity represents a core dimension of dancesport performance, with implications for both training and evaluation. Integrating expressive development with technical preparation may improve competitive outcomes. Further research should establish validated assessment frameworks and explore targeted interventions for enhancing expressive performance in dancesport.

Keywords: dancesport, expressivity, emotional expression, performance evaluation, aesthetic performance, movement perception.

1. Introduction

Dancesport is a distinctive performance domain situated at the intersection of sport, art, and embodied communication. Unlike sports judged primarily through objective outcomes, dancesport performance is evaluated through a combination of technical precision, musical interpretation, partner coordination, and artistic expressivity. Within this multidimensional evaluative framework, expressivity occupies a central position because it shapes how movement is perceived, interpreted, and valued by both judges and audiences. In dance research, expressivity has been defined as the performer's capacity to

communicate affective, intentional, and aesthetic meaning through movement qualities such as timing, dynamics, rhythm, spatial projection, and bodily energy (Christensen & Calvo-Merino, 2013). In competitive dance settings, these qualities may influence not only artistic impression but also the perceived overall quality of execution.

Recent scholarship has strengthened the view that expressive movement is not an incidental artistic addition to performance, but a meaningful component of how dance is cognitively and affectively processed. Work in empirical aesthetics and movement science has shown that aesthetic responses to dance are shaped by both stimulus properties and observer characteristics, including expertise, personality, context, and prior sensorimotor experience (Christensen et al., 2021; Christensen et al., 2025; Casale et al., 2024; Cross et al., 2024; Orgs et al., 2024; Orlandi et al., 2025). These findings support the idea that dance perception is a dynamic process in which expressive movement contributes directly to aesthetic appeal, interest, emotional resonance, and perceived authenticity. Recent experimental work has further shown that full body dance stimuli can reliably communicate discrete emotional states, reinforcing the value of dance as a valid model for studying expressive human movement (Christensen et al., 2023; Christensen et al., 2025).

At the neurocognitive level, current research increasingly interprets dance perception through embodied and action based frameworks. The neuroscience of dance has expanded considerably in recent years, highlighting the role of action observation, motor simulation, sensorimotor expertise, and embodied cognition in the perception of movement quality and aesthetic value (Bläsing et al., 2012; Vander Elst et al., 2023; Yang et al., 2023; Cross, 2025). Recent neuroaesthetic models suggest that the evaluation of moving bodies, especially in interactive and performative contexts, depends on the integration of sensory, motor, affective, and contextual processes rather than on visual analysis alone (Orlandi et al., 2025; Díaz-Vera et al., 2025). This perspective is particularly relevant to dancesport, where expressive meaning emerges not only from individual execution but also from coordinated dyadic interaction, mutual attunement, and shared performative intention.

The role of expertise in perceiving and evaluating expressive movement also remains highly relevant. Earlier evidence showed that trained observers are more sensitive to subtle performance cues and more accurate in judging expressive qualities (Cross et al., 2011). More recent studies have extended this line of research by showing that aesthetic judgments are influenced by prior bodily experience, synchrony perception, mutual gaze, and familiarity with movement structure (Casale et al., 2024; Cross et al., 2024; Orgs et al., 2024). These findings are especially important in dancesport, where judging depends on rapid visual interpretation of highly complex movement patterns performed under competitive conditions. They suggest that performance evaluation may be shaped not only by codified judging criteria, but also by the observer's embodied sensitivity to expressive and relational cues.

In parallel, psychological and social research has shown that expressive dance is closely linked to emotional awareness, regulation, interpersonal connection, and embodied agency. Reviews on dance and emotional functioning indicate that dance based participation supports emotional expression and affective regulation, while also strengthening self awareness and communication capacities (San-Juan-Ferrer & Hípola, 2020; Zhang et al., 2024; Zafeiroudi et al., 2025; Klaperski-van der Wal et al., 2025). In addition, recent work has emphasized the role of embodied agency and kinesthetic empathy in shaping both dance production and dance reception (Houston, 2024; Artpradid, 2023). In partnered forms such as dancesport, these processes may be even more salient, because performance depends on continuous emotional and motor negotiation between dancers. Supporting this view, research on DanceSport couples has shown that expressive ties, interpersonal perception, and athlete engagement are positively associated with competitive performance (Liu et al., 2023).

Another rapidly developing line of research concerns the use of digital and computational tools for movement analysis and evaluation. Recent studies and reviews indicate that machine learning, motion analysis, and multimodal modeling can identify features related to rhythm, dynamics, movement quality, and performance proficiency, opening new directions for the partial objectification of dance assessment (Turab et al., 2025; Zhang et al., 2025; Nogueira et al., 2024; Qu et al., 2024; Chen et al., 2025; Takagi et al., 2025). Although these approaches still face important limitations, especially in capturing artistic nuance and context dependent meaning, they show clear potential for complementing traditional human evaluation. For dancesport, this is a significant development, since one of the long standing challenges of the field is the tension between subjective artistic judgment and the demand for more transparent and consistent performance evaluation.

Despite this growing body of literature, the scientific understanding of expressivity in dancesport remains fragmented. Much of the recent evidence comes from contemporary dance, ballet, dance therapy, general movement perception, or broader neuroaesthetic models, while relatively few syntheses focus specifically on how expressivity functions within the competitive, judged, and partner based environment of dancesport (Vander Elst et al., 2023; Orlandi et al., 2025; Nogueira et al., 2024). Moreover, the literature often addresses emotional expression, aesthetic appreciation, embodiment, and movement analysis separately, rather than integrating them into a coherent framework applicable to dancesport performance and judging. This creates a clear scientific gap. There is still a limited narrative synthesis that brings together perceptual, psychological, neurocognitive, and evaluative perspectives in order to explain why expressivity matters in dancesport and how it may influence performance outcomes.

Against this background, the present narrative review seeks to provide an updated and interdisciplinary overview of expressivity in dancesport and related aesthetic dance performance. Its novelty lies in connecting recent findings from movement science, empirical aesthetics, neuroscience, psychology, and computational analysis to the specific context of dancesport evaluation. More precisely, the review aims to examine the relationship between expressivity and performance evaluation, identify movement characteristics associated with emotional and aesthetic communication, and analyse the psychological and perceptual mechanisms involved in expressive dance performance. By clarifying the role of expressivity in dancesport, this article aims to support more informed training practices, more conceptually grounded judging criteria, and a stronger scientific basis for future research in this field.

2. Materials and Methods

2.1. Study design

The present study was designed as a narrative literature review focused on expressivity in dancesport and related aesthetic dance performance contexts. A narrative review approach was considered appropriate because the topic is interdisciplinary and conceptually broad, bringing together perspectives from movement science, dance studies, psychology, neuroscience, empirical aesthetics, and performance evaluation. This design allowed the inclusion of both empirical and theoretical contributions relevant to understanding how expressivity is manifested, perceived, interpreted, and evaluated in dance performance.

The choice of a narrative review was also justified by the current state of the field. Although research on dance perception, emotional communication through movement, and aesthetic evaluation has expanded in recent years, the literature specifically addressing expressivity in dancesport remains relatively limited and fragmented. For this reason, a narrative synthesis was considered more suitable than a narrowly structured systematic approach, as it enabled the integration of findings from adjacent areas of dance research that are conceptually relevant to dancesport.

2.2. Literature search strategy

The literature search was conducted using major academic sources relevant to the topic, including Google Scholar, PubMed, and selected publisher databases and journal repositories. Additional studies were identified through manual screening of the reference lists of key publications retrieved during the initial search process. The search was conducted between January and March 2026 and focused on literature examining dance expressivity, emotional communication through movement, performance perception, aesthetic evaluation, and movement analysis.

The main keywords and keyword combinations used in the search process included “dance expressivity”, “expressive movement in dance”, “emotional expression in dance”, “dance perception”, “aesthetic evaluation in dance”, “movement analysis and dance”, “dance performance evaluation”, and “expressive movement”. These search terms were used individually and in combined forms, depending on the database and the relevance of the initial search results.

Particular attention was given to recent literature, especially studies published after 2020, in order to ensure the scientific relevance and currency of the review. At the same time, earlier seminal works were retained when they were considered essential for the conceptual foundation of the topic, particularly in relation to dance perception, embodiment, and aesthetic evaluation.

2.3. Eligibility Criteria

Studies were included in the review if they met the following criteria: they were published in peer reviewed journals or other reputable academic sources, they were written in English, and they addressed at least one of the following thematic directions: dance expressivity, emotional expression through movement, aesthetic performance, observer perception, performance evaluation, or technological approaches to movement analysis in dance.

Eligible sources included empirical studies, theoretical papers, narrative and systematic reviews, and methodological contributions, provided that they offered relevant information for understanding expressivity in dance and its implications for performance and evaluation. Because the present article specifically addressed dancesport, priority was given to studies directly examining dance performance and expressive movement. However, given the limited number of studies focused exclusively on dancesport, relevant evidence from broader dance and aesthetic performance research was also included when it was conceptually applicable to the dancesport context.

Studies were excluded if they focused on unrelated forms of physical activity without a clear analytical connection to dance performance, if they referred to dance only marginally, or if they lacked sufficient scientific relevance to the aims of the review. Non scholarly materials, popular texts, and sources with incomplete or unclear academic information were not included in the final analysis.

2.4. Study selection

The selection of studies was carried out in successive stages. In the first stage, titles and abstracts identified through database and repository searches were screened for thematic relevance. In the second stage, the full texts of potentially eligible studies were examined in relation to the objectives of the review. In the third stage, the reference lists of the selected articles were manually reviewed in order to identify additional publications of direct relevance to the topic.

The final selection was based on the direct contribution of each source to the understanding of expressivity in dance performance, with particular emphasis on dancesport, emotional communication, movement qualities, aesthetic judgment, and observer response. A total of 17 academic sources were selected for the core analysis of the topic. These sources formed the primary basis of the narrative synthesis. In addition, further foundational and recent references were used to strengthen the theoretical framing of the article and to support the broader interpretative discussion.

2.5. Data analysis

The selected literature was analyzed using thematic synthesis. This analytical approach was chosen because it allowed the identification of recurring concepts, shared findings, and major interpretative directions across studies originating from different disciplines and methodological traditions. The analysis focused on the ways in which expressivity was defined, described, measured, and discussed in relation to dance performance.

Particular attention was given to several key dimensions. These included the relationship between expressive movement and performance evaluation, the movement characteristics associated with emotional communication, the psychological and perceptual mechanisms involved in expressive dance, and the contribution of technological approaches to the study of movement expressivity.

Based on this process, the review was structured around four main thematic domains: expressivity and performance evaluation, movement characteristics of emotional expression, technological approaches to measuring expressivity, and psychological and social aspects of expressive dance. This thematic organization was considered appropriate because it reflected the main patterns emerging from the literature and supported a coherent narrative interpretation of the evidence from multiple disciplinary perspectives.

2.6. Methodological considerations

As a narrative review, the present study was not intended to provide an exhaustive systematic synthesis of all available literature and did not include meta-analytical procedures or formal risk of bias assessment. Its main purpose was to offer a critical, conceptually integrated, and interdisciplinary overview of the current scientific literature on expressivity in dancesport and related dance performance contexts.

Nevertheless, methodological transparency was supported through the explicit description of the review design, search strategy, eligibility criteria, study selection process, and thematic analysis. This approach was considered suitable for clarifying the current scientific understanding of expressivity in dancesport, identifying recurring directions in the literature, and highlighting relevant gaps for future research.

The authors acknowledge that the narrative review format involves a degree of interpretative selection and does not claim the level of comprehensiveness associated with systematic reviews. However, this format was considered particularly appropriate for a developing field in which conceptual integration is needed alongside empirical synthesis.

3. Results

3.1. Expressivity and performance evaluation

The reviewed literature consistently indicates that expressivity is a major determinant of how dance performance is perceived and evaluated. Across empirical and theoretical contributions, expressive qualities were associated with higher ratings of aesthetic appeal, stronger emotional impact, and greater perceived performance quality. This pattern suggests that performance evaluation in dance is shaped not only by technical execution, but also by the performer's ability to communicate intention, emotional content, and artistic coherence through movement.

Table 1 summarizes the main studies included in the narrative review and highlights their contribution to the understanding of expressivity in dancesport.

Table 1. Summary of the main studies included in the narrative review

Author(s), year	Main focus	Key contribution	Relevance for dancesport
Bläsing et al., 2012	Dance perception	Links dance perception to embodied and neurocognitive processes	Supports the perceptual basis of expressive evaluation
Christensen & Calvo-Merino, 2013	Dance aesthetics	Frames expressivity as central to dance aesthetics	Provides the main conceptual basis for expressivity
Christensen et al., 2021	Expressive movement	Shows stronger responses to expressive than neutral movement	Suggests higher audience and judge engagement
Christensen et al., 2025	Aesthetic ratings	Confirms that expressivity and authenticity raise aesthetic appeal	Supports the role of expressivity in scoring
Cross et al., 2011	Observer expertise	Shows experts detect expressive cues more accurately	Relevant for judging sensitivity
Foster, 2016	Kinesthetic empathy	Explains audience resonance with dance performance	Supports emotional impact in evaluation
Karin, 2016	Dance skill	Expands dance skill beyond technique alone	Supports broader performance criteria
Kimmel et al., 2024	Mindful movement	Connects dance with attention and embodied awareness	Relevant for expressive training
Moore, 2011	Dance and music	Highlights the role of musical timing in expression	Relevant for musicality in dancesport
Pollick, 2017	Emotion in dance	Identifies dynamics and timing as emotional cues	Supports movement based expressivity analysis
Ramos et al., 2026	Partner coordination	Emphasizes synchronization and shared intention	Highly relevant for couple performance
San-Juan-Ferrer & Hípola, 2020	Emotional intelligence	Links dance practice to emotional development	Supports the psychological side of expressivity
Sevdalis & Keller, 2011	Expression intensity	Shows observers perceive intended expressive intensity	Relevant for judge and audience perception
Sievers et al., 2023	Emotion recognition	Confirms emotions can be read from body movement	Supports direct expressive communication
Turab et al., 2025	Movement analysis	Uses structured analysis of expressive movement	Relevant for objective assessment tools
Zafeiroudi et al., 2025	Embodied awareness	Connects movement with self awareness and regulation	Supports expressive development in training
Zhang et al., 2025	Machine learning	Detects expressive patterns from motion data	Suggests future semi objective evaluation

Table 1 summarizes the principal studies included in the review and outlines their contribution to the understanding of expressivity in dance performance. Overall, the literature suggests that expressivity is a multidimensional construct that influences aesthetic evaluation, emotional communication, and performance perception, with direct relevance for dancesport.

Christensen et al. (2025) showed that the aesthetic appeal of dance actions depends strongly on expressivity, perceived authenticity, and the contextual characteristics of the performance situation. Their findings support the view that expressive movement is not an accessory element added to technical

execution, but a central dimension of how dance is valued by observers. In similar terms, earlier work by Cross et al. (2011) demonstrated that observers with greater physical experience in dance were more sensitive to expressive qualities and more accurate in evaluating artistic performance, indicating that aesthetic judgment is influenced by embodied expertise.

Taken together, the literature suggests that expressive performance modifies evaluative perception at multiple levels. It increases the perceived fluency and meaningfulness of movement, enhances the coherence between music and bodily action, and contributes to the impression of artistic maturity. In competitive contexts such as dancesport, this is particularly important because dancers with comparable technical proficiency may still differ substantially in final impression and perceived performance quality due to the level of expressivity they display.

Another important result emerging from the literature is that expressive evaluation appears to depend on both performer related and observer related factors. Performer related factors include emotional congruence, movement intention, and authenticity of execution. Observer related factors include prior dance experience, perceptual sensitivity, familiarity with movement vocabulary, and expectations concerning style and performance norms. This helps explain why expressivity remains one of the most influential, but also one of the most complex, dimensions of judged dance performance.

Overall, the findings indicate that expressivity should be understood as a performance relevant variable rather than as a purely artistic supplement. In dancesport, it appears to function as a differentiating factor that may shape judging outcomes, audience engagement, and the overall interpretative value of performance.

3.2. Movement characteristics of emotional expression

The literature reviewed in this study shows that emotional expression in dance is communicated through identifiable movement characteristics. Across studies, several recurring features were associated with expressive performance, including movement amplitude, tempo, rhythm, dynamic variation, energy modulation, spatial direction, and continuity of movement flow. These characteristics appear to influence how observers interpret emotional meaning and how convincingly a performance is perceived.

Research by Sievers et al. (2023) demonstrated that basic emotional qualities such as joy, sadness, and anger can be recognized from full body movement alone, even in the absence of contextual or verbal cues. This finding is highly relevant to dancesport because it supports the idea that expressive communication is carried directly by the body through structured movement patterns. Pollick (2017) likewise emphasized that subtle changes in dynamics and timing play a critical role in how emotional content is conveyed and perceived in dance.

The reviewed studies suggest that expressive clarity does not emerge from isolated gestures, but from the coordinated organization of multiple movement parameters. For example, increased amplitude and upward spatial projection are often associated with high arousal positive states, whereas reduced amplitude, slower timing, and lower movement energy may be interpreted as sadness or restraint. Dynamic shifts, changes in acceleration, rhythmic emphasis, and continuity of flow also contribute to the perception of intensity, tension, and emotional direction.

In methodological terms, these findings are important because they show that expressivity can be analysed through observable movement features, even if its full artistic meaning cannot be reduced to purely mechanical variables. Frameworks such as Laban Movement Analysis have been used to classify expressive qualities in a more structured manner, helping researchers distinguish between effort, shape, space, and flow related components of performance (Turab et al., 2025).

For dancesport, these results suggest that expressive training should focus not only on affective intention, but also on the refinement of specific movement qualities that make emotional content

perceptible to judges and audiences. In this sense, emotional communication in dancesport appears to depend on the interaction between technical control and expressive modulation of movement parameters.

3.3. Technological approaches to measuring expressivity

A growing number of recent studies have explored the possibility of analysing expressivity through technological and computational approaches. This line of research reflects an important development in the field, since one of the longstanding challenges in dance research has been the difficulty of describing and assessing expressive movement in objective terms.

The reviewed literature indicates that motion capture systems, movement tracking tools, and machine learning models can identify patterns associated with emotion related movement qualities. Zhang et al. (2025) reported that machine learning models trained on motion data were able to detect expressive and emotional patterns in dance performance with promising levels of classification accuracy. These findings suggest that movement features linked to rhythm, velocity, amplitude, timing, and dynamic variation can be quantified and used to model expressive behavior.

Technological approaches contribute in at least three important ways. First, they support the description of movement features that are difficult to capture through verbal observation alone. Second, they allow greater consistency in the comparison of performances across dancers or conditions. Third, they open the possibility of integrating objective descriptors into broader frameworks of performance analysis. This is particularly valuable in dancesport, where evaluation often depends on subjective impressions and where more transparent analytical tools could complement traditional judging.

At the same time, the literature also makes clear that current technological methods remain partial. They can measure movement structure and identify correlates of expressive behavior, but they do not fully capture artistic intention, interpersonal chemistry, stylistic appropriateness, or the contextual meaning of performance. Expressivity in dance is not reducible to kinematic data alone. Rather, technological analysis should be viewed as a complementary tool that may support, but not replace, human interpretative evaluation.

Therefore, the main result emerging from this theme is that technological methods offer promising support for the study of expressivity, especially in relation to movement quantification and emotion related pattern detection. However, the literature still indicates a need for more refined and ecologically valid models capable of addressing the artistic and relational complexity of dancesport performance.

3.4. Psychological and social aspects of expressive dance

The reviewed studies also show that expressivity in dance is closely connected to psychological and interpersonal processes. Expressive performance is not only a visible motor act, but also an embodied form of communication shaped by emotional awareness, self regulation, empathy, interaction, and social attunement.

San-Juan-Ferrer and Hípola (2020) highlighted the relationship between dance participation and emotional intelligence, suggesting that dance training may strengthen emotional awareness and expressive capacities. This finding is relevant to dancesport because expressive performance requires dancers not only to execute movement accurately, but also to regulate affect, project intention, and sustain a convincing performative presence under evaluative pressure.

Research on collaborative and partner based performance adds an important social dimension to this picture. Studies on coordinated dance interaction indicate that synchronization, mutual responsiveness, and emotional connection between performers contribute substantially to the perceived quality of performance (Ramos et al., 2026). In partner dance contexts, expressivity emerges not only from

the expressive resources of each dancer individually, but also from the quality of the interaction between them. This is especially relevant in dancesport, where dyadic coordination, mutual timing, and shared expressive intention are central to performance success.

The literature further suggests that audience perception may be influenced by the visible coherence of this interaction. When dancers appear emotionally connected, synchronized, and jointly engaged in the performance, observers tend to perceive greater authenticity and stronger artistic impact. In this sense, expressivity in dancesport has both an intrapersonal dimension, linked to emotional embodiment and intention, and an interpersonal dimension, linked to communication and shared movement organization.

These findings indicate that the psychological and social dimensions of expressivity should be considered essential components of performance development. Expressive competence in dancesport likely depends on a combination of emotional training, partner communication, attentional regulation, and embodied awareness. As a result, high level performance cannot be explained exclusively by biomechanics or technique, but must also be understood through the dancer's capacity to transform movement into meaningful interpersonal and aesthetic communication.

4. Discussion

The findings of the present narrative review indicate that expressivity represents a central component of dancesport performance, extending beyond artistic appearance alone. Across the reviewed literature, expressive movement emerged as a multidimensional construct shaped by movement qualities, emotional communication, interpersonal coordination, and observer perception. These dimensions are not independent, but interact dynamically in the production and evaluation of performance. Figure 1 synthesizes the conceptual relationships identified in the reviewed studies and illustrates how expressivity may influence both aesthetic impact and competitive evaluation in dancesport.

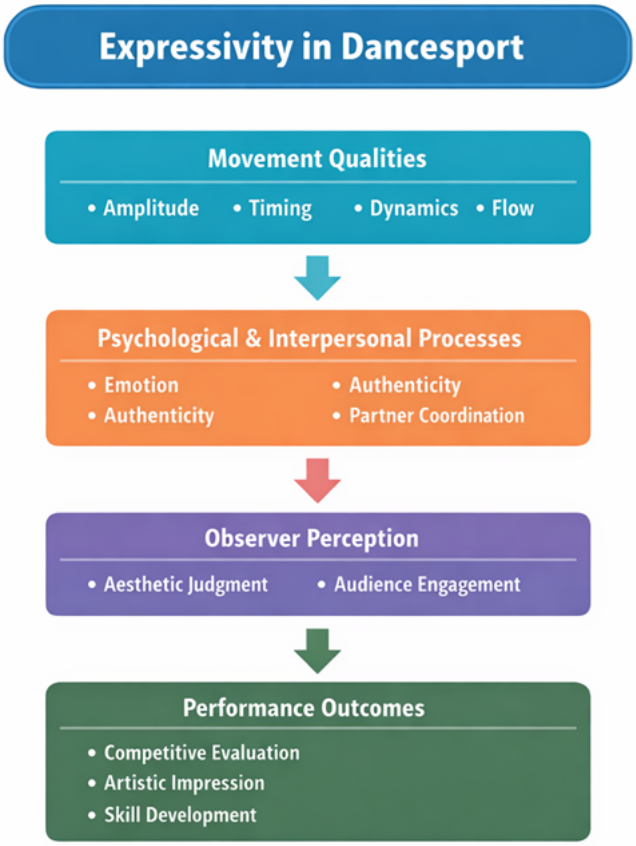


Figure 1. Conceptual framework of expressivity in dancesport performance and evaluation.

The findings of the present narrative review indicate that expressivity should be regarded as a central component of dancesport performance rather than as a secondary artistic addition. The literature reviewed in this study suggests that expressive movement contributes directly to aesthetic evaluation, emotional communication, audience engagement, and overall performance appraisal. This interpretation is consistent with the original conceptual perspective of the article, according to which technical execution alone is insufficient to explain why some performances are perceived as more convincing, authentic, and artistically valuable than others. In this respect, recent work has reinforced the idea that the aesthetic appeal of dance is shaped by the interaction between stimulus properties, observer characteristics, and contextual variables, rather than by movement correctness alone (Christensen et al., 2025; Casale et al., 2024; Orlandi et al., 2025).

Figure 1 illustrates this multidimensional interpretation by showing how movement qualities, psychological and interpersonal processes, observer perception, and performance outcomes interact in dancesport. This framework is supported by recent evidence indicating that expressive dance is processed not only visually, but also through embodied, affective, and predictive mechanisms that shape aesthetic judgment and perceived performance quality (Bläsing et al., 2012; Orgs et al., 2024; Takagi et al., 2025; Rai et al., 2025). In relation to our review, the benefit of this framework is that it helps connect findings from movement science, neuroscience, and performance evaluation into a coherent interpretative model directly applicable to dancesport.

A first major point emerging from the literature is that expressivity operates through identifiable movement features, but cannot be reduced to them entirely. The studies reviewed in the Results section showed that amplitude, timing, rhythm, dynamics, and flow are recurrent carriers of emotional meaning. This is in line with more recent research showing that full body dance movements can serve as robust stimuli for emotion perception research and that observers can reliably decode affective content from bodily motion alone (Christensen et al., 2023). It is also consistent with recent work on aesthetic evaluation showing that embodied experience alters judgments of movement beauty and reproducibility, suggesting that what is perceived as expressive is shaped by both the movement itself and the observer's sensorimotor history (Casale et al., 2024). In comparison with our review, these studies strengthen the argument that expressivity in dancesport should be understood as a structured and perceptible dimension of performance, not as an intangible or purely subjective phenomenon.

A second important point concerns the relationship between technical mastery and expressive communication. The initial article correctly argued that technical accuracy provides the structural basis of dance, whereas expressivity adds emotional depth and artistic meaning. The recent literature supports this interpretation. Christensen et al. (2025) showed that expressivity and perceived authenticity are strong determinants of aesthetic appeal in dance, while Nam et al. (2024) found that peak performance in dancers depends on a combination of technical competence, artistry, mental regulation, and adaptive self expression. Yu et al. (2025) further reported that different dance modalities may produce distinct gains in aesthetic interpretation, with rumba showing notable benefits in expressive and articulated movement. Compared with our review, these findings highlight a useful novelty, namely that expressive quality is increasingly being treated as trainable and performance relevant, rather than as a vague artistic trait.

A third major theme is the role of observer expertise and perceptual sensitivity. The original article cited Cross et al. (2011) to argue that trained observers are better able to detect expressive cues. More recent work confirms and extends this view. Casale et al. (2024) showed that embodied experience shapes enjoyment, familiarity, and reproducibility judgments when viewing movement. Orgs et al. (2024) demonstrated that movement synchrony among performers predicts brain synchrony among spectators, suggesting that emergent coordination is a salient aesthetic feature for both expert and novice viewers. Poikonen et al. (2024) also reported that dance and music expertise modify cortical oscillatory responses

during the observation of live dance, supporting the idea that expertise changes how performance is processed at the neural level. Relative to our review, these studies are beneficial because they provide stronger support for the claim that judging in dancesport may be influenced not only by codified criteria, but also by embodied expertise and perceptual attunement.

This point is especially relevant for dancesport because competitive evaluation takes place under conditions of speed, complexity, and stylistic density. In practice, judges do not evaluate isolated motor elements, but integrated performance wholes. Recent research on dance aesthetics indicates that audience and observer responses are sensitive to performance context, synchrony, arrangement, and cultural familiarity. For example, Kempe et al. (2025) showed that stage configuration can influence aesthetic evaluation, while Christensen et al. (2025) found that enculturation affects the perception of emotional expressivity in dance. He et al. (2026) further suggested, in a sports dance context, that appreciation behavior is shaped by multiple perceptual and evaluative dimensions. These newer findings compare well with our review because they reinforce the idea that expressivity in dancesport is not evaluated in a vacuum, but through context dependent interpretation.

Another valuable direction concerns the interpersonal nature of expressivity in partnered performance. The initial manuscript already noted that expressivity emerges not only from the individual dancer, but also from interaction between partners, citing Ramos et al. (2026). Recent evidence gives this idea greater weight. Orgs et al. (2024) showed that synchrony among performers has direct consequences for spectators' neural alignment, while Rai et al. (2025) found that audience brain synchrony tracks engagement with dance. Houston (2024) argued that embodied agency in dance is nurtured through movement based relational practice, and Narikbayeva et al. (2025) linked dance experience to improvements in social interaction, communication, and perception of others. In relation to our review, the benefit of these studies is that they support a more specific dancesport interpretation of expressivity as relational coordination, not merely individual display.

The psychological interpretation of expressivity also deserves emphasis. The original article linked expressive performance to emotional intelligence and emotional authenticity, especially through San Juan Ferrer and Hípola (2020). More recent literature suggests that dance based activity is associated with embodied agency, affective awareness, transformation of aesthetic experience, and broader socio emotional development (Houston, 2024; Pizzolante et al., 2024; Narikbayeva et al., 2025; Yang et al., 2025). Although some of these studies come from therapeutic, educational, or community settings rather than competitive dance, they remain relevant because they clarify the mechanisms through which expressive practice may shape self regulation, interpersonal attunement, and communicative presence. Compared with our study, these contributions are useful because they expand the theoretical basis for why expressive training may matter in dancesport beyond formal scoring alone.

The technological dimension identified in our Results section also gains stronger support from recent research. The original article argued that machine learning and motion analysis offer promising, but partial, tools for studying expressivity. This interpretation remains valid. Sun and Wu (2023) proposed a deep learning approach for emotional analysis of sports dance, while Zhang et al. (2024) explored how convolutional neural networks and multimodal methods may support dance education and movement evaluation. Zhao et al. (2025) proposed a framework for dance posture estimation and cognitive load assessment, and Takagi et al. (2025) showed that cross modal features explain dance evoked brain activity better than low level motion and audio features alone. Together, these studies suggest that computational approaches are progressing from simple kinematic description toward richer models of expressive movement. However, they also confirm the central conclusion of our review, namely that technological assessment can complement, but not replace, human interpretation of artistic meaning, authenticity, and relational nuance in dancesport.

A further point of comparison concerns the novelty of the present review. Much of the recent literature has examined isolated components of expressivity, such as emotion recognition, observer expertise, synchrony, neural processing, educational value, or computational analysis. By contrast, the present article brings these strands together around the specific context of dancesport. In this sense, its contribution lies less in presenting a new empirical dataset and more in offering an integrative interpretative framework for a judged, partner based, aesthetically evaluated sport. This is important because studies on sports dance often focus either on physiological performance or on technique, whereas the literature synthesized here supports the view that expressivity is a decisive mediator between movement execution and evaluative outcome (Yu et al., 2025; He et al., 2026; Sun & Wu, 2023).

From a practical perspective, the findings reviewed here suggest that dancesport training should treat expressive development as a structured part of preparation. This includes work on movement modulation, musical phrasing, emotional intention, partner attunement, and performative authenticity. It may also include reflective and observational training, since expertise appears to shape how expressive information is encoded and decoded. Recent studies on peak performance, observer expertise, embodied agency, and sports dance appreciation support the idea that high quality performance emerges from the integration of physical, cognitive, and affective capacities rather than from technique alone (Nam et al., 2024; Houston, 2024; He et al., 2026). For judges, the literature also points to the value of clearer conceptual understanding of expressive criteria, especially in contexts where artistic quality can influence rankings among technically similar couples.

At the same time, the present review should be interpreted in light of the limitations of the available evidence. As already noted in the initial article, relatively few studies address dancesport directly, and many relevant findings derive from contemporary dance, ballet, neuroscience, aesthetics, or broader dance based settings. This limits the degree to which conclusions can be transferred without caution. Even so, the convergence of findings across recent research, including emotion perception studies, synchrony research, neuroaesthetic models, and sports dance investigations, suggests that expressivity is a robust and meaningful construct for understanding dancesport performance (Christensen et al., 2023; Orgs et al., 2024; Orlandi et al., 2025; Yu et al., 2025).

Future research should move in three main directions. First, more studies are needed that examine expressivity directly within competitive dancesport, especially in relation to judging consistency, partner interaction, and score differentiation. Second, longitudinal and intervention based studies should test whether targeted expressive training improves competitive outcomes. Third, computational and neurocognitive approaches should be developed in more ecologically valid settings, so that expressive analysis reflects live partnered performance rather than only laboratory stimuli. Recent work on live audience aesthetics, dance evoked brain activity, synchrony, and computational assessment suggests that the field now has the tools to move in this direction (Christensen et al., 2025; Rai et al., 2025; Takagi et al., 2025; Zhao et al., 2025; Rutgeerts et al., 2026).

5. Strengths and Limitations

Several limitations should be acknowledged when interpreting the findings of the present review. First, the study was conducted as a narrative review and therefore was not intended to provide an exhaustive systematic synthesis of all available literature. Although the search strategy, eligibility criteria, and thematic analysis were described explicitly, the review did not follow a formal systematic review protocol and did not include meta analytical procedures or standardized risk of bias assessment.

Second, the number of studies directly focused on dancesport remains limited. As a result, part of the interpretative framework developed in this article was informed by evidence drawn from related areas

such as ballet, contemporary dance, general dance perception research, empirical aesthetics, and embodied cognition. Although these fields offer conceptually relevant insights, their direct transfer to competitive dancesport should be made with caution.

Third, the reviewed literature includes considerable methodological diversity, ranging from theoretical papers and narrative reviews to experimental, psychophysiological, and computational studies. This heterogeneity enriches the interdisciplinary perspective of the article, but at the same time makes direct comparison between studies more difficult.

Fourth, the concept of expressivity itself remains variably defined across the literature. Different studies emphasize distinct aspects such as emotional intensity, authenticity, aesthetic appeal, movement quality, interpersonal coordination, or observer response. This conceptual variation may limit terminological consistency and complicate the development of unified evaluative frameworks.

Finally, because the review focused primarily on English language academic sources, relevant studies published in other languages may not have been included. Future research should address these limitations by conducting more targeted empirical investigations in dancesport, developing clearer operational definitions of expressivity, and testing intervention based approaches capable of linking expressive training to competitive performance outcomes.

6. Future Directions

Future research on expressivity in dancesport should move toward more focused and methodologically diversified investigations. One important direction is the development of empirical studies conducted directly in competitive dancesport settings, since much of the current evidence still derives from broader dance contexts such as ballet, contemporary dance, or general movement perception research. Studies specifically examining elite and non elite dancesport performers would provide a more precise understanding of how expressivity functions in relation to technical performance, judging, and competitive outcomes.

A second important direction concerns the need for clearer conceptual and operational definitions of expressivity. The current literature uses the term in relation to emotional communication, authenticity, aesthetic appeal, movement quality, and interpersonal coordination, but these dimensions are not always clearly distinguished. Future studies should aim to establish more consistent theoretical models and more precise evaluation criteria that can support both scientific analysis and applied practice.

Another relevant area for future research is the relationship between expressive training and performance development. Longitudinal and intervention based studies are needed to examine whether targeted strategies such as emotional awareness exercises, improvisation, partner attunement training, observational practice, and performance psychology interventions can improve expressive competence and competitive performance in dancesport.

Further research should also explore the role of judges' expertise and perceptual sensitivity in the evaluation of expressive performance. Studies comparing judges, coaches, dancers, and non expert observers could help clarify how expressive cues are perceived across levels of experience and how this affects performance assessment. Such work would be especially valuable for improving transparency and consistency in judged competitions.

In addition, technological approaches deserve continued attention. Motion capture, machine learning, and multimodal performance analysis offer promising tools for identifying movement features associated with expressivity, but further work is needed to improve ecological validity and to account for artistic, contextual, and relational aspects of performance. Future studies should investigate how these tools can complement rather than replace expert human evaluation.

Finally, greater attention should be given to the interpersonal dimension of expressivity in partner based dance. In dancesport, emotional communication is shaped not only by individual movement quality but also by synchronization, mutual responsiveness, and shared performative intention. Future research should therefore examine couple dynamics more directly, including coordination patterns, dyadic expressivity, and the relationship between partner interaction and judged performance quality.

7. Conclusions

The present narrative review highlights expressivity as a fundamental component of dancesport performance and evaluation. The analysed literature indicates that expressivity is not limited to artistic appearance, but represents a multidimensional construct involving movement qualities, emotional communication, interpersonal coordination, observer perception, and performance related outcomes. In this sense, expressive movement should be understood as an essential dimension through which dancers communicate meaning, enhance aesthetic impact, and differentiate performance quality in competitive contexts.

The reviewed studies suggest that expressivity is conveyed through identifiable movement features such as amplitude, timing, rhythm, dynamics, and flow, while its perception is shaped by psychological, relational, and contextual factors. The literature also indicates that expressive performance may influence both audience engagement and evaluative judgment, especially in aesthetic and judged movement disciplines such as dancesport.

An important contribution of the present review lies in its interdisciplinary integration of findings from dance studies, movement science, neuroscience, psychology, and emerging technological approaches to performance analysis. By bringing these perspectives together, the article provides a broader conceptual understanding of how expressivity functions in dancesport and why it should be considered a central element of performance preparation and evaluation.

From a practical perspective, the findings support the inclusion of expressive development as a structured component of dancesport training. Technical preparation alone may not be sufficient to optimize performance quality if it is not accompanied by the development of emotional authenticity, movement modulation, partner attunement, and performative presence. In addition, the review suggests that future assessment frameworks in dancesport may benefit from combining expert judgment with more refined observational and technological tools.

Overall, the present review contributes to the growing scientific discussion on aesthetic performance by clarifying the relevance of expressivity in dancesport and by identifying directions for more conceptually grounded research and practice in this field.

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The Role of Physiotherapy in Increasing the Quality of Life in Patients with Meniscus Injuries

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Abstract

Background: Meniscal injuries are among the most common knee disorders and may substantially affect pain, joint mobility, muscle function, autonomy and overall quality of life. In the postoperative phase, physiotherapy plays an important role in restoring functional capacity and supporting the patient's return to daily activities.

Objective: This study aimed to examine the short-term effects of an individualized physiotherapy program on pain, knee mobility, muscle function, autonomy and quality of life in patients with postoperative meniscal injuries.

Results: Four patients admitted to the orthopedic department were monitored during a five day postoperative recovery program. Clinical and functional assessment included pain intensity, knee function, quality of life, range of motion and lower limb perimeters. The findings showed a favorable progression in all monitored cases, with reduced pain, improved joint mobility, better functional scores and increased autonomy in daily activities. Improvements in patient reported quality of life were also observed at the final assessment. Individual differences in recovery rate supported the need for tailored rehabilitation strategies.

Conclusions: The results suggest that early, individualized physiotherapy may contribute to short term functional improvement and better quality of life after meniscal injury surgery. These findings support the clinical value of structured rehabilitation and highlight the need for further studies on larger samples.

Keywords: meniscal injury, physiotherapy, rehabilitation, quality of life, knee function, postoperative recovery, pain, joint mobility.

1. Introduction

Meniscal injuries are among the most frequent knee disorders encountered in orthopedic and sports medicine practice, affecting both younger individuals exposed to rotational or traumatic mechanisms and older adults with degenerative intra articular changes. Beyond local structural damage, meniscal pathology may alter load distribution, joint stability, proprioception, mobility, pain perception, and participation in daily life, thereby reducing functional independence and health related quality of life (Calanna et al., 2022; Luvsannyam et al., 2022). In recent years, growing attention has been directed toward preserving meniscal tissue and optimizing rehabilitation, because meniscal dysfunction is strongly

associated with persistent symptoms and with the long term risk of joint degeneration (Petersen et al., 2022; Randazzo et al., 2022; Garcia et al., 2024).

Current evidence shows that recovery after meniscal injury should not be viewed only through the lens of tissue healing, but also through changes in pain, muscle performance, knee function, autonomy, and patient reported outcomes. Recent reviews and trials have shown that exercise based rehabilitation can improve pain and physical function, and in several clinical contexts may yield outcomes comparable to surgery or to surgery plus exercise, particularly in degenerative tears and selected symptomatic patients (Kemp et al., 2021; Mao et al., 2024; Berg et al., 2021; Skou et al., 2022; Fernández Matías et al., 2023; Clausen et al., 2023; Rotini et al., 2023). This broader perspective is important because successful recovery is increasingly defined not only by structural or surgical success, but also by the patient's ability to regain confidence, mobility, daily function, and quality of life (Macri et al., 2022; Sedgwick et al., 2024).

At the same time, postoperative rehabilitation after meniscal surgery remains an area marked by considerable heterogeneity. Earlier work already noted wide variation in weight bearing, range of motion progression, and return to activity criteria after meniscal repair (Spang et al., 2018). More recent syntheses confirm that this variability persists, despite the expansion of the evidence base, and that protocol selection still depends heavily on lesion type, surgical procedure, biological healing constraints, and clinician preference (Culvenor et al., 2022; Calanna et al., 2022; Monson et al., 2025; Bouchard et al., 2025; Albishi et al., 2026). International consensus statements published recently have tried to reduce this inconsistency by recommending criterion based rehabilitation after meniscectomy and combined time based plus criterion based progression after meniscal repair or reconstruction (Pujol et al., 2025; Prill et al., 2025).

Another important direction in the literature concerns the need to personalize rehabilitation according to symptom presentation, tear characteristics, and postoperative tolerance. Studies addressing exercise therapy, aquatic rehabilitation, neuromuscular recovery, and adjunctive strategies suggest that patients do not progress uniformly and that short term improvements in pain, strength, function, and perceived well being depend on both the content and the timing of intervention (Reep et al., 2022; Yesil et al., 2023; Yamanashi et al., 2024; Guida et al., 2024). In parallel, recent reviews have emphasized that the overall certainty of evidence for several rehabilitation components remains limited, especially when specific meniscal subgroups are analyzed separately or when early postoperative outcomes are considered (Culvenor et al., 2022; Garcia et al., 2024).

Despite these advances, an important scientific gap remains. Much of the recent literature focuses on comparative treatment strategies, surgical indications, return to sport criteria, or long term structural and patient reported outcomes. Fewer studies describe in a clinically integrated way the short term postoperative contribution of individualized physiotherapy to pain relief, joint mobility, limb measurements, knee specific function, and perceived quality of life in real hospital settings, especially in small scale monitored patient groups during the immediate recovery phase (Mao et al., 2024; Monson et al., 2025; Pujol et al., 2025; Albishi et al., 2026). This gap is relevant because early recovery often determines later adherence, gait restoration, confidence in movement, and the transition from protected mobility to functional autonomy.

Within this context, the present study brings a practice oriented contribution by examining the short term postoperative evolution of patients with meniscal injuries who followed an individualized physiotherapy program in an orthopedic setting. Its novelty lies in the combined assessment of pain, knee function, quality of life, range of motion, and lower limb perimeters during the early recovery period, with emphasis on how tailored physiotherapy may support functional improvement and autonomy. Therefore, the aim of this study was to analyze the effects of an individualized physiotherapy program on pain,

mobility, muscle related clinical parameters, knee function, and quality of life in patients with postoperative meniscal injuries.

2. Materials and Methods

2.1. Study design

This study was designed as a prospective descriptive case series conducted in the orthopedic department, with the aim of examining the short term effects of an individualized physiotherapy program in patients undergoing postoperative recovery after meniscal injury. The study focused on the clinical and functional evolution of the patients during the early rehabilitation period, with particular attention to pain, knee mobility, muscle related parameters, functional status, autonomy, and perceived quality of life.

The research was carried out under routine hospital recovery conditions. The intervention was applied individually, according to the clinical profile and postoperative tolerance of each patient, while maintaining the general structure of the department's recovery protocol.

2.2. Participants

The study group consisted of four patients, including two men and two women, aged between 29 and 56 years, who had been clinically and imaging diagnosed with meniscal injuries and were admitted to the orthopedic department in the postoperative stage.

The inclusion criteria were as follows: confirmed meniscal injury, postoperative status, medical recommendation for physiotherapy, ability to cooperate throughout the intervention, and agreement to participate in the study. The exclusion criteria included postoperative complications, severe associated cardiovascular or neurological disorders, contraindications to physiotherapy, lack of cooperation, and refusal to participate.

All patients were informed about the purpose and procedures of the study and provided informed consent prior to inclusion. Special attention was given to patient safety, comfort, and adaptation of the therapeutic approach to the functional status of each participant.

2.3. Procedures

At baseline, all patients underwent an initial clinical and functional assessment using standardized instruments and objective measurements selected to reflect the main dimensions of postoperative recovery.

Pain intensity was assessed using the Visual Analog Scale, a self reported instrument ranging from 0 to 10, where higher scores indicate greater pain intensity. Knee function was evaluated with the Lysholm Knee Scoring Scale, which reflects symptoms and functional limitations related to stability, mobility, and performance of daily activities. Quality of life was assessed using the Quality of Life Scale, which explores the patient's perceived satisfaction across relevant domains of daily living and personal well being.

Joint mobility was measured by goniometry, with recording of active and passive knee flexion and extension. Lower limb perimeters were measured with a measuring tape at standardized anatomical levels in order to monitor postoperative edema and muscle related changes. These assessments provided the clinical basis for tailoring the physiotherapy program and for comparing patient status before and after the intervention.

The physiotherapy program was implemented over five consecutive days, with one individual session per day, performed in the patients' room according to the orthopedic department protocol. The intervention was designed to address acute postoperative symptoms and to support early recovery of mobility and autonomy.

The therapeutic means included postural management, cryotherapy, passive mobilization, active assisted and active exercises, transfer training, standing, gait initiation, and stair negotiation according to tolerance. Positioning with pillow support was used to facilitate comfort and promote venolymphatic drainage. In the early postoperative phase, cryotherapy was applied to the anterior and lateral knee region for 15 to 20 minutes in order to reduce pain and inflammation.

Exercise therapy progressively included movements for the operated lower limb, with emphasis on quadriceps and hamstring activation. The exercises included hip flexion, controlled knee flexion on the bed plane, and ankle dorsiflexion and plantarflexion from the supine position. Passive knee mobilization with kinetec was performed within an individualized range between full extension and up to 90 degrees of flexion, depending on tolerance and clinical status.

As recovery progressed, patients were gradually assisted from bed positioning to sitting, edge of bed control, chair transfers, orthostatic posture, and assisted gait using crutches or a walking frame. Stair climbing and descending exercises were introduced when clinically tolerated.

At the end of the five day intervention period, the final assessment was conducted using the same instruments and measurements as at baseline. This allowed direct comparison of the patients' clinical and functional evolution during the monitored rehabilitation period.

2.4. Recovery program objectives

The recovery program was structured around the following objectives: reduction of postoperative edema, pain control, restoration of clinical and functional status, prevention of secondary complications, recovery of joint mobility, improvement of muscle function, increase in exercise tolerance, gait re education, improvement of autonomy in daily activities, enhancement of quality of life, and facilitation of socio professional reintegration.

These objectives guided the progression of the intervention and supported the individual adaptation of the therapeutic program to each patient's needs and recovery pace.

2.5. Data analysis

The collected data were analyzed descriptively. For the monitored parameters, the values obtained at the initial and final assessment were compared in order to observe short term clinical changes during the intervention period. The analysis focused on trends of improvement in pain, knee mobility, limb perimeters, knee function, and quality of life. Microsoft Excel was used for data organization and graphical representation. Given the small sample size, the findings were interpreted exploratorily and no inferential statistical tests were applied.

2.6. Methodological considerations

As a narrative review, the present study was not intended to provide an exhaustive systematic synthesis of all available literature and did not include meta-analytical procedures or formal risk of bias assessment. Its main purpose was to offer a critical, conceptually integrated, and interdisciplinary overview of the current scientific literature on expressivity in dancesport and related dance performance contexts.

Nevertheless, methodological transparency was supported through the explicit description of the review design, search strategy, eligibility criteria, study selection process, and thematic analysis. This approach was considered suitable for clarifying the current scientific understanding of expressivity in dancesport, identifying recurring directions in the literature, and highlighting relevant gaps for future research.

The authors acknowledge that the narrative review format involves a degree of interpretative selection and does not claim the level of comprehensiveness associated with systematic reviews. However, this format was considered particularly appropriate for a developing field in which conceptual integration is needed alongside empirical synthesis.

2.7. Ethical considerations

The study was conducted in accordance with the ethical principles applicable to observational clinical research. The intervention did not exceed the routine therapeutic framework of postoperative physiotherapy. All participants voluntarily agreed to take part in the study and signed an informed consent form before inclusion. Confidentiality and anonymity of patient data were respected throughout the study.

3. Results

The short-term postoperative evaluation showed a favorable clinical and functional evolution in all four patients included in the study. Comparative analysis of the initial and final assessments indicated improvements in pain intensity, knee related functional status, quality of life, joint mobility, and local clinical parameters monitored during the five-day physiotherapy program. These findings suggest a consistent positive response to the individualized rehabilitation approach applied under routine orthopedic ward conditions.

Pain intensity, assessed using the Visual Analog Scale, decreased in all patients between the initial and final evaluations. At baseline, pain scores ranged from 7 to 9 points, indicating a high level of postoperative pain. At the end of the intervention period, VAS values decreased to a range of 1 to 4 points, reflecting a marked reduction in pain severity and improved tolerance to movement and daily functional activities. This reduction was one of the most evident short-term changes observed during the monitored recovery period.

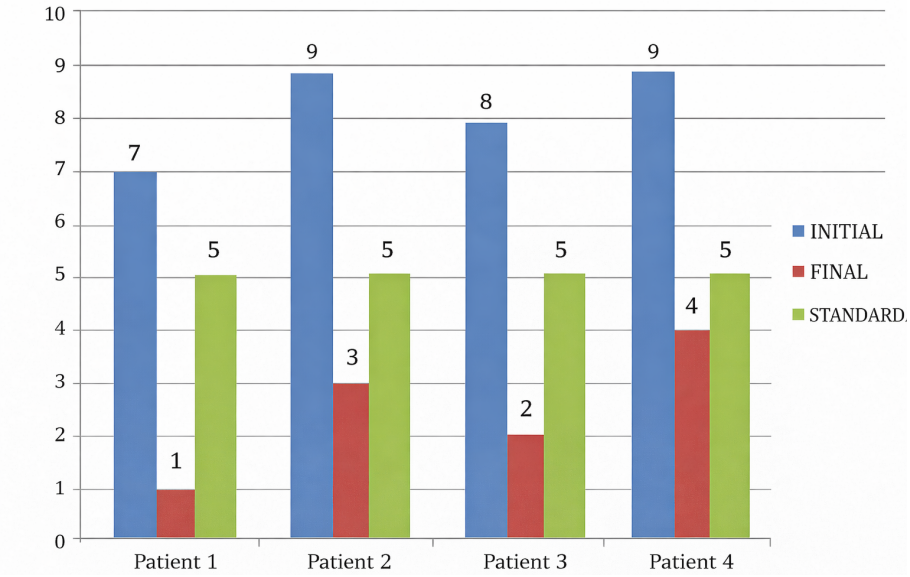


Figure 1. Changes in Visual Analog Scale pain scores between baseline and final assessment.

Quality of life, assessed with the Quality-of-Life Scale, also improved in all cases. Patient 1 increased from 76 to 88 points, patient 2 from 108 to 111 points, patient 3 from 90 to 101 points, and patient 4 from 68 to 83 points. Although the magnitude of change differed across participants, all patients recorded

higher final scores than at baseline, indicating a positive perceived impact of the intervention on daily life, well-being, and personal functioning.

Table 1. Changes in quality-of-life scores (QOLS) between baseline and final assessment

Scale QOLS			
	Initial	Final	Standard
Patient 1	76	88	112/112
Patient 2	108	111	
Patient 3	90	101	
Patient 4	68	83	
Scale Lysholm			
2/4	<60	84-90	>90
2/4	65-83	>90	

The evolution of thigh circumference was assessed in order to monitor local postoperative changes, particularly edema reduction and muscle related adaptations. As illustrated in Figure 2, slight decreases in thigh circumference were observed in all patients between baseline and final assessment.

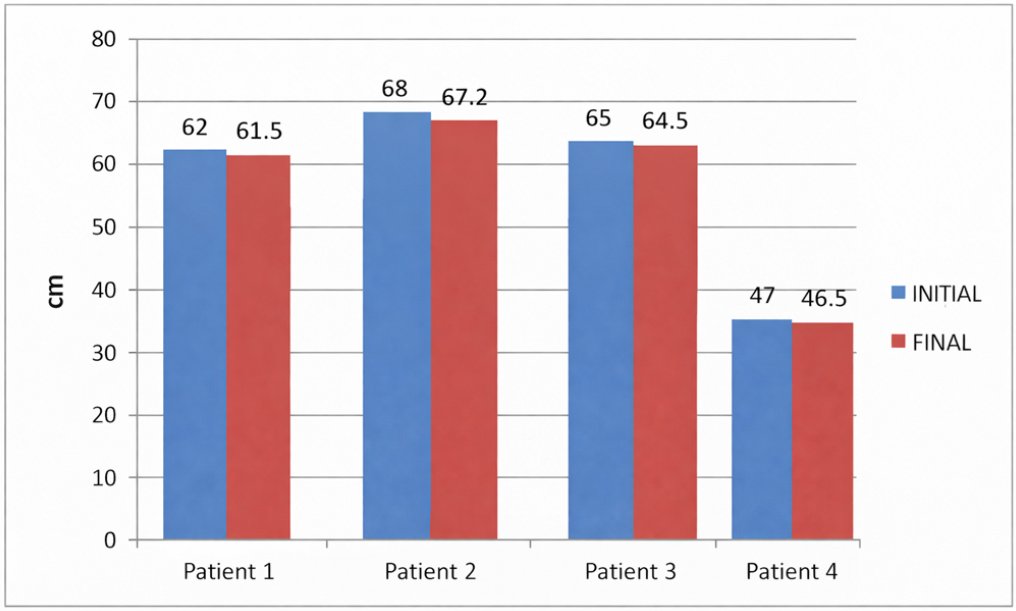


Figure 2. Changes in thigh circumference (cm) between baseline and final assessment

At baseline, thigh circumference values ranged from 47 cm to 68 cm across the four patients. Following the physiotherapy program, all patients showed a small but consistent reduction in measurements, with values decreasing by approximately 0.5 to 1 cm. Patient 1 decreased from 62 to 61.5 cm, patient 2 from 68 to 67.2 cm, patient 3 from 65 to 64.5 cm, and patient 4 from 47 to 46.5 cm.

These changes suggest a reduction in postoperative edema and an improvement in local tissue condition. Although the magnitude of change was modest, the consistent downward trend across all patients supports the effectiveness of early physiotherapy interventions in controlling swelling and facilitating initial recovery processes.

Knee function, evaluated by the Lysholm Knee Scoring Scale, showed a clear upward trend after completion of the physiotherapy program. At the initial assessment, two patients were classified in the category below 60 points, while the other two were in the 65 to 83 intervals, reflecting reduced functional knee status in the early postoperative stage. At final assessment, two patients progressed to the 84 to 90 interval and two patients exceeded 90 points. This shift indicates a clinically favorable progression in symptoms, functional stability, and activity related knee performance.

Knee perimeter was monitored to assess local postoperative swelling and the evolution of edema during the recovery period. As shown in Figure 3, all patients presented slight reductions in knee perimeter values between baseline and final assessment.

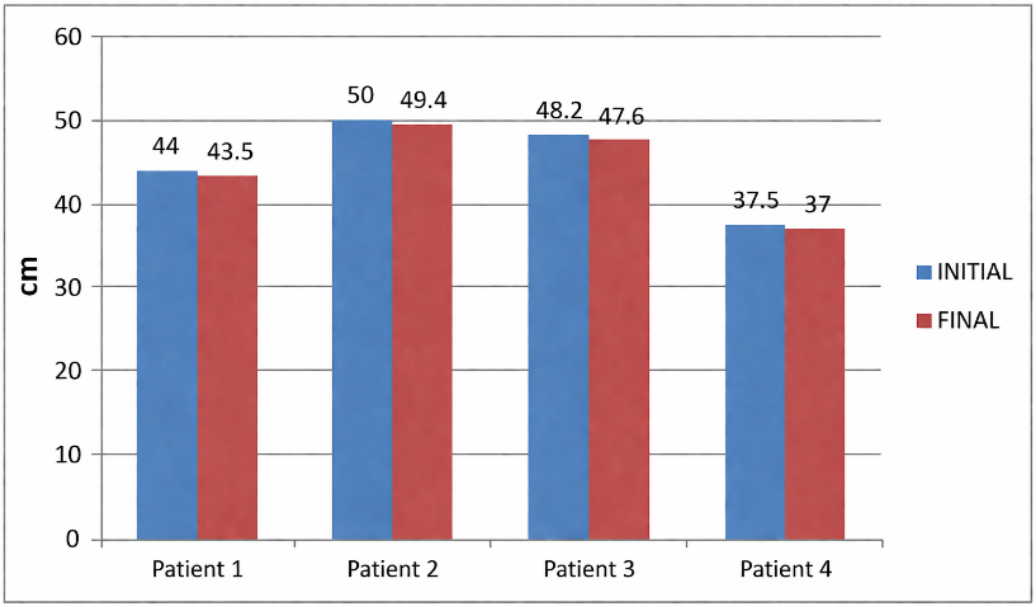


Figure 3. Changes in knee perimeter (cm) between baseline and final assessment.

At baseline, knee perimeter measurements reflected the presence of postoperative local swelling in all monitored cases. After completion of the physiotherapy program, all patients showed a decrease in knee perimeter values, suggesting a favorable reduction in edema and an improvement in local clinical status. This downward trend is consistent with the therapeutic objectives of early postoperative rehabilitation, particularly pain control, swelling reduction, and facilitation of joint mobility.

Although the magnitude of change was moderate, the uniform pattern observed across patients supports the role of the individualized physiotherapy program in improving local knee condition during the early recovery phase. These findings are clinically relevant because reduction in periarticular swelling may contribute to better tolerance to movement, improved joint function, and gradual restoration of autonomy in daily activities.

Calf circumference was assessed to monitor postoperative changes at the distal level of the lower limb, particularly in relation to edema and muscle condition. As illustrated in Figure 4, all patients showed slight reductions in calf circumference between baseline and final assessment.

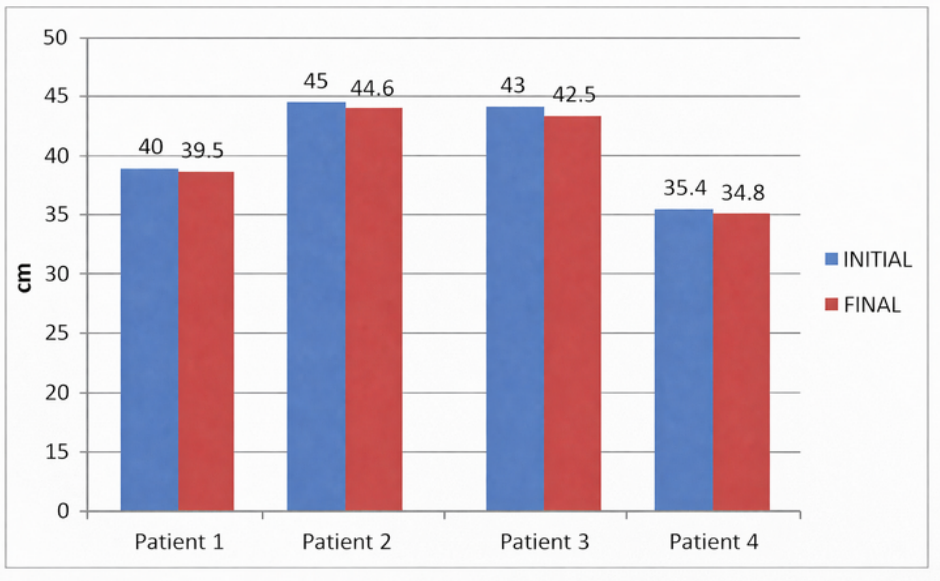


Figure 4. Changes in calf circumference (cm) between baseline and final assessment

At baseline, calf circumference values ranged from 35.4 cm to 45 cm across the four patients. Following the physiotherapy intervention, all patients demonstrated small but consistent decreases in measurements. Patient 1 decreased from 40 to 39.5 cm, patient 2 from 45 to 44.6 cm, patient 3 from 43 to 42.5 cm, and patient 4 from 35.4 to 34.8 cm.

These results indicate a reduction in distal postoperative swelling and suggest an improvement in local circulation and tissue condition. Although the changes were modest, the consistent decrease observed in all patients supports the role of early physiotherapy in managing edema and promoting recovery at the lower limb level.

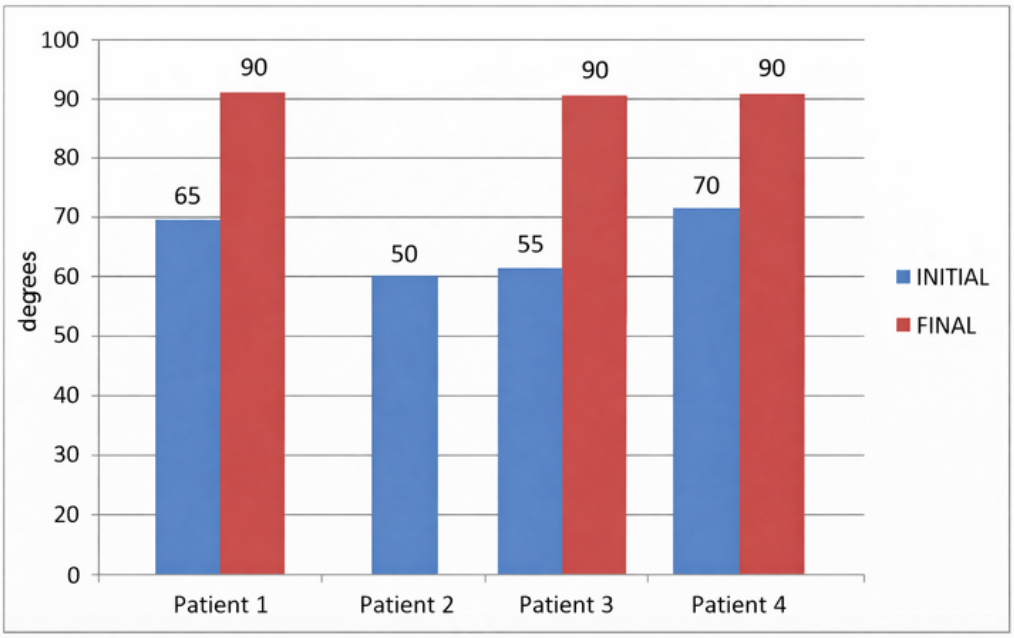


Figure 5. Changes in knee flexion (degrees) between baseline and final assessment

The evolution of lower limb perimeters, presented graphically in the original manuscript, showed changes consistent with the reduction of postoperative edema and progressive local recovery. The

monitored values at thigh, knee, and calf level suggested a favorable local response during the intervention period, supporting the clinical impression of improved tissue status and reduced swelling. These findings are in line with the therapeutic objectives established for edema control and early functional restoration.

Goniometric assessment of knee flexion and extension demonstrated progressive recovery of joint mobility from the initial to the final evaluation. The graphical data presented in the manuscript indicate an increase in knee flexion amplitude and an improvement in extension, suggesting a reduction in postoperative stiffness and better tolerance to active and passive mobilization. These changes are clinically relevant because restoration of range of motion is a central component of early postoperative rehabilitation and directly influences gait retraining and functional independence.

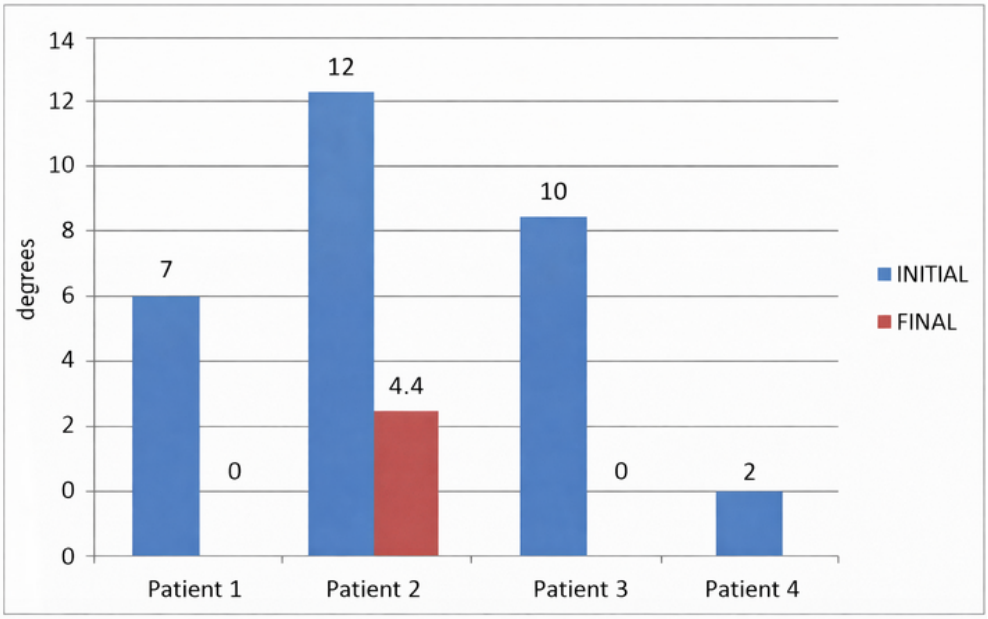


Figure 6. Changes in extension deficit (degrees) between baseline and final assessment

Figure 6 shows a reduction in extension deficit in all patients between baseline and final assessment. Patient 1 improved from 7° to 0°, patient 2 from 12° to 4.4°, patient 3 from 10° to 0°, and patient 4 from 2° to 0°. These results indicate a favorable recovery of knee extension during the early postoperative period. The reduction in extension deficit suggests decreased joint stiffness and improved functional readiness for standing, gait, and daily activities.

Taken together, the results support the descriptive observation that the individualized physiotherapy program was associated with short term improvements across the main domains targeted by the intervention, namely pain control, joint mobility, functional knee status, and perceived quality of life. Although the study was exploratory and based on a small case series, the uniform direction of change across all patients strengthens the practical relevance of the findings and supports the continuation of structured postoperative physiotherapy in patients with meniscal injuries.

4. Discussion

The present case series showed a favorable short term evolution in all monitored patients following the individualized postoperative physiotherapy program. The main findings were a reduction in pain intensity, improvements in knee related functional status, better perceived quality of life, decreases in lower limb circumferential measurements, and progressive recovery of knee flexion and extension. Although the intervention period was limited to five consecutive days, the uniform direction of change across all four patients suggests that early physiotherapy may play an important role in the initial

postoperative recovery process after meniscal injury. These findings are consistent with the current rehabilitation literature, which supports structured and progressive postoperative management aimed at controlling pain and swelling, restoring range of motion, and improving functional performance (Calanna et al., 2022; Culvenor et al., 2022; Pujol et al., 2025; Prill et al., 2025).

One of the most relevant findings in the present study was the decrease in pain scores at final assessment. This result is in agreement with recent evidence showing that rehabilitation based exercise and early postoperative management may contribute to pain reduction in patients with meniscal pathology. Mao et al. (2024) reported that exercise rehabilitation has potential to alleviate pain and improve mobility in patients with degenerative tibial meniscal tears, while Elsenosy et al. (2024) found that conservative management can provide meaningful pain relief in comparison with arthroscopic meniscal surgery in selected clinical contexts. Likewise, Fernández Matías et al. (2023) showed that exercise based approaches can provide outcomes comparable to surgery plus exercise over time in degenerative meniscal tears. In relation to these findings, the reduction in VAS values observed in our patients supports the practical value of early physiotherapy for postoperative symptom control.

The improvements observed in functional status and joint mobility are also in line with current concepts in meniscus rehabilitation. Recent reviews emphasize that postoperative rehabilitation should focus on progressive restoration of knee motion and function, while adapting the pace of recovery to lesion type, surgical procedure, and tolerance to loading. Culvenor et al. (2022) noted that the evidence base for meniscal rehabilitation remains heterogeneous, but still supports rehabilitation aimed at improving symptoms and physical function. Calanna et al. (2022) also highlighted that accelerated protocols with early partial weight bearing and range of motion progression may be appropriate in selected cases after isolated meniscal repair. More recently, Bozduman et al. (2023) reported that routine restriction of knee range of motion after arthroscopic meniscus repair may not be necessary, reinforcing the importance of individualized progression. In our study, the increase in knee flexion and the reduction in extension deficit are coherent with this rehabilitation direction.

Another important result was the slight but consistent reduction in thigh, knee, and calf circumferences, suggesting improvement in local postoperative swelling. This pattern is clinically relevant because edema control is closely linked to pain reduction, tolerance to mobilization, and restoration of quadriceps activation in the early phase of recovery. Although our study did not quantify inflammatory biomarkers or muscle strength through dynamometry, the circumferential changes observed in all patients support the role of local physiotherapy measures, positioning, cryotherapy, and progressive mobilization. This interpretation is indirectly supported by Lindner et al. (2023), who investigated postoperative pain management after arthroscopic meniscus procedures, and by Li et al. (2025), who reported improvements in VAS and Lysholm scores after arthroscopic management of meniscal injury.

The improvement in patient reported quality of life is another relevant aspect of the present study. Although our follow up was limited to the immediate postoperative phase, all patients reported higher QOLS scores at final assessment. This is important because meniscal pathology affects more than local knee symptoms. Filbay et al. (2022) showed that meniscal injury is associated with long term consequences for quality of life, work limitation, physical activity, and disease burden. Therefore, even modest early improvements in perceived well being may be clinically meaningful, especially when they accompany pain reduction and increased autonomy in daily activities. In this context, our results support the idea that postoperative physiotherapy should target both physical recovery and patient centered outcomes.

At the same time, our findings must be interpreted with caution. The study included only four patients, had no control group, and used a short observation window of five days. For this reason, the results cannot support strong causal inferences or broad generalization. Rather, they provide a clinically

oriented description of early postoperative evolution under an individualized physiotherapy program. This limitation is consistent with the wider literature, where rehabilitation protocols after meniscal injury still show marked heterogeneity and where recent international consensus statements continue to recommend individualized, criterion based progression rather than a single universal postoperative model (Culvenor et al., 2022; Pujol et al., 2025; Prill et al., 2025).

Another important point is that our results should not be interpreted as evidence against surgery or in favor of one single rehabilitation pathway. Instead, they support the practical role of physiotherapy within the broader continuum of meniscal care. Recent comparative studies indicate that exercise based management can achieve pain and function outcomes similar to surgical pathways in some patient categories, especially in degenerative tears, but postoperative rehabilitation remains essential when surgery is performed (Fernández Matías et al., 2023; Elsenosy et al., 2024). Our data fit this perspective, because the observed benefits emerged in a real postoperative setting in which physiotherapy served as the active recovery component.

Overall, the present study adds a small but clinically relevant contribution to the literature by documenting the short term postoperative evolution of patients with meniscal injuries in a hospital based rehabilitation context. Its practical value lies in the combined monitoring of pain, knee function, quality of life, range of motion, and circumferential measurements during the immediate recovery phase. Future research should include larger samples, longer follow up periods, more detailed characterization of tear type and surgical procedure, and standardized functional testing in order to better define the magnitude and durability of physiotherapy related improvements after meniscal injury. Recent literature supports exactly this direction, emphasizing the need for clearer and more standardized rehabilitation frameworks while preserving individualized decision making (Pujol et al., 2025; Prill et al., 2025).

5. Strengths and Limitations

This study has several strengths. First, it used a clinically relevant and patient centered perspective by combining the assessment of pain, knee specific function, quality of life, joint mobility, and lower limb circumferential measurements. Second, the rehabilitation program was applied in a real postoperative orthopedic setting, which increases the practical value of the findings for routine clinical care. Third, the repeated baseline and final assessment allowed a clear description of short term changes observed during the monitored recovery period.

At the same time, several limitations must be acknowledged. The most important limitation is the very small sample size, which restricts generalizability and prevents robust statistical analysis. The absence of a control group makes it impossible to establish causal relationships between the intervention and the observed improvements. In addition, the follow up period was limited to five days, which only reflects early postoperative recovery and does not allow conclusions regarding medium term or long term outcomes. Another limitation is the lack of detailed stratification according to meniscal lesion type, surgical procedure, and preinjury functional level. Therefore, the findings should be interpreted as preliminary and descriptive.

6. Future Directions

Future research should include larger patient samples and longer follow up periods in order to better understand the persistence and magnitude of physiotherapy related improvements after meniscal injury. Comparative studies involving different rehabilitation protocols, postoperative timelines, and patient subgroups would provide stronger evidence for clinical decision making. It would also be valuable to include additional outcome measures, such as objective muscle strength testing, gait analysis, return to activity indicators, and validated knee specific patient reported outcome measures. A more detailed

classification of injury type and surgical management would further improve the clinical applicability of future findings. Such developments may help define more standardized, yet individualized, rehabilitation strategies for patients recovering from meniscal injuries.

7. Conclusions

The present study suggests that an individualized postoperative physiotherapy program may support early recovery in patients with meniscal injuries by reducing pain, improving knee mobility, enhancing functional status, and increasing perceived quality of life. Although the findings are based on a small descriptive case series, the consistent positive trend observed across all patients highlights the clinical relevance of structured early rehabilitation. These results support the inclusion of personalized physiotherapy as an essential component of postoperative meniscal recovery and underline the need for larger and methodologically stronger studies to confirm these preliminary observations.

Author Contributions: Conceptualization, C.V.G. and A.M.B.; methodology, C.V.G. and A.M.B.; investigation, C.V.G.; data curation, C.V.G.; formal analysis, C.V.G.; writing, original draft preparation, C.V.G.; writing, review and editing, C.V.G. and A.M.B.; supervision, A.M.B. All authors have read and agreed to the published version of the manuscript.

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The Opinion of Sports Dance Specialists Regarding Physical Training

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Abstract

Background: Dance sport has evolved into a highly demanding discipline, marked by increasing technical complexity and higher performance standards that require the development of both technical and physical capacities. Despite this progress, the role of physical training remains insufficiently emphasized in both research and coaching practice.
Objective: The aim of this study was to explore the perceptions of dance sport specialists regarding the importance, structure, and role of physical training within the overall training process.
Results: A cross-sectional survey design was used, based on a structured questionnaire with eight items and Likert-type response scales, administered to 20 dance sport coaches. The collected data were analyzed using descriptive statistical methods. The findings showed that, although most specialists acknowledge the importance of physical training, its systematic planning and implementation remain inconsistent, which highlights a gap between theoretical knowledge and practical application. The motor capacities considered most relevant were coordination, rhythm, balance, and spatial-temporal orientation, while endurance-related capacities were considered less important.
Conclusions: The results highlight the need for structured and evidence-based physical training programs adapted to the specific demands of dance sport, in order to optimize performance and support a balanced development of motor skills.

Keywords: dance sport; physical training; performance; motor skills; coaching

1. Introduction

Sports performance is a complex and multifactorial construct shaped by the interaction of morphological, functional, technical, and psychological factors, and developed through a systematic training process aimed at optimizing performance capacity (Epuran, 2005; Bompa & Buzzichelli, 2019). Within this framework, physical training has a central role because it supports the development of the motor capacities required for efficient technical execution, injury prevention, and long term athletic

progression. In aesthetic sports, this relationship is even more important, because performance depends not only on technical precision but also on movement quality, control, expressiveness, and repeated execution under competitive stress (Koutedakis & Jamurtas, 2004; Koutedakis et al., 2005).

Dance sport is a discipline situated at the intersection of athletic performance and artistic expression. Its competitive demands require athletes to combine coordination, rhythm, balance, spatial temporal orientation, strength, mobility, and the ability to maintain movement quality throughout complex routines. Earlier literature already described dancers as performing athletes with specific physiological demands and highlighted the importance of targeted conditioning to support technical and artistic performance (Koutedakis & Jamurtas, 2004; Angioi et al., 2009; Twitchett et al., 2010). More recent evidence has further strengthened this perspective. A systematic review by Ngo et al. showed that strength and conditioning interventions can improve relevant physical qualities in dancers, supporting the inclusion of supplementary physical preparation alongside technical training. A 2025 meta analysis by Yang et al. also reported positive effects of strength training on dancers' physical fitness, especially in relation to strength, jump ability, and functional performance. In parallel, recent work has shown that structured physical fitness training may also contribute to reducing injury incidence in dance populations, although the available evidence remains methodologically heterogeneous (Ngo et al., 2024; Dang et al., 2024; Yang et al., 2025).

Recent studies have also emphasized that dance performance relies on a wide set of neuromuscular and sensorimotor qualities that extend beyond technical repetition alone. Research on postural stability and dance specific balance testing has shown that dancers develop superior balance and control, which are fundamental for precise execution and body alignment. Other studies have highlighted the importance of movement competency screening, proprioceptive training, and functional assessment in understanding performance readiness and injury risk. These findings support the idea that dance training should include systematic physical preparation and regular evaluation, rather than assuming that technical practice alone is sufficient to generate all relevant physical adaptations (Marinkovic et al., 2022; Johari et al., 2022; Callahan et al., 2024; Mancini et al., 2025).

At the same time, the current literature suggests that the practical implementation of physical training in dance settings is still inconsistent. Studies exploring attitudes toward strength training have shown that dancers, teachers, and students generally recognize its value, but perceptions, acceptance, and actual integration into training practice vary across groups and contexts. Similar findings were reported among vocational dance students, where positive perceptions of strength training did not always translate into a fully structured conditioning approach. This is important because favorable attitudes do not automatically guarantee methodological rigor in planning, dosage, or monitoring physical work within the annual training process (Farmer et al., 2021; Farmer et al., 2024).

Another important issue concerns training load and injury risk. Recent evidence from dance populations shows that high training demands, inadequate recovery, and poor load management are associated with musculoskeletal complaints, fatigue, and performance limitations. Injury related research in dance has increasingly recommended structured conditioning, better surveillance, and improved reporting of dancer capacities and risk factors. These findings are highly relevant for dance sport, where repeated technical drills, high movement precision, and competitive pressure may increase the need for balanced physical preparation. However, most recent studies have focused either on ballet, contemporary dance, breaking, or mixed dance populations, rather than on coaches working specifically in dance sport settings (Kenny et al., 2021; Arundale et al., 2023; Critchley et al., 2025).

Although the evidence base on physical preparation in dance has expanded in recent years, an important scientific gap remains. Much of the literature has examined intervention effects, injury patterns, balance, strength training, or broader dance related health outcomes, while fewer studies have investigated how dance sport specialists themselves understand the role of physical training within the overall preparation process. This gap is relevant because coaching beliefs influence planning decisions, training priorities, evaluation practices, and the balance between technical and physical work. In dance sport, where performance depends on both specific motor capacities and artistic execution, understanding specialists' perceptions is essential for identifying inconsistencies between scientific knowledge and field practice. Recent studies on multi dance training and peak performance attributes further support the need to connect physical preparation with discipline specific demands, but they do not directly clarify how coaches prioritize these components in everyday training design (Nam et al., 2024; Yu et al., 2025).

Therefore, the novelty of the present study lies in its focus on the opinion of dance sport specialists regarding the importance, structure, and practical role of physical training within the broader training process. By examining how coaches perceive the relationship between physical and technical training, the value of specificity, the relevance of assessment, and the hierarchy of motor capacities involved in dance sport effort, this study aims to contribute both to the theoretical understanding of dance sport preparation and to the practical optimization of training methodology. In this context, the following sections present the aim, objectives, hypothesis, research methods, and the results obtained from the questionnaire applied to dance sport coaches.

2. Materials and Methods

2.1. Study Design

The present study was designed as a cross sectional descriptive research based on a questionnaire survey. The aim of the study was to investigate the opinions of dance sport specialists regarding the importance of physical training and its role in optimizing performance capacity within the overall training process. A survey based design was considered appropriate because it allowed the collection of data on professional perceptions, methodological preferences, and training related priorities in a specific coaching population.

The study had an exploratory character, focusing on the identification of trends and patterns in specialists' responses rather than on testing causal relationships. This design was also suitable for examining how coaches perceive the relationship between physical and technical training, the relevance of motor capacities, and the role of assessment in dance sport preparation.

2.2. Participants

The study sample consisted of 20 dance sport coaches actively involved in the preparation of athletes from different age categories and competitive levels. The participants were selected on the basis of their professional involvement in dance sport coaching and their willingness to take part in the study. Including specialists with practical experience in different training contexts made it possible to obtain a broader perspective on the role and place of physical training in dance sport. All participants completed the questionnaire individually and voluntarily.

2.3. Eligibility Criteria

In order to ensure the relevance of the collected data, a series of inclusion criteria were established. Participants were eligible for the study if they met the following conditions:

- they were actively involved in dance sport coaching activities,
- they had practical experience in training athletes in organized dance sport settings,
- they agreed voluntarily to participate in the study,
- they completed the questionnaire in full.

Incomplete questionnaires were excluded from the final analysis. Individuals who were not actively involved in coaching practice at the time of the study were not considered eligible.

2.4. Questionnaire Development

The questionnaire used in the present study was developed by the authors in accordance with the aim of the research, the practical characteristics of dance sport training, and the main themes identified in the specialized literature. The formulation of the items was guided by key aspects related to the role of physical training, the relationship between physical and technical preparation, the specificity of effort, and the importance of motor capacities in dance sport performance.

The final version of the instrument included 8 items structured to provide a clear overview of coaches' perceptions regarding the place of physical training in the overall preparation process. The wording of the items was kept concise and accessible in order to facilitate understanding and ensure consistency in responses.

2.5. Instrument and Outcome Measures

Data were collected using a structured questionnaire consisting of 8 items with Likert type response scales. The questionnaire addressed the following dimensions:

- the perceived importance of physical training,
- the relationship between physical and technical training,
- the importance of planning the volume of physical training within the annual cycle,
- the effectiveness of specific and non specific training means,
- the importance of periodic assessment,
- the role of various motor capacities involved in dance sport effort,
- the importance of effort specificity in physical training,
- the relevance of research on motor capacity profiles in dance sport.

Each item was rated on a four point Likert scale with the following response options: not at all, to a lesser extent, to a great extent, and to a very large extent.

The main outcome measures were represented by the frequency and percentage distribution of responses for each questionnaire item. These indicators were used to identify the dominant opinions of specialists and to highlight the main tendencies related to the practical understanding of physical training in dance sport.

2.6. Procedures

The questionnaire was prepared in electronic format and distributed to participants by e mail. Before participation, all respondents were informed about the purpose of the study, the voluntary character of participation, and the anonymous treatment of the collected data.

Participants completed the questionnaire independently and returned it in digital format. After collection, all responses were centralized, verified for completeness, and prepared for statistical processing. The procedure was designed to provide a simple and accessible method of data collection while reducing the influence of external factors on the responses.

2.7. Ethical Considerations

The study was conducted in accordance with the principles of voluntary participation, confidentiality, anonymity, and respect for participants' rights. All respondents were informed about the aim of the research and the use of the collected data exclusively for scientific purposes.

No personal data allowing the direct identification of participants were collected or reported. Completion and return of the questionnaire were considered to reflect informed consent for participation in the study.

2.8. Statistical Analysis

The collected data were processed using descriptive statistical methods. Absolute frequencies and percentages were calculated for each response category in order to identify the distribution of answers across the questionnaire items.

The results were organized in tables and graphical representations to support interpretation and facilitate the presentation of findings. Given the relatively small sample size and the descriptive nature of the study, the statistical analysis remained exploratory and no inferential statistical tests were applied.

3. Results

The analysis of the questionnaire responses revealed several relevant findings regarding the perception of physical training in dance sport among specialist coaches. Overall, the results showed that physical training was widely recognized as an important component of the training process, although notable differences were observed in relation to its planning, specificity, and the perceived relevance of particular motor capacities.

Table 1. Perception of physical training components among dance sport specialists. of perceived importance of physical training components in dance sport.

No.	Item	Not at all n (%)	To a lesser extent n (%)	To a great extent n (%)	To a very large extent n (%)
1	Importance of the relationship between physical and technical training	0 (0%)	5 (25%)	5 (25%)	10 (50%)
2	Importance of determining the volume of physical training in the annual cycle	0 (0%)	10 (50%)	10 (50%)	0 (0%)
3	Effectiveness of non-specific training means	0 (0%)	10 (50%)	10 (50%)	0 (0%)
4	Effectiveness of specific training means	0 (0%)	5 (25%)	15 (75%)	0 (0%)
5	Importance of periodic assessment of physical training	0 (0%)	0 (0%)	5 (25%)	15 (75%)
6.	Which of the motor capacities below do you consider to be involved in dance sports?				

6.1	Speed under coordination	0 (0%)	0 (0%)	5 (25%)	15 (75%)
6.2	Speed under rhythmicity	0 (0%)	0 (0%)	5 (25%)	15 (75%)
6.3	Speed in resistance mode	0 (0%)	0 (0%)	10 (50%)	10 (50%)
6.4	Force under speed	0 (0%)	0 (0%)	5 (25%)	15 (75%)
6.5	Force under amplitude	0 (0%)	0 (0%)	5 (25%)	15 (75%)
6.6	Explosive force	0 (0%)	5 (25%)	10 (50%)	5 (25%)
6.7	Force in resistance mode	0 (0%)	15 (75%)	0 (0%)	5 (25%)
6.8	Specific resistance	0 (0%)	15 (75%)	0 (0%)	5 (25%)
6.9	Resistance under force	0 (0%)	10 (50%)	10 (50%)	0 (0%)
6.10	Resistance under coordination	0 (0%)	10 (50%)	10 (50%)	0 (0%)
6.11	Flexibility and joint mobility	0 (0%)	15 (75%)	0 (0%)	5 (25%)
6.12	Balance control capacity	0 (0%)	0 (0%)	15 (75%)	5 (25%)
6.13	Spatial-temporal orientation capacity	0 (0%)	0 (0%)	15 (75%)	5 (25%)
6.14	Rhythm and tempo capacity	0 (0%)	0 (0%)	15 (75%)	5 (25%)
7	Importance of specificity in physical training	0 (0%)	10 (50%)	5 (25%)	5 (25%)
8	Importance of research on motor capacity profiles	0 (0%)	0 (0%)	10 (50%)	10 (50%)

3.1. Overall Perception of Physical Training in Dance Sport

The responses indicated that most specialists acknowledged the importance of the relationship between physical training and technical training. Half of the respondents, n = 10, 50%, considered this relationship important to a very large extent, while 5 respondents, 25%, rated it to a great extent and another 5, 25%, to a lesser extent. No participant considered this relationship unimportant. These findings suggest that the majority of coaches recognize the close connection between physical preparation and technical performance in dance sport.

At the same time, the planning of physical training volume within the annual cycle generated a more balanced distribution of responses. Ten coaches, 50%, considered this aspect important to a lesser extent, while the remaining 10, 50%, rated it to a great extent. No responses were recorded in the categories not at all or to a very large extent. This result reflects a less consistent perception regarding the structured integration of physical training into the annual plan.

The effectiveness of non specific physical training means was also evaluated in a balanced manner, with 10 respondents, 50%, rating them to a lesser extent and 10 respondents, 50%, to a great extent. In contrast, specific training means were perceived more positively. Fifteen respondents, 75%, considered them effective to a great extent, while 5 respondents, 25%, rated them to a lesser extent. This distribution indicates a stronger preference for training methods that are directly related to the specific demands of dance sport.

A strong consensus was observed regarding the importance of periodic assessment of physical training. Fifteen respondents, 75%, rated it to a very large extent, while 5 respondents, 25%, rated it to a great extent. No lower ratings were recorded. Similarly, all participants expressed favorable views regarding the importance of research on motor capacity profiles in dance sport, with 10 respondents, 50%, selecting to a great extent and 10 respondents, 50%, selecting to a very large extent.

The importance of orienting physical training toward the specificity of effort produced more heterogeneous results. Ten respondents, 50%, rated this aspect to a lesser extent, while 5 respondents, 25%, selected to a great extent and 5 respondents, 25%, selected to a very large extent. This suggests that the principle of specificity is not equally emphasized by all specialists.

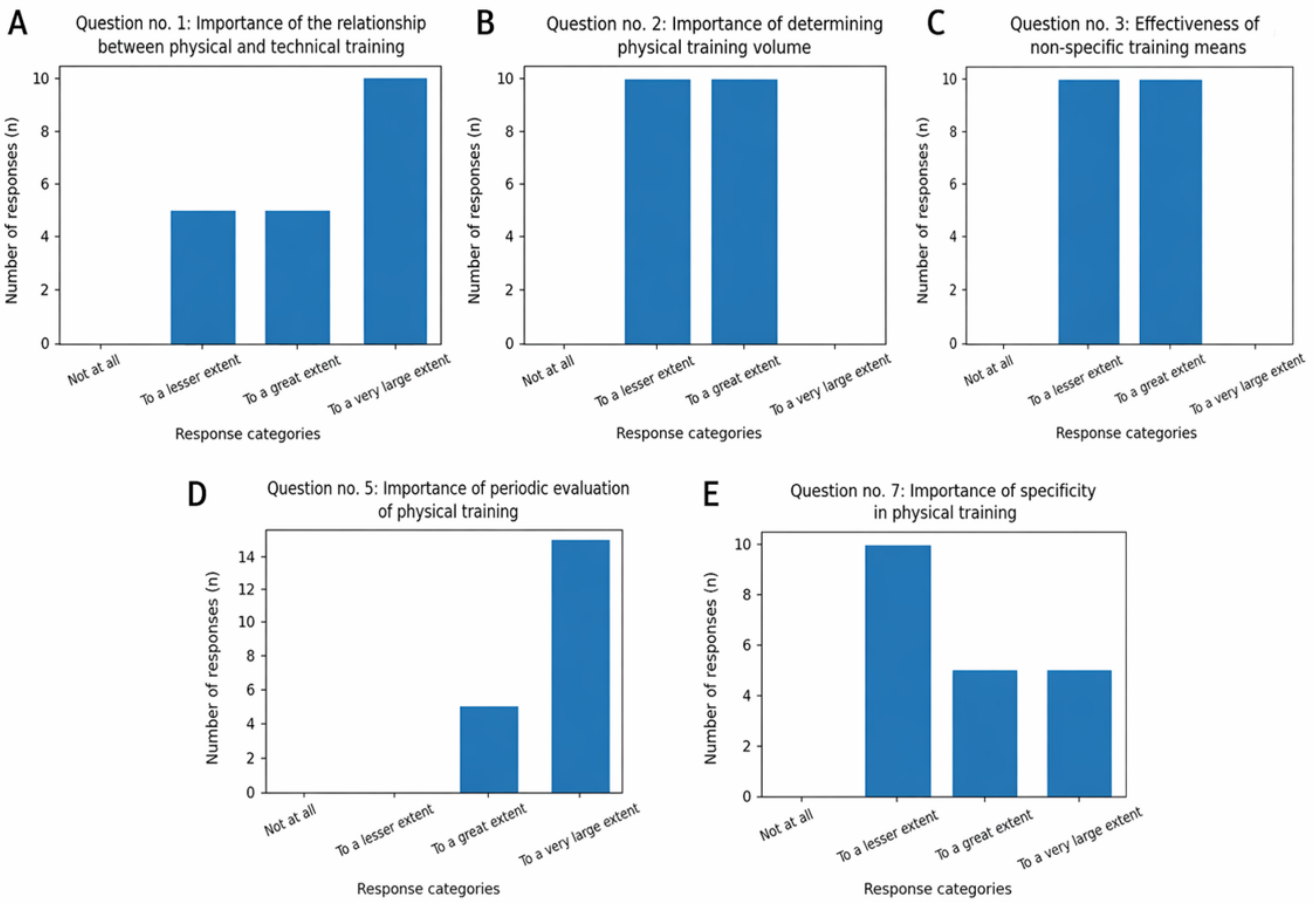


Figure 1. Distribution of responses regarding training planning, specificity, assessment, and research related aspects of physical training

3.2. Perceived Effectiveness of Specific and Non Specific Training Means

The comparison between specific and non specific training means revealed a clear difference in coaches' perceptions. Non specific means generated divided opinions, with equal percentages in the categories to a lesser extent and to a great extent. By contrast, specific means received more favorable evaluations, with 75% of respondents considering them effective to a great extent. These findings highlight the tendency of dance sport specialists to value training methods that reproduce or support the specific motor and coordinative demands of competition.

Although both categories of training means were recognized as relevant, the stronger support for specific methods indicates that coaches tend to associate performance development more closely with discipline specific preparation than with general physical conditioning.

This comparison is also reflected in Table 1 and contributes to the overall interpretation of how physical training is conceptually organized in dance sport practice.

3.3. Motor Capacity Profile Perceived as Relevant for Dance Sport

The analysis of the motor capacities included in the questionnaire revealed a differentiated hierarchy of perceived importance. The highest rated capacities were speed under coordination, speed under rhythmicity, force under speed, and force under amplitude. For each of these, 15 respondents, 75%, selected to a very large extent and 5 respondents, 25%, selected to a great extent. These results indicate a

strong consensus regarding the importance of capacities that directly support movement precision, rhythmic execution, and dynamic technical performance.

Balance control capacity, spatial temporal orientation capacity, and rhythm and tempo capacity were also highly appreciated. In each case, 15 respondents, 75%, rated these capacities to a great extent, while 5 respondents, 25%, rated them to a very large extent. This confirms the central role of coordinative and perceptual motor abilities in dance sport performance.

A moderate level of importance was observed for speed in resistance mode, where 10 respondents, 50%, selected to a great extent and 10 respondents, 50%, selected to a very large extent. Explosive force showed a more varied distribution, with 10 respondents, 50%, rating it to a great extent, 5 respondents, 25%, to a very large extent, and 5 respondents, 25%, to a lesser extent.

Lower ratings were recorded for force in resistance mode and specific resistance. In both cases, 15 respondents, 75%, selected to a lesser extent, while only 5 respondents, 25%, rated them to a very large extent. Resistance under force and resistance under coordination received intermediate evaluations, with 10 respondents, 50%, choosing to a lesser extent and 10 respondents, 50%, choosing to a great extent.

An unexpected result was observed for flexibility and joint mobility. Although these qualities are commonly associated with dance related activities, 15 respondents, 75%, rated them only to a lesser extent, while 5 respondents, 25%, considered them important to a very large extent. This distribution places flexibility and joint mobility among the lowest rated capacities in the specialists' hierarchy.

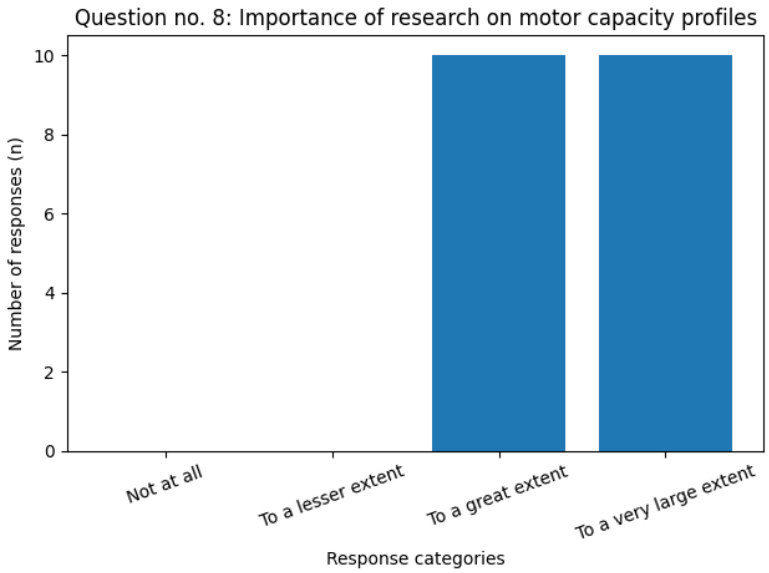


Figure 2. Perceived relevance of motor capacities involved in dance sport performance

3.4. Synthesis of the Main Findings

Taken together, the findings indicate that dance sport specialists generally recognize the importance of physical training and its connection with technical preparation. However, the results also reveal inconsistencies in the perceived importance of planning, specificity, and the role of certain motor capacities within the training process. The strongest consensus was recorded for the importance of assessment and for coordinative, rhythmic, and spatial temporal capacities, while lower importance was attributed to resistance related components and flexibility. These tendencies provide a useful basis for the interpretation of coaching practice in the subsequent discussion section.

4. Discussion

The present study aimed to explore the opinions of dance sport specialists regarding the role of physical training within the overall preparation process. The findings indicate that most coaches recognize the importance of physical training and its close relationship with technical preparation, yet the practical integration of this component appears to remain uneven and insufficiently structured. This discrepancy between conceptual acknowledgment and methodological consistency represents one of the central findings of the study.

A first relevant result is the strong recognition of the relationship between physical and technical training. Most respondents considered this relationship important to a great or very large extent, which suggests that dance sport specialists do not view physical preparation as separate from technical performance. This result is consistent with the classical perspective that dancers should be regarded as performing athletes, whose technical quality depends on adequate physical support, including strength, coordination, stability, and conditioning (Koutedakis & Jamurtas, 2004; Koutedakis et al., 2005). It is also in line with more recent evidence showing that dancers and dance students increasingly recognize the value of structured conditioning and strength training, even though acceptance and practical implementation still vary between settings and populations (Rosenthal et al., 2021; Farmer et al., 2024).

At the same time, the present results show that the planning of physical training volume within the annual cycle is not perceived with the same consistency. Half of the respondents rated this aspect only to a lesser extent, which suggests that physical training is often acknowledged in principle but not always periodized or clearly distributed within the training plan. This finding supports the idea that in dance related environments, physical development is still frequently expected to emerge indirectly through technical practice rather than through a distinct and progressive conditioning strategy. Similar concerns appear in recent literature, where researchers have emphasized that dance training load is often poorly quantified, inconsistently monitored, and methodologically underreported, despite its direct relevance for adaptation and injury risk (Volkova et al., 2023; Armando et al., 2025).

Another important observation concerns the preference for specific over non specific means of physical training. In the present study, specific training methods were rated more favorably than non specific ones, which reflects the logic of dance sport performance, where technical expression is strongly tied to rhythm, spatial control, timing, posture, and discipline specific movement patterns. This preference is understandable and practically relevant. However, the literature also suggests that general physical training should not be underestimated, because supplementary strength and conditioning programs can improve relevant physical qualities and may support both performance and resilience to injury when integrated appropriately (Ngo et al., 2024; Yang et al., 2025). In this sense, the current findings do not argue against specificity, but rather indicate the need for a better balance between specific and supportive training content.

The very high importance attributed to periodic assessment is one of the strongest and most encouraging findings of the study. Most respondents considered evaluation essential, which shows that specialists understand the value of monitoring training effects. This result is supported by recent work emphasizing the usefulness of dance specific assessment tools, movement competency screening, and functional testing for identifying deficits, monitoring adaptation, and potentially reducing injury risk (Beckman et al., 2022; Callahan et al., 2024). The growing interest in structured assessment in dance is also reflected in recent work on reliable injury and participation questionnaires, as well as in research on wearable technologies and monitoring practices, which aim to improve decision making in dance training environments (George et al., 2023; Volkova et al., 2023).

The hierarchy of motor capacities identified by the respondents also deserves close attention. Coordination based speed, rhythmicity, balance, and spatial temporal orientation were among the most

highly valued components. This profile is highly coherent with the specific demands of dance sport, where movement precision, synchronization with music, dynamic control, and rapid adaptation to partner and spatial constraints are essential for successful execution. Recent studies support this interpretation by showing superior balance performance, postural stability, gait control, and sensorimotor adaptation in dancers compared with non dancers, as well as beneficial effects of training protocols on balance related outcomes (Liu et al., 2022; Marinkovic et al., 2022; Senger et al., 2024; Hu et al., 2024).

At the same time, the lower importance attributed to resistance related capacities is noteworthy. Force in resistance mode, specific resistance, and resistance under coordination received less emphasis from the respondents, suggesting that endurance related aspects may be underappreciated within the effort profile of dance sport. This pattern is important because previous literature has already argued that insufficient aerobic and anaerobic conditioning may limit performance consistency and contribute to fatigue related technical decline (Twitchett et al., 2010). More recent data also reinforce the idea that dance performance includes substantial physiological demands and repeated exposure to high loads, especially in competitive and preprofessional contexts, making energy system support and load tolerance relevant even in predominantly coordinative disciplines (Gonzales et al., 2024; Barreau et al., 2024).

One particularly interesting result is the relatively low valuation of flexibility and joint mobility. From a traditional perspective, these qualities are often assumed to be central in most dance related disciplines. However, the present data suggest that coaches may not place them among the most decisive capacities for dance sport performance, at least relative to rhythm, coordination, balance, and spatial temporal control. This may reflect the specific competitive logic of dance sport, where dynamic coordination and expressive movement quality are prioritized over extreme range of motion. At the same time, the result may also indicate a methodological gap in how specialists conceptualize mobility, not as an isolated trait, but as a functional quality integrated into posture, control, and technical precision. This issue deserves deeper investigation in future research.

The findings should also be interpreted in light of the growing body of evidence linking insufficient or poorly structured physical preparation with injury risk in dance populations. Recent systematic reviews have concluded that physical fitness training may help reduce dance injury incidence, although evidence quality remains mixed, and conditioning based approaches are among the most common prevention strategies currently discussed in the literature (Dang et al., 2024; Critchley et al., 2025). Studies on injury epidemiology and risk factors also show that dancers are exposed to substantial musculoskeletal demands, especially at the lower limb, and that better monitoring, targeted conditioning, and more consistent reporting practices are needed across dance settings (Biernacki et al., 2021; Póvoa et al., 2023; Barreau et al., 2024). These observations strengthen the relevance of the present study, because coaching beliefs directly influence how physical training is planned, prioritized, and evaluated in practice.

From a scientific perspective, the present study addresses a relevant gap in the literature. Recent research has examined strength training effects, injury prevention, training load, balance, movement screening, and physiological demands in dancers, but fewer studies have focused specifically on how dance sport specialists conceptualize the role of physical training within the broader preparation process. In other words, the literature provides increasing information about what physical capacities matter and how they can be trained, yet less is known about how coaches in dance sport actually prioritize these components in everyday methodological practice. The novelty of the present study lies precisely in this perspective, as it captures the beliefs of specialists operating directly in the training environment and highlights the mismatch that may exist between scientific evidence and applied coaching logic.

From a practical point of view, the results suggest that dance sport training would benefit from more clearly structured physical preparation models that combine specificity with systematic conditioning support. Such models should include planned distribution of physical work across the annual cycle,

regular evaluation of key motor capacities, and better integration of strength, balance, coordination, and fatigue resistance according to the competitive profile of the discipline. This would allow coaches to move from an intuitive or fragmented use of physical training toward a more evidence informed methodology.

The study has several limitations that should be acknowledged. The sample size was relatively small, and the data were based on self reported opinions rather than direct observation of training sessions or objective performance testing. In addition, the cross sectional design does not allow causal interpretation. However, despite these limitations, the study offers a relevant exploratory perspective on an underexamined topic and provides a useful basis for future investigations involving larger samples, objective testing protocols, and comparative analyses across age groups and performance levels.

Taken together, the present findings support the view that physical training is recognized by dance sport specialists as an essential component of performance development, but its methodological integration remains incomplete. This gap between awareness and application represents both the main problem identified by the study and the main direction for future development. In this context, the following section presents the main conclusions and practical implications derived from the research.

5. Conclusions

The questionnaire survey conducted among specialists revealed that the majority consider physical training to be an important component of the training process, to a great extent. However, 50% of the surveyed coaches regard the determination of the amount of physical training (both general and specific) and the allocation of training hours within an annual cycle as important only to a lesser extent.

This finding reflects a practical reality frequently observed in coaching practice, namely that physical training is not approached with the same level of rigor as technical training. Instead, technical preparation is often expected to compensate for physical development objectives, thus supporting the hypothesis of the present research.

In this context, it is not surprising that 75% of the specialists consider specific means of physical training to be the most effective. This perspective is consistent with the particular demands of dance sport, where movement specificity plays a central role in performance development.

It is encouraging that all respondents emphasized the importance of regular assessment of physical training levels. This highlights the need to disseminate the results and conclusions of the present research among dance sport coaches, especially given the expressed interest in such studies across both junior and senior performance categories.

Regarding the hierarchy of motor capacities considered essential for dance sport performance, specialists ranked coordination-based speed, rhythmicity, spatial-temporal orientation, and rhythm-tempo ability among the most important. In contrast, strength endurance and coordination endurance were considered less relevant within the specific effort profile of dance sport.

The present study provides relevant insights into the perception of dance sport specialists regarding the role of physical training within the overall training process. The findings confirm that, although physical training is widely recognized as essential, its practical implementation remains inconsistent and insufficiently structured.

A key conclusion is the existence of a discrepancy between theoretical awareness and applied practice. While coaches acknowledge the importance of the relationship between physical and technical training, the relatively low emphasis placed on planning and periodization suggests that physical training is often integrated implicitly rather than systematically. This approach may limit training efficiency and the long-term development of performance capacity.

The results also highlight the central role of specific motor capacities, particularly coordination, rhythm, spatial-temporal orientation, and balance, which are fundamental for dance sport performance. These findings are aligned with the specific demands of the discipline, where precision, synchronization, and control are essential. However, the reduced importance attributed to endurance-related capacities

suggests a possible gap in understanding the physiological demands required to sustain performance during prolonged routines.

Another important aspect revealed by the study is the strong recognition of the need for periodic assessment of physical training. This indicates that coaches are aware of the importance of monitoring and evaluation, although these practices may not yet be fully integrated into a structured methodological framework.

From a practical perspective, the study highlights the necessity of developing and implementing structured and periodized physical training programs tailored to the specific requirements of dance sport. Such programs should include clearly defined objectives, appropriate training loads, and systematic evaluation protocols.

From a scientific perspective, the findings emphasize the need for further research focused on identifying optimal training models for different age categories, quantifying the contribution of specific motor capacities to performance, and developing evidence-based guidelines for integrating physical and technical training.

The main limitation of the study is the relatively small sample size and the reliance on self-reported data, which may introduce subjectivity. Future studies should include larger samples and objective performance measures in order to strengthen the validity of the conclusions.

In conclusion, aligning training practices with scientific evidence and adopting a more structured approach to physical preparation represent essential steps for improving performance outcomes and advancing the methodological framework of dance sport.

6. Practical Implications

The findings suggest that coaches should integrate physical training more systematically into the annual training plan and align it more closely with the technical and coordinative demands of dance sport. Greater attention should also be given to periodic evaluation and to the balanced development of both coordinative and conditional motor capacities.

7. Study Limitations

The main limitations of the study are the small sample size, the descriptive design, and the use of self reported responses. These aspects limit the generalizability of the findings and call for cautious interpretation.

8. Future Research Directions

Future studies should include larger and more diverse samples, compare coaches from different performance levels, and combine survey based data with objective motor and physiological assessments in order to better understand the role of physical training in dance sport.

Author Contributions:

Conceptualization: A.C.R., S.G.N.
Methodology: A.C.R.
Writing: S.G.N.

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Developing Upper-body Coordination Through the Use of Mobile Apps in Physical Education Classes for 8th-grade Students

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Abstract

Background: In eighth-grade physical education, digital tools can provide interactive stimuli that improve reaction time, hand-eye coordination, and movement combination capacity.

Objective: This study investigated whether smartphone-based basketball activities improve upper-body coordination, with a focus on reaction time, multisensory responsiveness, and movement combination ability.

Results: A total of 32 eighth-grade students, 16 girls and 16 boys, were divided into a control group and an experimental group. Over a three-month period, the control group performed conventional exercises, while the experimental group used smartphone apps for basketball-specific tasks. Performance was assessed using the Deary-Liewald reaction time task, a hand-eye coordination test through the Reaction Time app, and a reactive movement combination test through the Flash Screen app. The data were analyzed using descriptive statistics, paired samples t-tests, and independent samples t-tests, with $p < 0.05$. The experimental group showed significant improvements from initial to final testing and achieved greater progress than the control group.

Conclusions: Smartphone applications proved effective in improving coordination and reaction time, which supports their integration into physical education activities.

Keywords: coordination; reaction speed; physical education

1. Introduction

The integration of various technologies into traditional education has sparked considerable interest over the years and has opened up numerous opportunities for study. For example, the benefits of blended learning have been confirmed by major studies. (Wang et al.,2023)

Today's societal demands request the use of information technologies in the educational system (Hawkridge ,2022), (Timothheou et al.,2023).Along with a new educational framework, internet-based learning environments also introduce new teaching, learning, and assessment techniques that broaden the scope of the learning process(Nguyen, 2022)

(Merrynda et al.,2022.). Organizing and improving the educational process, developing teamwork skills, viewing the instructor as a mentor in the learning process, as well as experimenting with and creating

innovative teaching strategies are all areas in which these environments offer significant value.(Țurcanu, 2022).Basketball is a required subject in physical education classes for eighth-grade students in Romania.

An important area of sports, with unique educational value, is basketball, a team sport (Kolokoltsev et al..2023)It brings together the benefits of physical activity and sport with the educational value of play, creating an ideal environment for the long-term development of motor skills and abilities (Nae,2021).Success in sports performance is due both to psychomotor performance and to the specific motor skills associated with certain sports (Rogowska et al.,2022). As measures of physical fitness, anthropometric performance, speed, strength, endurance, coordination, and agility are important components of successful athletic performance (Gómez-Ruano et al.,2023). The six skill-related components of physical fitness are strength, speed, agility, balance, coordination, and reaction time. (Hassan et al.,2022)

Reaction speed is the time required to perceive a stimulus and initiate an appropriate action (Hassan et al.,2022). In basketball, it directly influences defensive effectiveness, fast breaks, rebounds, and tactical decisions. In basketball, reaction speed describes a player's ability to react quickly and successfully to a specific in-game stimulus, such as a pass, an opponent's change of direction, a referee's signal, or an opportunity to intercept the ball (Vučković et al.,2022) A rapid movement of the entire body, involving a change in speed or direction, in response to a stimulus is the definition of agility, considered essential in basketball. .(Horníková & Zemková 2022).

In physical education classes, developing reaction speed is essential for basketball performance (Badau et al.,2022). Among the tools for developing reaction speed are interactive devices such as the "Fitlight Trainer," a system of wireless-controlled LED lights used to test and improve reaction time. Students must touch the lit lights as quickly as possible, developing hand-eye coordination and decision-making speed. Another interactive device is the "Blazepod," a light system that can be placed on the floor or wall and configured via an app. It is used in reaction, dribbling, and change-of-direction exercises. On the other hand, there are also digital and sensory exercises such as "mobile apps with reaction games"; through this exercise, students can practice their reflexes via interactive games that simulate game situations. Another digital exercise involves "motion sensors and video cameras"; this modern technology analyzes reaction time to visual or auditory stimuli in exercises such as passing, dribbling, or changing direction.

Before the use of modern technologies, basketball players relied on simpler but effective techniques that were suited to the technology available to improve their reaction time. Exercises that required players to respond quickly to auditory or visual cues, such as lights or whistles, were among the most popular. Reactions to unexpected movements were also stimulated through training with a mirror or a partner. The primary methods for measuring reaction time were manual stopwatches and direct observation by the coach. In addition, in a relaxed environment, active exercises such as "jumping" and "reacting to a pass" help develop quick reflexes. These conventional techniques laid the foundation for cognitive and motor training in basketball, although they lacked the precision of modern technologies.

Main Hypothesis: Based on an analysis of previous research, we began with the assumption that by introducing basketball-specific exercises that utilize smartphone apps, we can achieve higher motor coordination scores among eighth-grade students.

Specific hypotheses:

- By introducing basketball-specific methods that utilize smartphone apps, we can improve reaction time
- By introducing basketball-specific methods that utilize smartphone apps, we can improve hand-eye coordination

- By introducing basketball-specific methods that utilize smartphone apps, we can develop the ability to combine movements

2. Materials and Methods

Objectives

The main objective of this study is to improve upper-body coordination in eighth-grade students through the use of smartphone apps.

The specific objectives of this study are:

- to develop reaction speed
- to improve the ability to react to visual, auditory, and tactile stimuli through specific exercises
- improving the efficiency of connections between the central nervous system and the locomotor system for faster reactions
- cultivating divided attention and concentration, which are essential for rapid decision-making
- the program aims to use a series of cognitive and physical training techniques to effectively elicit reactions to stimuli

2.1. Participants

A total of 32 eighth-grade students participated in this study; they were divided into two equal groups (16-16), namely the experimental group and the control group. Three tests were used in this study.

2.2. Procedure

The event took place in Tîrgu-Mureș at the "Prodcomplex" sports hall and in the gym of the "Electromures" school. Exactly three months passed between the first test and the last test. We took the first test on November 3 and the last test on February 3.

2.3. Statistical Analysis

The data analysis combined descriptive and comparative procedures and was conducted using IBM SPSS Statistics 26. Descriptive indicators (mean, standard deviation, minimum, maximum, coefficient of variation, and kurtosis) were calculated to describe the distribution of results for each test, group, and testing moment. Changes over time within each group were examined using paired-samples t-tests between initial and final measurements. Differences between the experimental and control groups were analysed using independent-samples t-tests, with Levene's test applied to assess the equality of variances. Statistical significance was set at $p < 0.05$, and confidence intervals were reported to aid interpretation of the findings.

Training procedure

Within the training procedures, mobile phones were integrated as practical tools to support the development of coordination and motor skills. Specific applications were used to provide visual and auditory stimuli, allowing exercises to be adapted in real time to the students' responses. This approach enabled the design of interactive tasks that combined movement execution with reaction demands, contributing to the improvement of hand–eye coordination, reaction speed, and overall motor control.

Testing procedure

Test 1 Deary-Liewald task

The first test is a choice reaction task on the page titled “PsyToolkit run experiment,” and the test title is “Deary-Liewald task for testing simple and choice response time.” The students are seated with their laptops in front of them. This test consists of two parts: a simple test and a complex test. In the simple test, a white box appears on the screen. When an X appears, the student must press the spacebar as quickly as possible. They will need to do this multiple times, and the timing of the X’s appearance varies slightly from trial to trial; the X appears 20 times in the simple test. In the complex test, four white boxes are visible on the screen. A cross appears in one of them. Students must press the corresponding key as quickly as possible. The following keys are used: Z, X, the comma or less-than sign on the keyboard, the period or greater-than sign on the keyboard. For example, if the cross appears in the first box, then the student must press the Z key, as shown in the following image.

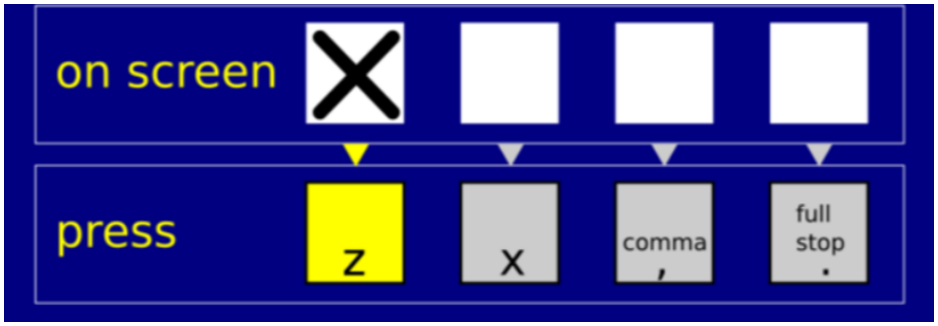


Figure 1. Deary-Liewald task for testing simple and choice response time 1.

There are four different possibilities and four different answers. This test will be repeated several times. You never know in advance where the cross will appear.

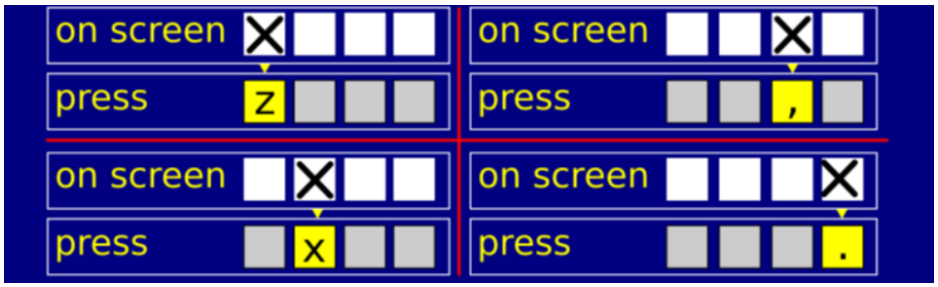


Figure 2. Deary-Liewald task for testing simple and choice response time 2.

In this test, the students’ fingers are already positioned on each of the four buttons. The cross appears 40 times during the complex test.

The test results are displayed separately after both tests are completed. First, the average score for the simple test is displayed, followed by the average score for the complex test.

Test 2-Hand-eye coordination test

The second test focuses on improving hand-eye coordination and reaction time. This test uses a phone app called “Reaction Time,” available on App Store and Google Play. The bench is 110 cm high; the phone is placed on it. The student sits facing the bench with knees bent, using one hand to bounce the basketball up to knee level and the other hand to perform the reaction test on the phone. The app has 5 rounds; the screen is red, and when it turns green, students must tap the screen as quickly as possible. After the 5 rounds, the app displays the average reaction time. Then the student switches hands, dribbling the basketball with one hand while tapping the screen with the other. In this test, it counts if the student loses the basketball while dribbling.



Figure 3-4. Hand-eye coordination Test.

Test 3-Reactive movement combination capacity

In the third test, we used a mobile app called "Flash Screen," which can be downloaded from the App Store or Google Play. This app changes colors automatically; we set it to 3 colors (blue, yellow, red), the tempo was 28 bpm, and the frame duration was 959 ms. We placed the phone against the wall, and the subject was facing the wall, about a meter and a half away. He holds a tennis ball in one hand and a basketball in the other. When a color appears on the phone screen, he always throws the tennis ball from one hand to the other in front of him, regardless of the color; the basketball, however, depends on the color displayed. If it's blue, he throws it in front of him; if it's yellow, between his legs; and if it's red, behind his back. We tested them to see how many out of 10 the student could do correctly.



Figure 5-6. Reactive movement combination capacity.

3. Results

Test 1 Deary-Liewald task

Table 1 shows a general improvement in reaction time values from the initial to the final testing in both groups, as reflected by the decrease in mean scores. In the experimental group, both simple and choice reaction times show slight reductions, indicating faster responses after the intervention. A similar trend is observed in the control group, with a more pronounced decrease, especially in simple reaction time. The coefficient of variation remains relatively low across all conditions, suggesting good homogeneity of the groups, while kurtosis values indicate distributions close to normal, with some variability in the control group at final testing. Overall, the results suggest improved reaction performance over time in both groups.

Table 1. Descriptive statistics Test 1 Deary-Liewald task.

Test	N	Minimum	Maximum	Mean	Std. Deviation	Kurtosis		CV
						Statistic	Std. Error	
EG Simple Rt - It	16	0.36	0.46	0.40	0.03	0.21	1.09	EG Simple Rt - It
EG Simple Rt - Ft	16	0.32	0.42	0.38	0.03	-0.02	1.09	EG Simple Rt - Ft
EG Choice Rt - It	16	0.41	0.62	0.53	0.07	-0.78	1.09	EG Choice Rt - It
EG Choice Rt - Ft	16	0.39	0.60	0.51	0.06	-0.73	1.09	EG Choice Rt - Ft
CG Simple Rt - It	16	0.37	0.43	0.40	0.02	-0.62	1.09	CG Simple Rt - It
CG Simple Rt Ft	16	0.28	0.36	0.31	0.02	3.60	1.09	CG Simple Rt Ft
CG Choice RT - It	16	0.42	0.63	0.53	0.06	-0.54	1.09	CG Choice RT - It
CG Choice RT - Ft	16	0.38	0.56	0.44	0.06	-0.56	1.09	CG Choice RT - Ft

The paired-samples t-test results from table 2 indicate statistically significant improvements between the initial and final measurements in both groups. In the experimental group, both simple and choice reaction times show small but consistent mean differences (0.02), with high t-values and p-values below 0.001, confirming significant progress. In the control group, the mean differences are larger (0.09), also accompanied by high t-values and strong statistical significance. The confidence intervals do not cross zero in any case, reinforcing the presence of real changes over time. Overall, these results suggest that reaction time improved significantly from initial to final testing in both groups.

Table 2. Dependent student T test Deary-Liewald task.

				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	p
EG Simple Rt	0.02	0.01	0.00	0.02	0.03	9.87	15	0.000
EG Choice Rt	0.02	0.01	0.00	0.02	0.03	11.55	15	0.000
CG Simple Rt	0.09	0.02	0.01	0.08	0.11	17.17	15	0.000
CG Choice RT	0.09	0.02	0.01	0.07	0.10	14.57	15	0.000

The independent-samples t-test results from table 3 show that, at the initial testing, no significant differences were found between the experimental and control groups for simple reaction time ($p = 0.84$), indicating similar baseline performance. At the final testing, statistically significant differences emerged in both simple and choice reaction times ($p < 0.001$), with the experimental group showing better performance, as reflected by the positive mean differences. Levene's test indicates that the assumption of equal variances was generally met, except for simple reaction time at final testing, where variance differences were present. The confidence intervals at final testing do not include zero, supporting the existence of real differences between groups after the intervention.

Table 3. Independent student T test Deary-Liewald task.

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	p	t	df	p	Mean Difference	Std. Error Difference	95% C.I.	
								Lower	Upper
Simple Rt - It	1.13	0.30	0.20	30	0.84	0.00	0.01	-0.01	0.02
Simple Rt - Ft	5.64	0.02	8.61	30	0.00	0.07	0.01	0.06	0.09
Simple Rt Ft	0.31	0.58	-0.01	30	0.99	0.00	0.02	-0.04	0.04
Choice RT - Ft	0.13	0.72	3.12	30	0.00	0.07	0.02	0.02	0.11

Test 2 hand-eye coordination test

Table 4 indicates improvements in hand–eye coordination performance in both groups, reflected by the decrease in mean values from initial to final testing. The experimental group shows a moderate reduction in mean scores (from 0.80 to 0.75), suggesting improved reaction performance, while the control group presents a more pronounced decrease (from 0.85 to 0.66). The variability of results slightly decreases in both groups, as shown by lower standard deviation and coefficient of variation values at final testing. Kurtosis values remain close to normal distribution, with a slight tendency toward flatter distributions. Overall, the results suggest enhanced hand–eye coordination over time in both groups.

Table 4. Descriptive statistics hand-eye coordination test.

Test	N	Min	Max	Mean	Std. Deviation	Kurtosis		CV
						Statistic	Std. Error	
EG Hand Eye T - It	16	0.53	1.22	0.80	0.21	-0.64	1.09	EG Hand Eye T - It
EG Hand Eye T - Ft	16	0.52	1.17	0.75	0.18	-0.11	1.09	EG Hand Eye T - Ft
CG Hand Eye T - It	16	0.60	1.32	0.85	0.21	-0.01	1.09	CG Hand Eye T - It
CG Hand Eye T - Ft	16	0.46	0.88	0.66	0.13	-1.07	1.09	CG Hand Eye T - Ft

The paired-samples t-test results from table 5 show statistically significant improvements in hand–eye coordination in both groups from initial to final testing. In the experimental group, a modest mean difference (0.05) is observed, with a significant t-value and p = 0.001, indicating a real improvement over time. In the control group, the mean difference is larger (0.19), with a higher t-value and p < 0.001, suggesting a more pronounced change. The confidence intervals in both cases do not include zero, confirming that the observed differences are statistically significant. Overall, both groups demonstrate significant progress in hand–eye coordination between testing moments.

Table 5. Dependent student T test Deary-Liewald task.

				C.I. 95%				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	p
EG Hand Eye T	0.05	0.05	0.01	0.02	0.08	3.99	15	0.001
CG Hand Eye T	0.19	0.10	0.02	0.14	0.25	7.73	15	0.000

The independent-samples t-test results indicate that there were no statistically significant differences between the experimental and control groups in hand–eye coordination at either testing moment. At initial testing, the groups show very similar performance (p = 0.51), confirming comparable baseline levels. At final testing, although the mean difference suggests slightly better results in one group, this difference is not statistically significant (p = 0.11). Levene's test indicates that the assumption of equal variances was met in both cases. Additionally, the confidence intervals include zero, further supporting the absence of significant differences between groups.

Table 6. Independent student T test hand-eye coordination test.

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	p	t	df	p	Mean Difference	Std. Error Difference	95% C.I.	
								Lower	Upper
Hand Eye T - It	0.00	0.99	-0.67	30.00	0.51	-0.05	0.07	-0.20	0.10
Hand Eye T - Ft	2.05	0.16	1.65	30.00	0.11	0.09	0.06	-0.02	0.21

Table 7 highlights changes in reactive movement combination capacity between initial and final testing in both groups. The mean values increase in both the experimental group (from 2.19 to 3.25) and the control group (from 2.00 to 4.81), indicating improved performance over time. The control group shows a larger increase, suggesting a more pronounced progression. Variability remains relatively high, especially at initial testing, as reflected by the elevated coefficients of variation, although a reduction is observed at final testing, particularly in the control group. Kurtosis values indicate some deviation from normality, especially in the experimental group at initial testing. Overall, the results suggest improvements in reactive movement combination capacity in both groups, with greater changes observed in the control group.

Table 7. Descriptive statistics reactive movement combination capacity.

Phase	Test	N	Min	Max	Mean	Std. Deviation	Kurtosis		CV
							Statistic	Std. Error	
EG It	Reactive Movement Combination Capacity Test	16	1.00	6.00	2.19	1.42	2.04	1.09	65.12%
EG Gt		16	1.00	7.00	3.25	1.53	0.96	1.09	47.00%
CG It		16	1.00	5.00	2.00	1.26	0.49	1.09	63.25%
CG Ft		16	3.00	8.00	4.81	1.47	-0.16	1.09	30.56%

The paired-samples t-test results indicate statistically significant improvements in reactive movement combination capacity in both groups. In the experimental group, the negative mean difference (-1.06) reflects an increase in performance from initial to final testing, with a significant t-value and $p < 0.001$. In the control group, the change is more pronounced (mean difference = -2.81), also highly significant. The confidence intervals in both cases do not include zero, confirming that the observed differences are meaningful. Overall, both groups show significant progress over time, with greater improvement observed in the control group.

Table 8. Dependent student T test reactive movement combination capacity

Group	Test	Mean	Std. Deviation	Std. Error Mean	C.I. 95%		t	df	p
					Lower	Upper			
GE	Reactive Movement Combination Capacity Test	-1.06	0.57	0.14	-1.37	-0.76	-7.41	15	0.000
GC		-2.81	0.75	0.19	-3.21	-2.41	-15.00	15	0.000

The independent-samples t-test results show that, at initial testing, there were no statistically significant differences between the experimental and control groups ($p = 0.70$), indicating similar starting levels of reactive movement combination capacity. At final testing, however, a statistically significant difference is observed ($p = 0.01$), suggesting a divergence in performance between groups. The negative mean difference indicates that the experimental group obtained better results compared to the control group. Levene's test confirms homogeneity of variances in both cases, and the confidence interval at final

testing does not include zero, supporting the presence of a real difference between groups after the intervention.

Table 9. Independent student T test reactive movement combination capacity

Phase	Test	Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	p	Mean Diff.	Std. Error Diff.	95% C.I.	
									Lower	Upper
Ti	Reactive Movement Combination Capacity Test	0.15	0.70	0.39	30.00	0.70	0.19	0.48	-0.79	1.16
Tf		0.00	1.00	-2.95	30.00	0.01	-1.56	0.53	-2.65	-0.48

Overall, the results indicate that both groups showed significant improvements across all tested variables, including reaction time, hand–eye coordination, and reactive movement combination capacity. While progress was observed in both groups over time, the experimental group demonstrated more consistent improvements in reaction-based tasks, particularly at final testing, where significant differences emerged compared to the control group. In contrast, although hand–eye coordination improved in both groups, no significant differences were found between them. For reactive movement combination capacity, both groups progressed significantly, with a notable advantage for the experimental group at final testing. These findings suggest that the implemented training approach contributed positively to the development of coordination and motor skills.

4. Discussion

In this study, we focused on improving upper limb coordination and reaction time by having students use a mobile app. Upon reviewing recent research, we identified a number of studies that are consistent with our study and its relevance(Steff et al.,2024), has implemented Fitlight technology in the process of sports training and motor skills assessment aimed at improving the agility and reactive agility of junior basketball players. The common thread is the emphasis on the innovative use of technology, particularly in the development of agility and reaction speed Hassan. (Hassan et al.,2022) used reactive agility exercises with the FITLIGHT training system to assess the visual reaction time and dribbling ability of basketball players. A common element with this study is the use of digital technology, but specifically the development of visual speed. In contrast, Hassan(Hassan et al.,2022)provides an in-depth analysis of the system's ability to improve certain aspects of a player's performance, focusing instead on enhancing the visual reaction speed of a single group. In conclusion, although both highlight how Fitlight training helps young basketball players become more agile and perform better, we offer a more varied study based on age group and compare the new approach with more conventional training methods. This in-depth and comparative method not only validates the benefits of using state-of-the-art technology in sports training but also expands our knowledge of its use and effectiveness in student development.

5. Conclusions

The relevant results of this study demonstrate that, in all tests of reaction time, hand-eye coordination, and the ability to combine movements, the experimental group showed superior and statistically significant improvements compared to the control groups. Our study revealed significant improvements in the reaction speed abilities of students in the experimental groups, due to the support

provided by the development of coordination, thereby contributing to the optimization of student performance. Future research may focus on determining how, depending on the level of training and sport-specific details, the application of information technologies adapted to the unique characteristics of various sports will improve the motor skills and technical abilities of different categories of students.

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The Importance of Self-Defense Techniques in the Training of Military Students: A Questionnaire-Based Analysis

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Abstract

Background: In the military environment, whether in regular armed forces or security forces, protecting personnel is a priority. Self-defense techniques play an essential role in military safety because they help personnel respond effectively to threats and protect both themselves and their comrades.

Objective: This study examined the role of self-defense techniques in the training of military students and aimed to evaluate how these techniques contribute to physical preparedness, psychological resilience, and situational awareness.

Results: The research used a questionnaire-based approach and collected data from military students across multiple training levels, focusing on their perceptions, experiences, and confidence in applying self-defense skills in realistic scenarios. The findings showed that structured self-defense training significantly improved students' confidence, reaction time, and decision-making under pressure. Respondents also reported better discipline and a stronger sense of personal security. The study further revealed variations in perceived effectiveness according to training intensity and prior experience.

Conclusions: Self-defense techniques are essential for operational readiness and also support the holistic development of military students by improving both professional performance and personal confidence in demanding environments. The results support the integration of comprehensive self-defense modules into military curricula.

Keywords: Self-defense training, military students, physical fitness

1. Introduction

"Physical training is an integral component of the educational system, aimed at fostering balanced physical and mental development, as well as the formation of moral character."(Jinga G., 2007, p.11) . Martial arts are fundamental forms of combat that have evolved in the modern era into sports, self-defense, and hobbies. The practice of martial arts has a positive effect on longevity, promoting health and harmonious development among millions of practitioners. The benefits of this sport are reflected in a significant improvement in health and inner balance, enhancing overall well-being.

Martial arts can be used to boost students' self-confidence and effectiveness. Confident individuals have learned to navigate the dangerous and stressful situations they have encountered throughout their lives. Because martial arts inherently involve facing high-pressure situations, military students develop the ability to regulate negative emotions such as fear, uncertainty, and anger. (Ribeiro &

Howell, 2016). The self-control gained through these practices is responsible for increasing their level of confidence in their own abilities.

Regardless of age, practicing martial arts gives practitioners an extra boost of energy. At the same time, they discover ways to release the negative energy accumulated throughout the day or week through various methods and exercises such as meditation, sparring, stretching, etc. (Okazaki, 2006).

Incorporating self-defense into a fighter's training regimen is essential for developing both practical combat effectiveness and psychological preparedness in high-risk situations. Self-defense refers to structured physical and cognitive techniques used to prevent, resist, or escape physical aggression, and it is widely integrated into martial arts and combat sports training systems to improve real-world survivability (Ball & Martin, 2011; Magill, 2011).

Within combat sports such as boxing, judo, karate, and mixed martial arts, self-defense training enhances reaction time, situational awareness, and decision-making under stress, which are critical components of performance in unpredictable environments (Davies et al., 2002; Ozer & Bandura, 1990).

Research indicates that martial arts practice not only develops physical conditioning but also fosters self-efficacy, emotional regulation, and confidence in managing threatening encounters (Kimberly & Martin, 2011; Koçak & Balçıkanlı, 2021). Furthermore, self-defense instruction emphasizes defensive stances, blocking techniques, and counterattacks that are designed to neutralize threats efficiently while minimizing injury risk (Burke, 2007). In addition, modern self-defense systems are often adapted from traditional martial arts and military combatives, highlighting their practical orientation toward real-world violence scenarios rather than sport-based competition rules.

From a physiological perspective, martial arts training contributes to improved neuromuscular coordination, balance, and power output, which are essential for executing defensive and offensive movements effectively under pressure (Davies et al., 2002). Psychologically, engaging in structured self-defense practice has been associated with reduced fear responses and increased perceived control in threatening situations, particularly in populations exposed to violence or high-stress environments (Ball & Martin, 2011). Moreover, combat training environments simulate stress exposure, enabling athletes to adapt to adrenaline responses and maintain cognitive clarity during confrontation (Magill, 2011).

Studies also suggest that consistent martial arts participation may reduce aggression while improving discipline and self-regulation, which are important for responsible application of self-defense skills (Zvi & Lavi, 2025). Additionally, training systems that combine technical skill development with scenario-based drills are considered more effective for transferring skills to real-life situations compared to isolated technique practice (Pekel et al., 2025). Overall, self-defense training serves as a multidimensional component of fighter development, integrating physical skill acquisition, psychological resilience, and tactical awareness to prepare individuals for both competitive and non-competitive conflict situations (Ball & Martin, 2011; Magill, 2011; Davies et al., 2002).

2. Materials and Methods

We employed a social survey research method, using a questionnaire as a tool to collect and obtain data from students at the "Nicolae Bălcescu" Land Forces Academy in Sibiu. I chose this research method because the information obtained will be both quantitative and qualitative, allowing for a detailed analysis based on specific criteria. Thus, we will be able to gain a deeper understanding of issues related to the importance of physical training, the importance of integrating contact sports into the university curriculum, and the necessity of knowing self-defense techniques as a military student and as a future leader.

2.1. Participants

This study was conducted on a sample of 60 students out of a total of 96 third-year infantry students at the "Nicolae Bălcescu" Land Forces Academy in Sibiu.

2.2. Procedure

To complete the survey, which consisted of 20 items, the participants could choose from the following options on the Likert scale: to a very small extent – 1 point; to a small extent – 2 points to a moderate extent – 3 points; to a large extent – 4 points; to a very large extent – 5 points. Their responses were then quantified and analyzed. The questionnaire consisted of two sections; the first, comprising 5 questions, focused primarily on general physical fitness, while the following 15 questions in the second section of the questionnaire were specific to the characteristics of contact sports.

3. Results

Table 1. Results of the student survey, average scores

Results of the student survey							
Total number of responses							
Question no.	To a very small extent – 1 point	To a small extent – 2 points	To a moderate extent – 3 points;	To a large extent – 4 points	To a very large extent – 5 points	Total number of questionnaires	Average score
1	0	0	5	15	40	60	4.583
2	0	0	3	20	37	60	4.566
3	3	8	22	18	9	60	3.366
4	1	3	14	22	20	60	3.95
5	1	3	22	20	14	60	3.71
Section Two							
6	2	0	5	17	36	60	4.41
7	0	3	4	16	37	60	4.45
8	0	0	3	23	34	60	4.51
9	0	1	1	22	36	60	4.55
10	0	1	1	23	35	60	4.53
11	0	1	2	29	28	60	4.4
12	1	0	4	15	40	60	4.55
13	0	1	7	20	32	60	4.38
14	0	1	3	19	37	60	4.53
15	0	0	5	21	34	60	4.48
16	1	0	4	26	29	60	4.36
17	23	14	7	8	8	60	2.4
18	12	18	14	5	11	60	2.75
19	0	1	2	26	31	60	4.45
20	18	19	11	8	4	60	2.35

The main objectives of this research were:

- To determine whether physical training is a key element among military students;
- To assess military students' willingness to participate in a contact sport;

- To identify the desire and motivation among military students to learn and practice a contact sport.
- To assess the extent to which students are familiar with self-defense techniques.

This study aims to identify military students' perceptions regarding the importance of physical training, their willingness to participate in contact sports, and their level of motivation to learn and apply self-defense techniques. The study also examines the students' familiarity with such techniques.

Questions 1 and 2 focused on assessing the importance placed on physical training. The results highlight a high level of conviction, reflected in average scores of 4.58 and 4.56, with the majority of respondents choosing the options "to a large extent" and "to a very large extent." These results confirm that physical training is perceived as an essential element of military training.

In terms of time (item no. 3), most students consider that they have a moderate amount of time for physical activities (36.7%), while 30% feel they have enough time, and 15% consider that they have a great deal of time. The average score of 3.36 indicates a moderate perception, suggesting the existence of time constraints, influenced in part by individual preferences.

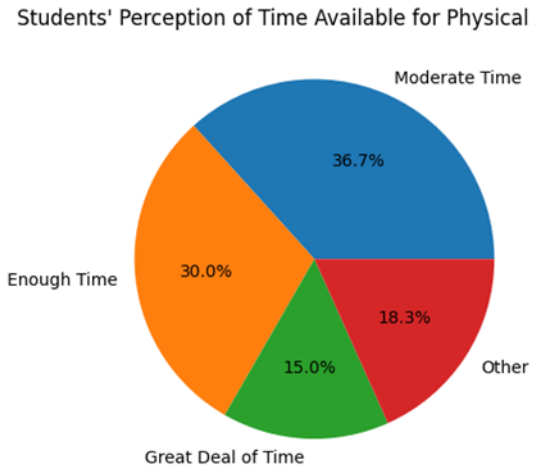


Figure 1. Students ´ Perception of Time Available for Physical Activity

Regarding material resources (item no. 4), 70% of respondents believe that the institution provides adequate sports facilities, with an average score of 3.95. In comparison, it is observed that, although material resources are sufficient, the time allocated to physical training is perceived as insufficient.

Item No. 5 reveals perceptions regarding the balance between physical and theoretical training. The average score of 3.81 suggests a moderate tendency to view physical training as underrepresented relative to other components of military training.

Regarding human resources (item no. 6), the results indicate a positive perception of the competence of staff specialized in contact sports, with an average score of 4.41. Most respondents appreciate their high level of professionalism and expertise.

Students' willingness to participate in contact sports is highlighted by the responses to questions 7 and 8, where over 85% of participants selected the higher rating options. The average scores of 4.45 and 4.51 confirm the strong interest in including these activities in the academic curriculum.



Figure 2. Demand for Additional Contact Sports Training

Finally, the perception of the benefits of combat sports is significantly positive, with an average score of 4.55. In addition to physical development, these activities contribute to improving mental health, concentration, emotional control, and strategic skills, thereby supporting the holistic development of military students.

The survey results indicate that question no. 11, which concerns the need for students at the "Nicolae Bălcescu" Land Forces Academy to be familiar with a contact sport, received a strong affirmative response. Approximately 95% of students selected the responses "to a very large extent" and "to a large extent."

The average score of 4.4 for this question shows that most students consider it very important to know a contact sport within their academy.

There are several possible reasons for this strongly positive response. One of them may be that contact sports can be directly relevant to the branch of the military to which they belong. Additionally, contact sports can contribute to the development of self-confidence, determination, and mental resilience.

The overwhelmingly positive results indicate that the academy should consider the importance of incorporating a contact sport into their training program. This may involve including specific contact sport lessons and training sessions, allocating adequate resources for student instruction and support in these sports, and fostering a culture of contact sports among students.

The responses to item 12 confirm this trend, with an average score of 4.55 indicating that students consider knowledge of a contact sport necessary for effectively managing threats specific to the military environment.

An analysis of perceptions regarding the benefits of introducing a combat discipline reveals an average score of 4.38, suggesting a positive impact on concentration and physical endurance. The majority of respondents (53.3%) believe that these activities contribute to improved mental focus.

Regarding the role of self-defense in leadership training (item no. 15), the average score of 4.48 indicates a high appreciation of the importance of these skills. Furthermore, the results suggest a correlation between practicing contact sports and self-confidence, evidenced by the average score of 4.36.

However, the analysis of items regarding knowledge of self-defense techniques against weapons and unexpected attacks indicates a low level of specific training. This aspect underscores the need to introduce structured programs aimed at developing these skills, in accordance with the requirements of the military operational environment.

In response to item 17, the majority of respondents indicated a low or non-existent level of training, and the results of item 18 show that 50% of students are not prepared to respond effectively to unexpected attacks. These results confirm the existence of gaps in practical training.

In this context, the responses to item 19 indicate a clear demand for the introduction of additional training hours in contact sports, with approximately 95% of students supporting this need (average score 4.45).

Regarding the perception of the role of physical fitness in daily life, the results highlight that most students believe they cannot cope with daily threats without adequate physical fitness. The average score of 2.35, the lowest in the questionnaire, reflects an awareness of its importance.

4. Conclusions

The results of the study allow us to draw the following conclusions, in line with the research objectives.

The results indicates in the graph below that physical training is perceived as essential (M = 4.58). Students showed high willingness to participate in contact sports (M = 4.45) and to learn self-defense techniques (M = 4.53). However, many reported insufficient practical training, with 50% stating they are not prepared for unexpected attacks.

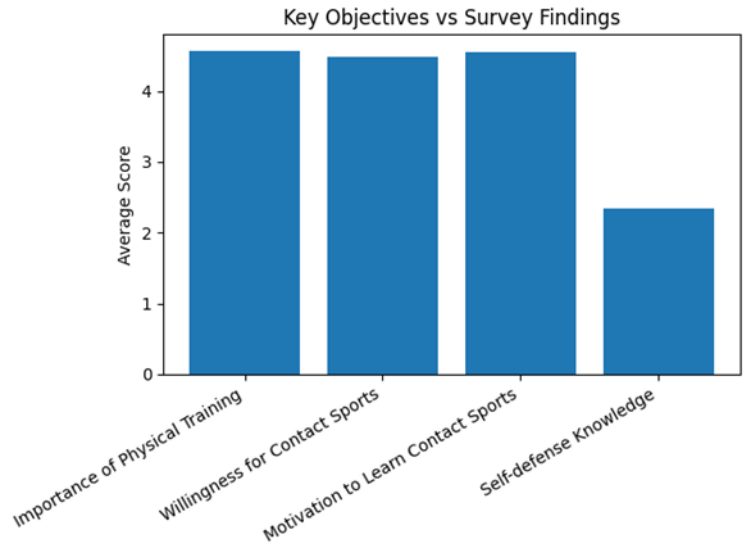


Figure 3. Key Objectives vs Survey Findings

Physical training is perceived as a fundamental element in the education of military students, as it is considered essential for the development of operational capabilities and for managing high-risk situations.

Students demonstrate a high level of willingness to participate in contact sports, recognizing their benefits both physically and psychologically.

There is strong motivation among students to learn and deepen their understanding of self-defense techniques, and they are open to the introduction of specific programs within the curriculum.

Despite the increased interest, the current level of training is insufficient, as most students lack the necessary skills to react effectively in unforeseen situations.

The results highlight the need to introduce practical modules on self-defense and contact sports, based on hands-on training and realistic scenarios, to help develop specific skills.

Students recognize that adequate physical fitness is indispensable for coping with both professional and everyday challenges.

In conclusion, the systematic integration of contact sports and self-defense techniques into the military training process is an objective necessity, with a direct impact on the operational effectiveness and personal development of future officers.

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Appendices

SURVEY ON THE IMPORTANCE OF SELF-DEFENSE TECHNIQUES IN THE MILITARY

Item no 1. To what extent do you consider physical training to be important for military students?
Item no 2. Do you believe that students at the Army Academy need exemplary physical training?
Item no 3. Do you believe you have enough time allocated for physical training?
Item no 4. Does the academy have sufficient sports facilities for physical training?
Item no 5. Do you believe that in military training, the emphasis is placed less on physical training compared to theoretical and specialized training?
Item no 6. Do you feel that the staff specializing in contact sports is well-trained?
Item no 7. Would you like to practice a contact sport at the academy?
Item no 8. Would you like to see a contact sport introduced into the academic curriculum?
Item no 9. Do you believe that practicing a contact sport has a positive impact on physical health?
Item no 10. Do you find practicing a contact sport beneficial for mental health?
Item no 11. Do you think it is necessary for all academy students to know at least one contact sport?

Item no 12. To what extent do you believe that military students should know at least one contact sport in order to defend themselves against potential threats?
Item no 13. To what extent do you consider practicing contact sports necessary for improving concentration?
Item no 14. Are you willing to learn new self-defense techniques?
Item no 15. Do you consider knowledge of self-defense techniques a necessary element for students?
Item no 16. Would knowing self-defense techniques boost your self-confidence?
Item no 17. To what extent are you familiar with self-defense techniques against knives or firearms?
Item no 18. To what extent are you familiar with techniques for countering unexpected attacks?
Item no 19. Do you believe that specific training in combat sports would be necessary?
Item no 20. To what extent could military students cope with future threats without well-developed physical training?

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Effects of Reactive Agility Training on Physical and Game Performance in Competitive Padel Players

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Article type	Conference track	Language and length
Original Research Article	Movement Science and Human Performance	English, 8 pages

Abstract

Background: Padel is a rapidly growing racket sport characterized by high-intensity rallies, frequent changes of direction, and high perceptual-cognitive demands. Reactive agility is a key performance factor because players must constantly adapt their movements to unpredictable stimuli such as ball rebounds and opponents' actions.

Objective: The aim of this study was to investigate the effects of an 8-week reactive agility training program on physical and game-related performance in competitive padel players.

Results: A randomized controlled trial was conducted on 40 competitive padel players, with a mean age of 24.3 ± 3.1 years, randomly assigned to an experimental group, n = 20, and a control group, n = 20. The experimental group followed a structured reactive agility training program, while the control group continued standard training routines. Performance was assessed before and after the intervention through reactive agility tests, reaction time measurements, and padel-specific performance indicators. Statistical analysis included paired and independent t-tests, with significance set at $p < 0.05$. The experimental group showed significant improvements in reactive agility, −8.2%, $p < 0.001$, reaction time, −12.5%, $p < 0.001$, and padel-specific performance, +15.4%, $p < 0.001$. The control group showed only minor improvements, between 2% and 5%. Between-group comparisons revealed statistically significant differences in favor of the experimental group across all variables.

Conclusions: Reactive agility training significantly improves both physical and perceptual-cognitive performance in competitive padel players. Integrating stimulus-based training into regular practice may improve movement efficiency, decision-making, and overall competitive performance.

Keywords: padel, reactive agility, reaction time, performance, perceptual-cognitive training

1. Introduction

Padel is one of the fastest-growing racket sports worldwide, characterized by high-intensity rallies, rapid changes of direction, and continuous interaction between players and environmental constraints. Unlike other racket sports, padel is played in a confined court surrounded by walls, which creates complex and unpredictable ball trajectories. These characteristics impose significant physical and perceptual-

cognitive demands, requiring players to rapidly perceive, interpret, and respond to dynamic game situations.

From a physiological perspective, padel involves intermittent efforts of moderate to high intensity, combining aerobic and anaerobic energy systems. Match play is characterized by repeated short bursts of activity interspersed with brief recovery periods, similar to other open-skill sports (Sánchez-Alcaraz et al., 2018). However, beyond physical capacities, performance in padel is strongly influenced by perceptual-cognitive abilities, including anticipation, reaction time, and decision-making (Mann et al., 2007).

Reactive agility, defined as the ability to change direction in response to external stimuli, has been identified as a key determinant of performance in dynamic sports environments (Sheppard & Young, 2006). In padel, this ability is particularly important due to the unpredictable nature of ball rebounds from walls and the need for continuous positional adjustments. Consequently, reactive agility may be more relevant than pre-planned change-of-direction speed in this sport.

Previous research in racket sports has shown that perceptual-cognitive skills differentiate higher-level athletes from less experienced players, particularly in terms of visual search strategies and anticipation (Mann et al., 2007). In padel, these abilities are essential for successfully managing complex game situations and maintaining performance under time constraints. Recent studies have also highlighted the importance of reaction time and movement efficiency as key performance indicators in padel (Escudero-Tena et al., 2021; Martín-Miguel et al., 2023).

Despite the growing popularity of padel, scientific research focusing on training interventions remains limited. Most existing studies have primarily examined match demands and technical aspects, while fewer investigations have explored methods to improve performance through targeted training approaches. In particular, there is a lack of experimental studies evaluating the effectiveness of reactive agility training in padel players.

Recent developments in sports training emphasize the integration of cognitive and motor components within representative learning environments, aiming to enhance perception–action coupling and improve transfer to competitive performance (Davids et al., 2008; Pinder et al., 2011). Training approaches that incorporate external stimuli and decision-making elements may therefore be particularly effective in sports characterized by high uncertainty, such as padel.

Accordingly, the aim of this study was to investigate the effects of an 8-week reactive agility training program on reactive agility, reaction time, and padel-specific performance in competitive players. It was hypothesized that the experimental group would demonstrate significantly greater improvements compared to the control group.

2. Materials and Methods

The present study employed a randomized controlled trial (RCT) design to investigate the effects of a reactive agility training program on performance in competitive padel players. The study followed a pre-test–post-test experimental design over an 8-week intervention period.

Participants were randomly assigned to either an experimental group (EG) or a control group (CG). Both groups followed similar training volumes and schedules, with the only difference being the inclusion of reactive agility training in the experimental group.

2.1. Participants

A total of 40 competitive padel players participated in the study (mean age: 24.3 ± 3.1 years). All participants were actively involved in structured training programs and regularly competed at regional or national levels.

Inclusion criteria were as follows:

- minimum of 3 years of competitive padel experience
- regular participation in training (≥3 sessions per week)
- active involvement in official competitions

Exclusion criteria included:

- musculoskeletal injuries within the previous 6 months
- neurological or visual impairments
- absence from more than 10% of training sessions during the intervention

Participants were randomly allocated into:

- Experimental Group (EG, n = 20)
- Control Group (CG, n = 20)

All participants provided written informed consent prior to participation. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

2.2. Procedure

The intervention lasted 8 weeks, with three training sessions per week, each one lasting approximately 90 minutes. Both groups followed a standardized training structure consisting of:

- warm-up (15 minutes)
- technical–tactical training (40 minutes)
- physical conditioning (20 minutes)
- intervention component (15 minutes)

Experimental Group (Reactive Agility Training)

The experimental group performed a structured reactive agility training program designed to simulate game-specific situations and enhance perception–action coupling.

The training protocol included:

- stimulus-based movement drills requiring responses to visual cues (e.g., lights, coach signals, ball direction)
- multidirectional agility drills performed under unpredictable conditions
- padel-specific drills involving movement and shot execution following wall rebounds
- decision-making tasks requiring rapid selection of appropriate responses

Training complexity was progressively increased by reducing reaction time and increasing stimulus variability, and introducing fatigue conditions.

Control Group (Standard Training)

The control group followed a traditional padel training program consisting of technical drills, tactical exercises, and general physical conditioning. There were no structured reactive or stimulus-based training elements were included.

Performance was assessed before and after the intervention under standardized conditions using the following tests:

Reactive Agility Test

The reactive agility test involved multidirectional movements in response to randomized visual stimuli. Players were required to react as quickly as possible to directional cues, and total completion time (seconds) was recorded.

Reaction Time Test

Reaction time was assessed using a light-based system that generated random visual signals, requiring an immediate motor response. The average response time (milliseconds) was calculated across multiple trials.

Padel-Specific Performance Test

The padel-specific performance test consisted of simulated rally situations in which players were required to execute appropriate shots under time pressure. Performance was evaluated based on successful shot execution and decision-making accuracy (%).

Each test was performed in three trials, and the best performance was retained for analysis.

2.3. Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics (Version 26.0).
The following procedures were applied:

- descriptive statistics (mean ± standard deviation)
- paired samples t-tests (within-group comparisons)
- independent samples t-tests (between-group comparisons)
- effect size calculation using Cohen's d

Normality of data distribution was assessed using the Shapiro–Wilk test. Statistical significance was set at $p < 0.05$.

3. Results

Descriptive statistics for all measured variables are presented in Table 1. At baseline, no statistically significant differences were observed between the experimental group (EG) and the control group (CG) ($p > 0.05$), indicating initial group homogeneity.

Table 1. Descriptive statistics of performance variables (Mean ± SD)

Variable	Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)
Reactive Agility (s)	EG	5.42 ± 0.31	4.97 ± 0.28
	CG	5.39 ± 0.29	5.26 ± 0.27
Reaction Time (ms)	EG	421 ± 32	368 ± 28
	CG	418 ± 30	402 ± 29
Padel Performance (%)	EG	64.5 ± 5.7	74.3 ± 5.1
	CG	65.1 ± 5.9	68.2 ± 5.6

Within-group comparisons revealed statistically significant improvements in the experimental group across all measured variables ($p < 0.001$). Reactive agility performance improved substantially, with completion time decreasing by approximately 8.3%. Reaction time also showed a significant reduction (−12.6%, $p < 0.001$), indicating enhanced perceptual-motor responsiveness.

Padel-specific performance increased significantly (+15.2%, $p < 0.001$), suggesting improved decision-making and execution under game conditions.

In contrast, the control group demonstrated only moderate improvements. Reactive agility improved slightly ($p < 0.05$), while changes in reaction time were not statistically significant ($p > 0.05$).

Table 2. Within-group comparisons (paired t-test)

Variable	Group	t	p	Effect Size (d)
Reactive Agility	EG	8.11	<0.001	1.70
	CG	2.35	<0.05	0.40
Reaction Time	EG	9.24	<0.001	1.95
	CG	1.89	>0.05	—
Padel Performance	EG	8.67	<0.001	1.80
	CG	2.41	<0.05	0.45

Independent samples t-tests performed on post-test values revealed statistically significant differences between groups across all variables, consistently favoring the experimental group.

The largest between-group differences were observed in reaction time ($t = -5.36$, $p < 0.001$) and padel-specific performance ($t = 5.08$, $p < 0.001$), indicating a substantial advantage of reactive agility training.

Table 3. Between-group comparisons (post-test)

Variable	t	p
Reactive Agility	−4.12	<0.001
Reaction Time	−5.36	<0.001
Padel Performance	5.08	<0.001

Percentage changes further highlight the effectiveness of the intervention (Table 4). The experimental group showed consistently greater improvements compared to the control group, particularly in reaction time and padel-specific performance.

Table 4. Percentage improvements (%)

Variable	EG (%)	CG (%)
Reactive Agility	−8.3	−2.4
Reaction Time	−12.6	−3.8
Padel Performance	+15.2	+4.8

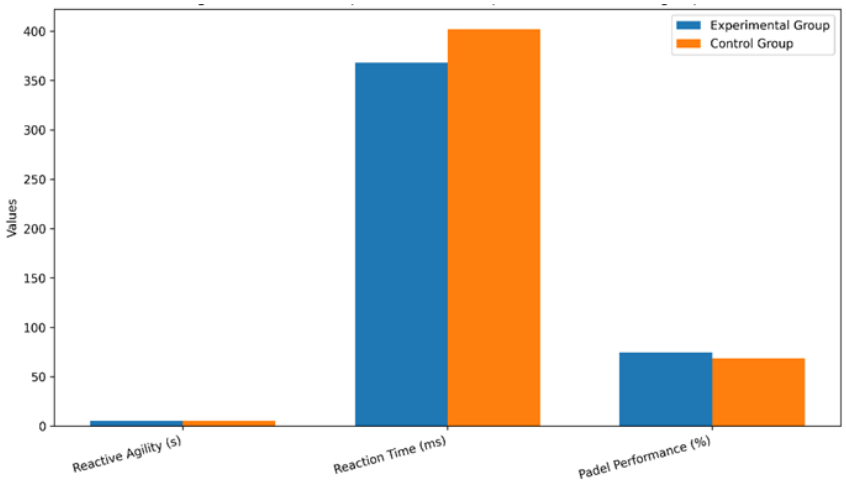


Figure 1. Post-test comparison between experimental and control groups.

The experimental group demonstrated superior performance across all variables, with lower reactive agility time, faster reaction time, and higher padel-specific performance compared to the control group.

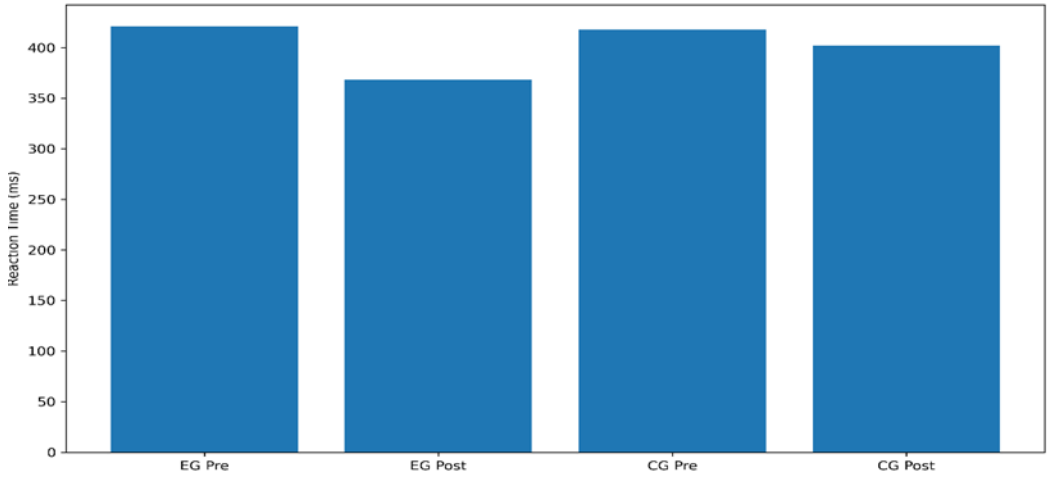


Figure 2. Reaction time changes in experimental and control groups.

The experimental group showed a greater reduction in reaction time compared to the control group, indicating improved perceptual-cognitive processing speed.

4. Discussion

The aim of the present study was to investigate the effects of an 8-week reactive agility training program on performance in competitive padel players. The results support the initial hypothesis, demonstrating that the experimental group achieved significantly greater improvements in reactive agility, reaction time, and padel-specific performance compared to the control group.

One of the most important findings of this study was the substantial improvement in reactive agility observed in the experimental group. Reactive agility is a key determinant of performance in open-skill sports, where athletes must continuously adapt their movements in response to unpredictable environmental stimuli (Sheppard & Young, 2006). In padel, this ability is particularly relevant due to the dynamic nature of rallies and the complexity of ball rebounds from walls. The observed reduction in

completion time suggests that stimulus-based training effectively enhances movement efficiency under game-specific conditions.

The significant improvement in reaction time further supports the effectiveness of the intervention. Faster reaction times reflect enhanced perceptual processing and improved neuromuscular coordination, both of which are essential in padel due to the limited time available to respond to opponent actions. These findings are consistent with previous research indicating that training under conditions of uncertainty improves perceptual-cognitive performance (Mann et al., 2007).

Another key outcome of this study is the significant increase in padel-specific performance in the experimental group. This improvement reflects enhanced decision-making and execution during game situations, suggesting that reactive agility training promotes more effective perception–action coupling. Given the complex and unpredictable nature of padel, the ability to rapidly interpret game scenarios and select appropriate responses is crucial for performance optimization (Martín-Miguel et al., 2023).

In contrast, the control group showed only moderate improvements, primarily in reactive agility, with no significant changes in reaction time. This finding supports the notion that traditional training approaches, which focus mainly on technical and physical components, may not sufficiently address the perceptual-cognitive demands of padel. Therefore, integrating stimulus-based training appears to provide a clear advantage in improving performance outcomes.

From a theoretical perspective, the findings align with the principles of ecological dynamics, which emphasize the importance of training in representative environments that simulate real-game conditions (Davids et al., 2008; Pinder et al., 2011). By incorporating unpredictable stimuli and decision-making elements, the intervention likely enhanced perception–action coupling, facilitating the transfer of training effects to competitive performance.

The magnitude of improvements observed in the experimental group highlights the importance of combining cognitive and motor training components. In sports such as padel, where performance depends on rapid adaptation to dynamic situations, training approaches that integrate these elements are likely to produce superior results compared to traditional methods.

From a practical perspective, coaches may incorporate reactive agility drills within regular training sessions to improve players' responsiveness and decision-making under competitive conditions.

5. Strengths and Limitations

The present study has several strengths. First, the use of a randomized controlled design enhances the internal validity of the findings. Second, the intervention was conducted in a real training environment, increasing ecological validity. Third, the study evaluated both physical and perceptual-cognitive variables, providing a comprehensive assessment of performance.

However, some limitations should be acknowledged. The relatively small sample size may limit the generalizability of the results. Additionally, the duration of the intervention was limited to 8 weeks, preventing the assessment of long-term adaptations. Furthermore, performance evaluation was based on specific tests rather than full match analysis, which may limit the ecological validity of the findings. Additionally, the accuracy of reaction time measurements may be influenced by the limitations of the testing device.

6. Future Directions

Future research should investigate the long-term effects of reactive agility training and its applicability across different performance levels. The use of advanced performance analysis methods,

such as motion tracking or video-based analysis, may provide deeper insights into perceptual-cognitive adaptations in padel.

7. Conclusions

The present study demonstrated that reactive agility training significantly improves both physical and perceptual-cognitive performance in competitive padel players.

The experimental group exhibited substantial improvements in reactive agility, reaction time, and padel-specific performance compared to the control group, confirming the effectiveness of stimulus-based training approaches.

These findings highlight the importance of integrating perceptual-cognitive components into traditional training programs, particularly in sports characterized by dynamic and unpredictable environments such as padel.

From a practical perspective, incorporating reactive agility training into regular practice sessions may enhance movement efficiency, decision-making, and overall competitive performance.

Overall, reactive agility training represents an effective strategy for optimizing performance in padel players.

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Development of Motor Coordination Through Thee Folk Dance "Breaza" - Applied Study

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Article type	Conference track	Language and length
Original Research Article	Movement Science and Human Performance	English, 4 pages

Abstract

Background: Folk dance is an important form of cultural identity expression and an effective means of physical and social development. Through rhythmic movement, coordination, and collaboration among dancers, traditional dances support both the preservation of cultural heritage and the development of essential motor skills.

Objective: This article aimed to analyze the folk dance "Breaza", performed by the student ensemble of the Faculty of Physical Education and Mountain Sports in Brașov, and to highlight its cultural, educational, and motor value, as well as the role of ensemble participation in the development of young student dancers.

Results: The methodology was based on participatory observation and descriptive analysis, considering the author's direct experience within the ensemble. The choreographic structure, musical rhythm, movement coordination, and group synchronization were examined. The results showed that practicing the "Breaza" dance contributes to the development of balance, coordination, rhythmic perception, and spatial orientation. At the same time, participation in the ensemble strengthens team spirit and attachment to local traditions.

Conclusions: The folk dance "Breaza" is not only an artistic form of expression, but also a valuable tool for cultural education and motor development.

KEYWORDS: folk dance, romanian traditions, motor coordination, cultural heritage, folklore

1. Introduction

Folk dance is an essential component of intangible cultural heritage and a means through which communities transmit their values, traditions, and cultural identity from one generation to another. International organizations such as UNESCO emphasize the importance of preserving and promoting cultural traditions, including folk dances, as they reflect the history and identity of a community.

Romania is distinguished by a rich diversity of folk dances, each region having specific styles, rhythms, and choreographic elements. These dances are preserved and promoted especially through folk ensembles, where young people learn both movement techniques and the cultural significance of traditions.

Through artistic activities and participation in cultural events, the ensemble provides young people with the opportunity to discover and practice traditional dances specific to the area.

In motor coordination, an evaluation system was used to monitor: integral execution, body rotation, balanced position, reduction of the support surface, fluidity of movements, balanced execution, stable position, accuracy in movement, synchronization, and the level of performance of dance coordination.

One of the representative dances performed within the ensemble is the “Breaza” dance. It is characterized by an energetic rhythm, well-structured steps, and precise synchronization between dancers. Practicing this dance involves the development of coordination, balance, and rhythmic perception, while also cultivating respect for local traditions.

The aim of this study is to highlight the importance of the “Breaza” dance both from a cultural perspective and from the standpoint of motor and social development of young dancers, as well as to analyze, through a case study conducted on a group of students, the impact of practicing this dance on motor coordination

2. Materials and Methods

2.1. Participants

The study was conducted on a sample of 10 students aged between 19 and 23 years, divided as follows:

8 students with dance experience (folk, contemporary, street dance)

2 students without prior dance experience

2.2. Procedure

Participants were involved in a 4-week program in which they practiced the “Breaza” dance three times per week.

The following were evaluated:

motor coordination

balance

group synchronization

The evaluation was carried out on a scale from 1 to 10:

before the start of the study program

after the completion of the study program

3. Results

Table 1. Test Results

Students	Dance experience (years)	Initial coordination	Final coordination
S1	5	6	8
S2	6	7	9
S3	4	5	7
S4	7	7	9
S5	5	6	8
S6	6	7	9
S7	0	3	6
S8	0	2	5
S9	3	5	7
S10	4	6	8

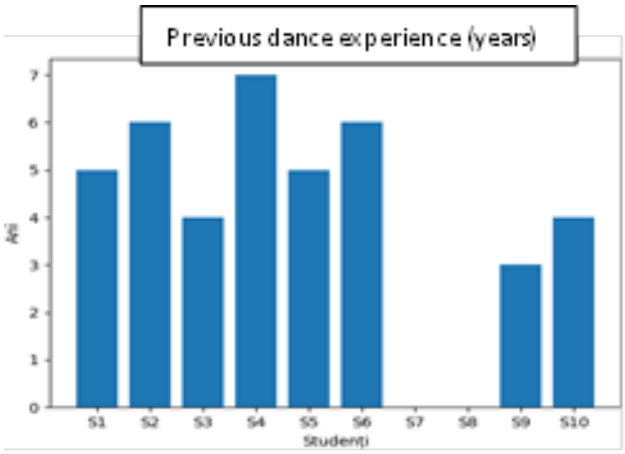


Figure 1. Level of previous dance experience.

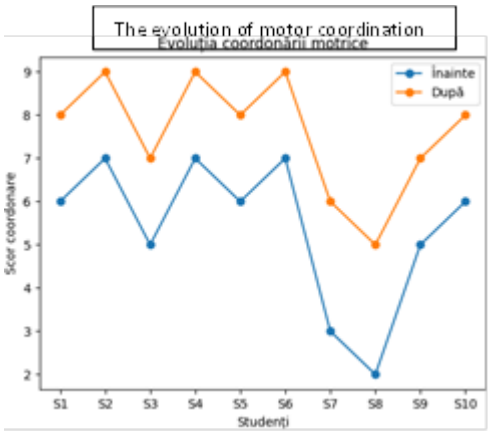


Figure 2. Motor coordination evolution before and after theprogram.

The results indicate an overall improvement in motor coordination for all participants. Data analysis shows an average increase of approximately 2 points in coordination scores.

Students with prior dance experience had higher initial values but also recorded noticeable improvements. At the same time, participants without experience (S7 and S8) showed the greatest relative progress, increasing from low initial scores (2–3) to significantly improved levels (5–6).

Figure 1 highlights the diversity of experience levels within the group, supporting the relevance of the study for different categories of participants.

4. Discussion

The results confirm the hypothesis that folk dance contributes to the development of motor coordination, regardless of the initial level of training.

The progress observed in beginners suggests that the “Breaza” dance is accessible and effective, facilitating the rapid development of

basic motor skills. At the same time, experienced students improved the precision and synchronization of movements, indicating that folk dance also enhances already developed skills.

Another important aspect is the social dimension of the activity. Group participation promoted cooperation, synchronization, and adaptation to the collective rhythm.

The results are consistent with the specialized literature, which highlights the role of dance in the development of coordination, balance, and social integration.

5. Conclusions

The study highlights that the folk dance “Breaza” is an effective tool for the
development of motor coordination and social skills among young people.

The case study conducted on a group of 10 students demonstrates that, regardless of prior experience, participants achieve significant progress within a relatively short period of time.

Furthermore, the results confirm that folk dance contributes to:
improving body control
developing rhythmic sense
increasing teamwork ability

Therefore, the inclusion of folk dance in educational or extracurricular activities can have a positive impact on both physical development and cultural identity formation.

The “Breaza” dance is not only an artistic form but also a modern and effective means of motor and social education.

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Introduction Of New Technologies In Medical Education: Application Of Merrill's Instructional Design Principles in Pediatric Physiotherapy

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Original Research Article	Movement Science and Human Performance	English, 19 pages

Abstract

Background: Physiotherapy uses physical techniques to improve joint mobility, muscle strength, posture, pain management, healing, functional recovery, and quality of life. In pediatric settings, physiotherapists work with children from infancy to adulthood, supporting normal motor development and identifying deviations from age-related developmental stages.

Objective: The objective of this study was to investigate the impact of the physiotherapist's influence on students' physical well-being and to provide evidence for the benefits of having at least one physiotherapist in educational units.

Results: The physiotherapist plays an important role in promoting physical activity and health, preventing disabilities and injuries, and improving quality of life. The study was designed as a prospective longitudinal cohort study and included 30 children divided into two groups, an experimental group and a control group. Participants completed a questionnaire about their daily habits and were evaluated three times through posturology and anthropometry, before, during, and after the experiment. Based on the results of the initial assessment, a personalized exercise program was developed for each child.

Conclusions: The study supports the value of physiotherapy interventions in improving students' physical well-being and highlights the potential benefit of including at least one physiotherapist in educational institutions.

Keywords: physiotherapy, physical activity, educational units.

1. Introduction

Design represents a plan or a drawing produced to present the appearance and function or operation of a structure, an article, or an object before it is made (https://languages.oup.com/google-dictionary-en/). Instructional refers to the provision of information on how to do or use something: providing instructions (https://www.britannica.com/dictionary/instructional).

Design is often reduced to an aesthetic issue: creating attractive products that stand out from the competition. Good design is not just about being "pleasing to the eye". Good design means improving our life experiences by creating practical, intuitive tools that solve our problems and integrate seamlessly into our environment, our routines, and our value systems (Lamé et al., 2024).

Learning theories provide the foundation for selecting training strategies and enable a reliable estimation of their effectiveness. To achieve efficient learning outcomes, the science of education and educational design models guide the development of strategies that stimulate appropriate cognitive processes (Khalil & Elkhider, 2016).

With the development of new technologies, new ways of transmitting knowledge emerge. Scientists are always seeking new methods to optimise student education, especially in online classes (Abuhassna et al., 2020). Because specific disciplines require practical activities and specialised professional training to acquire the necessary skills, integrating a technological environment presents educators and course creators with even greater challenges (Kamal, 2020). Instructional design has thus become increasingly important in the educational context. Instructional designers have played a crucial role as agents of change, contributing to the pedagogical and technological transformation of teachers and students (Vaill & Testori, 2012).

E-learning refers to learning conducted through electronic means, usually via the internet (https://languages.oup.com/googledictionary-en/). Also known as a virtual environment, it uses internet-based technologies and pedagogical tools to create a teaching and learning environment through concrete actions (Konstantinidis et al., 2022).

E-learning as part of distance education has become increasingly popular over the last decade; however, its use varies widely across schools. Distance learning does not exclude traditional learning processes; it is often used alongside professional training procedures and practices, as well as in the classroom. Distance learning is used for self-education, tests, results, and exams, as well as for individual examination services. The ability to work in exercise mode with image files and questions is an attractive way to self-educate (Masic, 2008). The emergence of e-learning programs has transformed the traditional approach to learning worldwide, including in schools and universities (Kashifi et al., 2022).

Merrill's principles represent a task-centred approach that focuses on ways to facilitate learning (https://whatfix.com/blog/instructional-design-models/).

The implementation of Merrill's instructional principles in designing MOOCs and actively engaging learners in a problem-solving-centred learning process can lead to improved outcomes and higher satisfaction levels (Badali et al., 2020).

This paper aims to explore and analyse how Merrill's educational principles, particularly those related to active learning and the application of educational theories, can be implemented in pediatric care using modern technology. Applying Merrill's principles in paediatric medical education can encourage active, practical learning among medical personnel through technologies such as medical simulators, interactive online platforms, and mobile applications that integrate real cases and practical situations in paediatrics, providing relevant context and an active learning experience.

Types of Instructional Design with Applicability in Didactics

Instructional design plays an essential role as an agent of change in facilitating the pedagogical and technological transformation of educators and students. However, some instructors consider instructional design a challenge and exhibit gaps in their understanding of instructional design models, categories, educational contexts, and recommendations for future work (Abuhassna & Alnawajha, 2023).

Thus, although there are many different design models, all include the following essential phases of instructional design: analysis, design, development, implementation, and evaluation. The designer's

main activity is to conduct an instructional analysis to determine educational objectives, develop training strategies, and create and implement an evaluation. They consider the program's goals to identify its essential elements.

However, the teaching staff's activities in designing and planning educational activities should be guided and supported by the science of learning and instruction (Khalil et al., 2016).

Applied science lacks a systematic approach to developing learning strategies for online training in evidence-based practices that consider the context of real-world practice. The field of instructional design offers systematic and ecologically valid processes for developing learning strategies for workforce development and performance support (Patel et al., 2018).

The ADDIE Model

Instructional design using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) – in the development and evaluation of e-learning modules as a strategy within a multidimensional approach to implementing a training system (Dick et al., 2005).

The ADDIE model comprises five phases, starting with identifying the needs of key stakeholders, educational objectives, and optimal methods for content delivery (analysis) (Kirkpatrick D & Kirkpatrick J, 2006).

The ADDIE model is used to create a teaching curriculum or training program that achieves concrete learning outcomes and behavioural changes. It provides a systematic approach to analysing learning needs, designing and developing a learning program, and implementing and initially evaluating a professional training program (Reiser et al., 2012).

The analysis phase of ADDIE instructional design focuses on data collection to determine what needs to be taught. The design component of ADDIE creates a blueprint that must be followed to systematically teach new skills. The development phase completes the programming plan created in the design phase. Focusing on the fundamentals of programming could include efforts to individualise both teaching procedures and the teaching model. In the implementation phase of the ADDIE model, teachers develop and implement the school curriculum. Evaluation can focus on the social validity of what is taught, how it is taught, and the resulting outcomes. This refers to thinking, and authentic reflection affects all other elements of the ADDIE process (LaMarca et al., 2024).

1.2 Constructivist Design

University education focuses particularly on shifting from a more traditional teaching approach – "instructivist" – to a more student-centred approach – "constructivist" – to encourage the development of key competencies (Do HN et al., 2023).

Constructivist theory emphasises students' experiences with the natural world, prior knowledge, and beliefs (Jonassen, 1991). Thus, students acquire knowledge by integrating new information with knowledge they already possess (Bada & Olusegun, 2015).

The new learning environment is based on constructivist theory and supports the creation of an educational environment that fosters lifelong learning. This method stimulates student exploration of the main problem and defines instruction as a task to promote the learning process (Lea & Troy, 2003).

In social constructivist theory, students are at the centre, not the instructors. Students actively construct their own understanding through social engagement with their peers; the outcomes in the learning process can be effective. They are encouraged to develop their own answers and experiment with new theories. The instructor's responsibility is to facilitate the students' learning process on a specific topic. Students must practice their knowledge development skills by designing and structuring learning activities (Pande & Bharathi, 2020).

Problem-Based Learning – PBL

The PBL approach, an innovative teaching and learning method, is designed to provide more challenges and motivation by exploiting realistic contexts to stimulate and interact with students by developing their prior knowledge, improving their ability to understand basic concepts, and forming acquired knowledge in parallel to establish a complex, yet elaborate and integrated knowledge schema (Virk A et al., 2022).

The main objective of problem-based learning (PBL) is to develop problem-solving skills. Unlike the traditional curriculum, which mainly relies on lectures, PBL is based on students working in groups to solve a problem. The PBL method is a promising teaching and learning approach that can be adopted across all fields, especially in medical education (Jaganathan & Sabarinathan, 2024).

There are "four key learning principles for PBL: constructive, collaborative, contextual, and self-directed learning" (Telang, 2014).

Students identify knowledge gaps, analyse and design the approach, track progress, and monitor their evolution as group members during a PBL session (Trullàs et al., 2022).

Multimedia Instructional Design

Multimedia is an association of several media types, such as text (alphabetic or numeric), symbols, images, photographs, audio, video, and animations, usually with the aid of technology, for the purpose of enhancing understanding or memorisation (Guan et al., 2018). The hardware and software used to create and run multimedia applications are known as multimedia technology (Kapi et al., 2017).

Multimedia technology features integration, diversity, and interaction, allowing people to communicate information or ideas through digital and printed elements. In this context, digital and printed elements refer to multimedia applications or tools used to transmit information to help people better understand concepts (Abdulrahaman, 2020).

In the modern era, when most medical students learn in a digital format, the design and accessibility of multimedia learning programs significantly impact learners. Multimedia in the learning context refers to the use of words, written or spoken, in juxtaposition with images, static or dynamic, ranging from presentations to videos and animations (Mayer RE, 2005). A synthesis analysis of research in the fields of learning sciences and educational design establishes design principles that govern the design and use of multimedia based on the content and context in which the media is presented (Sweller, 1994). Thus, the use of structural means, such as diagrams and metaphors, helps learners connect new and existing knowledge (Park & Hannafin, 1993). This research-based finding constitutes the foundation of the cognitive theory of multimedia learning, which establishes a clear relationship between cognitive benefits and the use of both words and images to support learning (Mayer, 2005).

Gamified Instructional Design

Gamification in e-learning involves a set of processes and activities conducted in a non-game framework to address educational problems by applying gamified design principles and elements, resulting in greater ease of use, student engagement, knowledge retention, and learning (Lopes et al., 2019).

Gamification is becoming increasingly common in e-learning as a new technology that can stimulate student motivation and engagement through simple virtual incentives, such as badges, points, rewards, challenges, leaderboards, progress monitoring, and earning performance points (Aguiar-Castillo et al., 2020). Gamification and game-based learning, although used interchangeably in e-learning, are quite different. The former is the application of game mechanics in a non-game context, while the latter uses

game elements to teach specific skills to learners to achieve specific learning objectives (Hamari et al., 2014).

Gamification in e-learning combines course material with game elements to enhance attractiveness. Compared with the basic appearance and learning experience of content, game components, such as progress graphics and different levels, motivate learners more. Collecting points on scoreboards can foster a sense of competitiveness, further motivating learners to surpass their peers and increasing engagement and competition (Ghai et al., 2023).

Personalising e-learning enables effective adaptation to student needs, leading to greater satisfaction. Artificial intelligence should be an effective means of development. Rewards are synonymous with trophies or badges in most gamified schemes (achievements). To achieve the proposed objectives, learners are encouraged to complete various assignments within e-Learning systems (Yamani, 2021).

2. Technologies with Applicability in Instructional Design

Due to the interaction between instructional design and learning technology, it is necessary for instructional designers, at any level of experience, to have technical knowledge and the interest to develop their skills. Technology plays an essential role in all phases of course development, from analysis to evaluation, and technical skills are needed for creating and delivering teaching materials. In addition, technology helps collect valuable information about course performance. Technology-based learning enhances student engagement through interactive tests and digital games, and advanced technologies such as augmented and virtual reality can provide immersive educational experiences (https://www.digitallearninginstitute.com/blog/instructional-design-and-technology).

2.1 E-learning

E-Learning provides access to a wide range of courses, eliminates geographical barriers, and encourages lifelong learning. Students in isolated areas have limited access to quality education. E-Learning gives students access to a wide range of courses and allows them to learn at their own pace and convenience. E-Learning systems are gaining increasing popularity by providing access to quality education at an affordable cost. The demand for E-Learning has grown exponentially in recent years, transforming how students learn and access education (Pachauri et al., 2024).

2.1.1 E-learning Platforms

Moodle is an interactive online learning platform, a true virtual amphitheatre, which breaks down geographical and spatial barriers, capable of providing continuing education (Koama et al., 2021).

Moodle is primarily used within university disciplines and effectively improves student performance, satisfaction, and engagement. Moodle is increasingly used as a platform for adaptive and collaborative learning and is used to improve online assessments. The use of Moodle is rapidly developing to address issues of academic integrity, ethics, and security, to improve speed and navigation, and to incorporate artificial intelligence (Gamage et al., 2022).

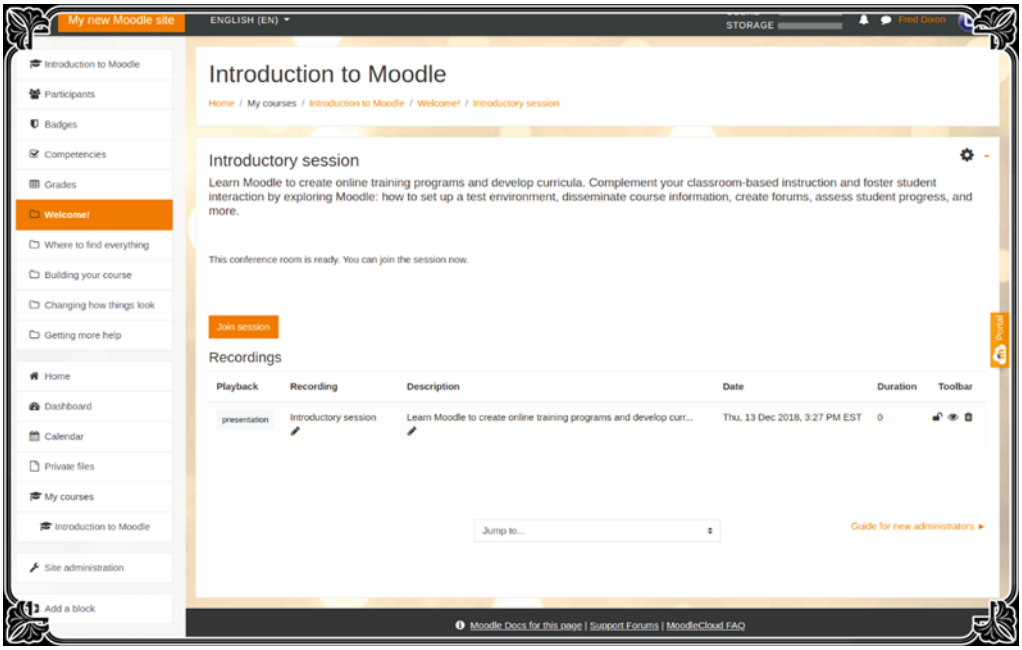


Figure 1. Moodle platform (https://moodle.org/).

Khan Academy

Khan Academy is a nonprofit educational organisation whose mission is: "providing a high-quality education for anyone, anywhere." The Academy's website offers a free online collection of over 3,200 micro-lessons in video tutorials on YouTube, covering a variety of subjects, including science, medicine, and healthcare. In addition to videos, the Khan site offers over 320 exercises, problem sets, assessment tools, and peer-to-peer tutoring to support the creation of teaching materials (O'Donnell, 2012).



Figure 2. Khan Academy platform (https://www.khanacademy.org/).

Advanced eLearning (AeL), used in most schools and high schools, is an integrated platform for teaching, learning, testing, and assessment, with a curricular design. AeL provides support for managing educational content, including interactive materials, simulations, tutorials, and educational games. The educational library is adaptable, configurable, indexable, allows easy searching, and allows access rights to be customised. The platform supports communication between local and regional centres in the SEI program and provides advanced content administration and search capabilities.

The educational platform MyKoolio, approved by the Ministry of Education as a teaching aid, uses a modern teaching method based on interactive educational games. It provides engaging lessons, immediate feedback, and approved content structured according to the school curriculum. MyKoolio allows teachers and students to collaborate from anywhere, anytime, on any device, ensuring continuity of teaching and access to quality educational materials (https://revistaeducatie.ro/wp-content/lic/informatica/UTILIZAREA-PLATFORMEI-EDUCA%C8%9AIONALE-%C3%8EN-ACTIVITATEA-DIDACTIC%C4%82.pdf).

As tertiary students advance toward employment, they need relevant knowledge and integration skills to solve real-world problems. For example, veterinarians must combine information from various fields – parasitology, host response, diagnosis, treatments, animal management, epidemiology, and clinical communication – to effectively manage parasitic diseases. Therefore, training in parasitology can exemplify how technology supports the integration of this knowledge (Jabbar et al., 2016).

The use of teaching technologies, such as Smart Sparrow or Articulate Storyline 360, can distract from pedagogical objectives. It is essential to focus on learning objectives – the targeted knowledge and skills – and frequently return to them during design, to ensure the relevance of the final activity (Pfeiffer & Jabbar, 2019).

2.1.2 Simulators and Virtual Reality

Virtual reality (VR) is revolutionising various fields, from entertainment to medicine and architecture. The central element of the VR experience is the headset (HMD), such as Oculus Quest 2, HP Reverb G2, or Valve Index, which gives users access to captivating virtual worlds.

In entertainment, VR transforms video games and cinematography, allowing users to explore historical environments, engage with interactive stories, and choose different endings. In the arts, VR becomes a creative environment for artists and designers, offering tools such as Adobe Substance 3D

Modeller for 3D modelling. In architecture, technology allows clients to explore virtual spaces before construction, and in medicine, it facilitates training and empathy through anatomical simulations or captivating experiences.

Additionally, VR is used in aviation for pilot training and in the military for complex tactical simulations. This innovative technology enhances learning, collaboration, and creativity, redefining interaction with virtual environments (https://www.adobe.com/ro/products/substance3d/discover/what-is-vr.html).

2.2 Applicability of Merrill's Principles in the Technologized Romanian Education System

Merrill's principles for instructional design align with the SMART.Edu document's priorities for the digitalisation of education in Romania. These principles emphasise the importance of authentic tasks, the activation of prior knowledge, demonstration, application, and integration of knowledge, all of which are essential in modern digital training. Emphasis is placed on developing digital competencies and digital literacy for 90% of the population, and on technological infrastructure in schools, to respond to rapid changes in society and the labour market.

The principle of real-world tasks can be implemented through VR simulators for professional training, and adaptive platforms support activation of prior knowledge. Knowledge demonstration can be achieved through interactive videos and AR. Application and integration of knowledge are supported through gamified simulators and collaborative platforms. SMART.Edu aims to create high-performance, inclusive educational environments that align Romanian education with European standards (https://www.edu.ro/sites/default/files/SMART.Edu%20-%20document%20consultare.pdf).

The use of virtual learning resources (VLR) developed with immersive technologies, such as virtual reality, is becoming increasingly popular in medical education, especially in anatomy. However, if VLRs are to be used on a broader scale, they must be appropriately designed (Birbara et al., 2021).

Online multimedia lessons have proven to be a popular and effective learning tool, and the cognitive theory of multimedia learning provides a set of solid theoretical principles for creating them. By using learning science to formulate applications and using practical applications to consolidate science, we can continue to advance our theoretical understanding of learning while also providing instructors with practical guidelines for creating effective online multimedia lessons (Cavanagh et al., 2023).

3. Merrill's Principles

The author introduced the first principles of instruction in 2002. He stated that implementing these principles promotes effective, efficient, and engaging instruction. These principles and their corollaries represent Merrill's attempt to develop a prescriptive theory of instructional design (Merrill et al., 2022).

Merrill's first principles of instruction (Merrill, 2002), a meta-model that provides a general summary of available ID guidelines (Gagne et al., 1990), proposes five key instructional principles for task-centred learning. These are based on careful analysis of a wide range of cognitive learning models: identification of an authentic problem (because learning is promoted when learners are involved in real-world problems), activation of prior knowledge as a basis for new knowledge, demonstration of the task to be learned, application of newly acquired knowledge by learners, and integration or transfer of new knowledge into the learner's world (de Melo et al., 2022).

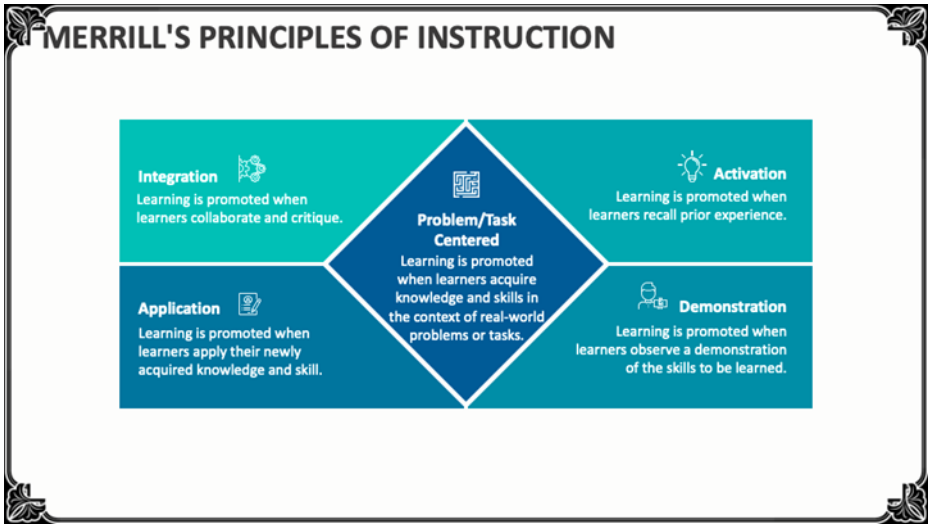


Figure 3. Merriill's principles of instruction (https://www.collidu.com/presentation-merills-principles-of-instruction).

Problem-Centered

In Merrill's opinion, students acquire knowledge and skills by solving real-world problems. However, problems should not be too complex. A "sink or swim" approach will only actively discourage students from learning.

Nevertheless, to master any skill, it is necessary to solve a series of problems of varying difficulty. According to Merrill's pebble-in-the-pond theory, students should start with minor, easy problems and gradually progress to more difficult ones.

These tasks and problems should activate and engage the student's knowledge. Challenges that work best for acquiring new knowledge and skills should be rooted in the real world and ideally, as tailored as possible to each learner (https://instructionaldesign.com.au/merrills-instructional-design-principles/).

Activation

According to David Merrill's first principles of instruction, adapting the learning experience to each student begins with the activation phase.

Each person's prior experience is different. Some students may not have a solid foundation for new knowledge. Others may have approached similar materials before and feel bored.

The solution for the former is to provide them with a rapid learning experience to bring them up to speed. For the latter, providing ample opportunities to demonstrate their knowledge based on real-world examples will keep them engaged.

However, activation does not just mean testing memory. It also helps activate the mental models needed to effectively absorb new knowledge and skills (https://www.thinkific.com/blog/instructional-design-models/).

Demonstration

"Show, don't tell" is an effective teaching technique for a reason. When an instructor gives examples of new concepts, visualises processes, and models behaviour, students are more likely to absorb new information.

Not all demonstrations are equal. Teachers must ensure that the way they demonstrate the teaching material is relevant to the information presented. Using a few different media (e.g., text, images, video) can make presenting new information more engaging (https://www.yorku.ca/unsdgs/toolkit/wp-content/uploads/sites/617/2023/04/Implementing-MerrilFirstPrinciples.pdf).

Using comparisons and real-world examples can help students develop frameworks that will later help them solve a variety of problems (Truong et al., 2019).

Application

We all know that practice makes perfect. David Merrill agrees, saying that progress is only possible when the learner applies new knowledge.

Nevertheless, the application of new knowledge should not happen ad hoc. Authentic learning is facilitated when the practical solving of problems is guided through feedback and an adequate level of training, which should decrease as the learner's skills increase (Merrill & Marriner, 2007).

Merrill even states that adequate practice is the most neglected aspect of effective instruction. No one expects a musician to perform a few hours after learning something new. However, this is precisely the expectation in most training programs (Chin et al., 2006).

Integration

The final phase in Merrill's model of the first principles of instruction involves integrating new knowledge into the learner's life or publicly demonstrating new skills. When the learner understands the context and integrates the newly acquired skill or knowledge into daily life, the concept will be better learned.

Integration could mean:

- Working on real projects

- Analysing case studies
- Testing hypotheses
- Solving real problems

When students demonstrate improvement, they become even more motivated to progress (https://www.learningeverest.com/merrills-first-principles-of-instruction/).

4. Applicability in Didactics of Merrill's Principles

The advancement of information and communication technologies has transformed education, requiring the adoption of digital tools to meet learners' needs in the digital environment. E-learning platforms have become essential tools in modern education. They offer interactive, personalised learning experiences that adapt to each student's unique needs and learning style. These platforms provide interactive, personalised experiences that adapt to learners' diverse needs and preferences. By incorporating models such as flipped classrooms and Gamification, they not only increase student engagement but also stimulate motivation and improve academic outcomes (Alshiha et al., 2024).

Studies have shown that educational robotics (ER) can impact student learning, especially in STEM (science, technology, engineering, and mathematics) fields. Within STEM, especially for younger children, "E" and "T" are considered missing letters because few studies have focused on teaching and assessing technology and engineering through ER activities. This study aimed to develop and test the effectiveness of an ER protocol for teaching robotics in a sample of 389 students, with the hypothesis that girls would be as successful as boys. The data indicated significant improvements for all age ranges considered. No gender differences were found. To assess the effectiveness of a teaching intervention that uses ER, it is important to evaluate the impact on children's technological and engineering knowledge (robotics, in particular) (Castro E et al., 2018).

Current research explores children's appreciation of children's literature in the context of the visual literacy era. The capacity of early childhood to appreciate visual literature can be viewed as a creative capacity within the context of early childhood visual literacy. This present research aims to examine how children in early childhood (5-6 years) appreciate children's literature (children's stories on screen) and to interpret their appreciation. The theoretical framework of this paper comprises the concepts of children's literature, literary appreciation, and visual literacy. This current qualitative research positions children's appreciation of children's literature (children's stories on screen) in a reader-response approach. Two girls, aged 5 and 6, who could not yet read or write, were included as participants (visual text readers). In the initial phase, the two readers enjoyed their favourite story series, My Little Pony, on YouTube Kids every day for over a year. Data obtained from the Q&A session were documented and interpreted. The findings show that children appreciate visual literature on screen by forming particular ideas from the detailed images of the story. The findings show that children can explore life narratives from stories: conditions denoting "being" and "becoming" and the struggle between good and evil, as the situations demonstrate conflicts and solutions (Wolf & Shelby, 2014).

Peer interaction is more effective when it is orchestrated around a progression of problems. Problem-centred learning is enhanced through carefully structured peer interactions. Problem-centred instruction is a form of direct instruction in which instructional components are taught in the context of problems. An effective problem-centred instructional strategy involves (a) actively facilitating learners' activation of relevant mental models, (b) demonstrating problem solutions to learners, (c) allowing learners to apply solutions to new problems, and (d) facilitating integration into out-of-class activities through critique, discussion, and reflection. Instruction is more effective when there is appropriate peer interaction during each of these phases: sharing among peers during activation, discussion among peers during

demonstration, collaboration among peers during application, and critique among peers during integration (Merrill & Gilbert, 2008).

Children must develop various skills to manage toxic stress and optimise their development. Research shows that age-appropriate play, done with parents and peers, promotes socio-emotional, cognitive, and self-regulation skills, essential for executive function and the development of a prosocial brain. Play supports safe, stable relationships with caregivers, thereby improving brain structure and function. Lack of play and safe relationships can disrupt development, and in the presence of adversity, play becomes essential. Paediatricians can promote the benefits of play and recommend such activities for healthy development (Michael Yogman et al., 2018).

5. Applicability in the Field of Pediatric Physiotherapy

Pediatric physiotherapy is a branch of physiotherapy that helps treat or improve movement problems in infants and children, supporting a child's developmental stages. Orthopaedics, congenital malformations, neurology, neuropsychiatry, respiration, and prematurity are among the systems that affect children (Di Chiara, 2019). Pediatric physiotherapists deal with developmental delays and neuromotor disorders. They treat children of all ages, from infants to adolescents, and have specific knowledge and training regarding growth and development, syndromes, and diagnosis (Desai & Sindoor, 1997).

For children with various congenital and acquired developmental disorders, the importance of early intervention and individualised treatment programs is emphasised, highlighting the need for immediate intervention to influence long-term functional outcomes and quality of life (Srushti Sudir & Sharath, 2023).

Table 1. Classic Plan vs. Plan Adapted According to Merrill's Principles (personal source)

CLASSIC REHABILITATION PLAN	APPLICABILITY OF MERRILL'S PRINCIPLES IN PEDIATRIC PHYSIOTHERAPY
History and assessment of deficits - clinical and specialised paraclinical examination; - somatoscopic examination; - anthropometric evaluation; - joint and muscle balance; - sensitivity evaluation; - ADL evaluation.	History and assessment of deficits Specialised clinical and paraclinical examination; Somatoscopic examination and anthropometric evaluation: - BAIOBIT - BTS Poseidon - PRO-RIN Easy - BTS INFINI-T - BTS GAITLAB FREEWALK - Assessment of sensitivity; - Assessment of ADL and IADL: - BTS NIRVANA - VRRS
Establishing objectives Long therm Short therm	Objectives will be set automatically
Exercise plan	Exercise plan: 1. Problem-Centred Ex: With the help of VR glasses, the patient must solve simple tasks (avoiding an obstacle, moving objects, maintaining balance) 2. Activation

	With the help of BTS Nirvana, the patient will become the main character of a known animation, performing specific recovery tasks. 3. Demonstration Visualising tasks through videos on various e-learning platforms. 4. Application With the help of educational games and gamified platforms. 5. Integration With the help of VRRS.
Re-evaluation and results	

Merrill's principles offer a modern, practical approach to pediatric rehabilitation that addresses the limitations of traditional rehabilitation plans. Unlike traditional methods, which are often rigid and repetitive, these principles place the child at the centre of the process, transforming recovery into an interactive experience adapted to individual needs.

An essential aspect of Merrill's principles is personalisation. Each child has their own particularities, and this approach allows the adaptation of exercises to their pace and interests, thereby increasing motivation and active participation. Furthermore, integrating modern technologies, such as virtual reality and interactive platforms, makes the process more engaging and stimulating, providing instant feedback and faster results. Moreover, these principles use educational games and playful methods to turn exercises into enjoyable activities, eliminating the monotony of traditional plans. Through the child's active involvement and the emphasis on transferring skills to daily life, rehabilitation becomes more functional and relevant.

Finally, the relationship between the therapist and the child improves through a more friendly, interactive approach, which increases trust and collaboration. Thus, Merrill's principles not only make pediatric recovery more efficient but transform it into a dynamic process, centred on the child's needs and potential.

In pediatric physiotherapy, integrating modern technologies within the framework of Merrill's principles offers an innovative approach to supporting children's recovery and motor development. These principles – activation, demonstration, application, and integration – create a clear structure, which, when combined with advanced tools such as BTS GaitLab, FreshWalk, and VRRS Nirvana, ensures a personalised, engaging, and effective therapeutic intervention.

The process begins with the activation stage, where the therapist gathers essential information about the child's condition. This involves a detailed analysis of motor and functional deficits, using state-of-the-art technologies. For example, BTS GaitLab provides a complex assessment of the child's gait and posture, precisely identifying biomechanical dysfunctions. At the same time, FreshWalk allows monitoring of daily activities, such as walking or maintaining balance, providing a clear picture of basic functional performance. Also, VRRS Nirvana introduces an interactive virtual environment that analyses sensitivity, coordination, and other important motor aspects. This data forms the basis for developing a personalised therapeutic plan.

Next is the demonstration stage, where the child is familiarised with the therapy's objectives and the methods used to achieve them. The therapist uses technologies to illustrate the necessary activities, thus creating a clear link between the established goals and the means to achieve them. In the short term, VRRS Nirvana becomes a valuable resource through its virtual simulations, which help children understand and practice the correct movements. For example, a child learning to maintain balance can visualise in VR

how to adjust their posture to prevent falls. In the long term, FreshWalk allows progress monitoring, encouraging the child to take small but sure steps toward motor independence. These tools not only explain but also inspire the child to participate in the recovery process actively.

The personalised exercise plan, which constitutes the application stage, is the heart of the therapeutic process. Here, the child is directly involved in specific activities, adapted to their needs. BTS GaitLab is used to evaluate the effectiveness of exercises in real-time, providing immediate feedback to the therapist and patient. For example, if a child has difficulty walking, BTS GaitLab can highlight problem areas, and the therapist can adjust exercises on the spot. In parallel, VRRS Nirvana creates an engaging environment where the child participates in educational games designed to develop coordination, balance, and strength. These games transform the recovery process into a pleasant activity, motivating the child to overcome their limits. FreshWalk, in turn, complements this plan by constantly measuring physical progress, helping the therapist adapt the intensity and complexity of exercises based on results.

The final stage, integration, represents the moment when the child begins to apply the acquired skills in daily life. Constant re-evaluation, supported by the BTS GaitLab, provides a clear picture of progress. For example, the child can be observed while walking a simple route, and the technology highlights the adjustments needed to optimise their movements. At the same time, VRRS Nirvana introduces new virtual challenges that build on skills already developed and prepare the child for real-world situations, such as climbing stairs or crossing uneven terrain. FreshWalk, by monitoring daily activities, validates the therapy's success and shows how the child integrates skills into everyday life.

Another essential aspect of this process is the use of active learning elements. Motivational games and scenarios simulated through VRRS Nirvana not only engage the child in functional exercises but also help them understand the purpose. For example, the child can learn to avoid obstacles or maintain balance in a safe, controlled environment. Also, e-learning platforms and demonstration videos help consolidate these skills, giving the child the opportunity to repeat exercises and improve their performance.

By applying Merrill's principles and leveraging modern technologies, pediatric physiotherapy becomes a transformative experience. It is a process that not only treats physical deficits but also inspires the child to participate actively, explore, and build confidence in their own strengths. Ultimately, this holistic approach gives children not only the chance to recover but also to regain their independence and joy of living.

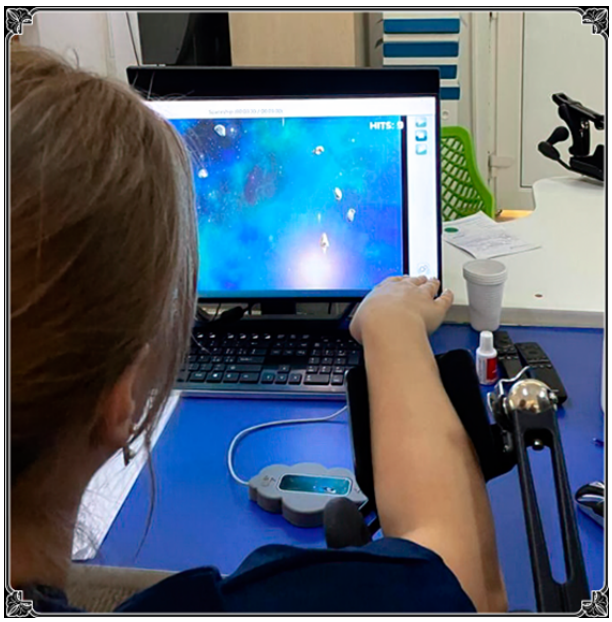


Figure 4. Armeo Therapy (personal source).



Figure 5. Khymeia VRRS (personal source).

6. Discussion

This paper's findings highlight the significant potential of integrating Merrill's First Principles of Instruction into pediatric physiotherapy, particularly when supported by modern technological tools. The analysis suggests that this approach enhances the effectiveness of rehabilitation by promoting active participation, engagement, and individualised learning, all of which are essential components of pediatric care. These results are consistent with existing literature on Gamification and technology-enhanced learning, which demonstrate improved motivation and better learning outcomes when interactive and learner-centred strategies are applied (Aguiar-Castillo et al., 2020; Ghai et al., 2023). The mechanisms underlying these improvements include increased patient motivation, continuous feedback, and stimulation of neuroplasticity, all of which contribute to more efficient motor learning and functional recovery.

Moreover, the application of Merrill's principles introduces a structured yet flexible framework that allows therapists to design rehabilitation programs tailored to each child's specific needs, thus addressing one of the main limitations of traditional physiotherapy approaches. A key strength of this study lies in its interdisciplinary perspective, combining concepts from instructional design and physiotherapy to propose a more holistic model of care. However, several limitations must be acknowledged, including the lack of extensive experimental validation and the limited availability of quantitative data to support the observed benefits. These constraints suggest that the conclusions are primarily based on theoretical integration and existing literature rather than robust empirical evidence. Therefore, future research should focus on conducting controlled clinical trials and quantitative studies to validate the effectiveness of this approach, measure outcomes using standardised tools, and explore long-term impacts on pediatric rehabilitation.

7. Conclusions

In relation to the paper's title, the analysis demonstrates that applying Merrill's principles in paediatrics is essential for optimising children's education and recovery through modern technologies. The title is supported by concrete examples in the paper, such as VRRS Nirvana, BTS GaitLab, and FreshWalk, which facilitate the activation, demonstration, application, and integration of knowledge. These technologies allow the creation of an adapted learning and recovery environment where children can acquire practical skills and transfer this knowledge to real-life situations.

The paper achieves its proposed aim, demonstrating the applicability of Merrill's principles in pediatric recovery and rehabilitation programs through the use of modern technology. The study

emphasises the efficiency of medical simulators and e-learning platforms in designing interactive courses for medical personnel and in creating personalised therapeutic plans, highlighting the positive impact of these technologies on learners' and patients' motivation and engagement.

Merrill's principles provide a structured framework for educational design, focusing on tasks and active learning to support both the development of competencies and the practical application of knowledge. The integration of innovative technologies, such as medical simulators, virtual reality, and interactive e-learning platforms, optimises the educational process through the use of educational games, problem-based learning, and virtual scenarios, which increases patient engagement and satisfaction. In pediatric physiotherapy, these principles allow for the personalisation of interventions and transform recovery into a captivating and efficient process, supported by immediate feedback and activities adapted to individual needs.

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Improving Reaction Time Using Blazepod Technology In Students Practising Traditional Karate

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Original Research Article	Movement Science and Human Performance	English, 11 pages

Abstract

Background: Reaction time is a key component in traditional karate performance, where fast and accurate responses to external stimuli are essential. Modern technologies such as Blazepod may support training by providing interactive and sport-specific reaction exercises.

Objective: The main objective of this study was to evaluate the effectiveness of implementing a specific exercise program using Blazepod technology to improve the reaction time of students practicing traditional karate.

Results: The study included 40 participants aged up to 15 years, divided into a control group and an experimental group. An initial test and a final test were conducted, with a 12-week training period between them. The experimental group performed training sessions that included exercises with Blazepod technology, while the control group followed regular training without this technology. Five tests were used: two for the upper limbs, one assessing simple reaction time and one assessing choice reaction time, two with the same structure for the lower limbs, and one karate-specific complex reaction test involving upper-limb techniques specific to traditional karate. The results showed that both groups improved from initial to final testing, but the experimental group achieved greater reductions in reaction time across all five tests, with statistically significant advantages in the final assessment.

Conclusions: The study demonstrates that training programs using Blazepod technology are effective in improving the reaction time of students practicing traditional karate.

Keywords: traditional karate, reaction time, Blazepod technology, training program, motor performance.

1. Introduction

Traditional karate is a self-defence martial art originating in Okinawa, Japan, based on the principle of TODOME (decisive technique) (Kim, J., & Kim, E. (2022); International Traditional Karate Federation (n.d.). TODOME can only be executed when the opponent is in KYO (a moment of mental imbalance) (Romanian Traditional Karate Federation. (n.d.). Traditional karate employs only the human body, using attack and defence techniques executed with bare arms and legs, as well as various footwork and other body movements to achieve the intended objective. As a self-defence martial art, the attacker's strength and size are irrelevant, which is why there are no weight categories in traditional karate. Traditional karate is based on the principles of DOJOKUN and the samurai code of BUSHIDO. (Romanian Traditional Karate Federation (n.d.).

Dojōkun (松濤館乃道場訓) is a code of principles or rules that the student must adhere to both inside the dojō and in their daily life. The 5 principles of Dojokun and their translation:

Hitotsu! Jinkaku kansei ni tsutomuru koto! (First, perfect your character; that is how you should act!)

Hitotsu! Makoto no michi o mamoru koto! (First of all, be sincere, that's what you should do!)

Hitotsu! Doryoku no seichin o yashinau koto! (First of all, be faithful and loyal, that's how you do it!)

Hitotsu! Reigi o omonzuru koto! (First of all, be respectful, that's what you should do!)

Hitotsu! Kekki no yu o imashimuru koto! (First of all, don't be violent, that's how you do it!) (Romanian Traditional Karate Federation (n.d.).

Thus, the moral principles of Karate, such as those mentioned above, complement formal education, providing children with important life lessons. In addition to its sporting and technical aspects, karate is a comprehensive form of physical education that contributes to the healthy development of children. Through exercises that involve coordination, balance, strength, flexibility and reaction speed, karate helps to achieve the objectives of modern physical education. (Cynarski, W. J. (2017).

The integration of martial arts into the school curriculum has gained international popularity due to its numerous benefits, both physical and mental, as well as social. Martial arts provide an opportunity to develop physical fitness, mental skills and interpersonal abilities simultaneously. (Kuzhelnyi, S., et al. (2024).

In recent years, the Chinese government launched the 'Healthy China 2030' initiative, which aims to improve the health and well-being of citizens through healthcare reforms. Announced in 2016, the programme highlights the importance of physical fitness and health education in various settings, including schools. (Yu, L., Houlbert, I., & Mantuhac, P. B. (2024). The programme also highlights that promoting a healthy lifestyle from an early age is crucial for building a healthier population. In this regard, physical education plays a very important role, as it constitutes a key part of the education system that directly influences pupils' physical and mental health. (Han, X., Li, H., & Niu, L. (2025).

Integrating martial arts would be one of the most promising ways to enhance physical education, as they play a significant role in developing physical fitness, while also promoting discipline, emotional control and self-regulation. By incorporating martial arts into the school curriculum, schools can provide pupils with valuable lessons to improve their self-regulation function, which encompasses managing their own behaviour, emotions and thoughts, in order to achieve long-term goals. Self-regulation is an important skill for academic success and personal development. This includes cognitive, emotional and physical regulation, all of which can be cultivated through the regular practice of martial arts. Martial arts training involves repetitive practice, attention and goal-setting, which are essential components of self-regulation. (Massey, W. V., Meyer, B. B., & Naylor, A. II. (2015). For example, when learning complex techniques, concentration and perseverance are required, while sparring teaches students to control their emotions and remain calm under pressure. These skills are applicable in other everyday situations, helping pupils to manage their stress levels more effectively, improve their concentration and adopt healthy habits. (Yu, L., Houlbert, I., & Mantuhac, P. B. (2024).

In karate, one of the key attributes is speed, in all its forms. Among these, the focus was on reaction time, as it is particularly important for karate practitioners, and reducing it by a few hundredths or tenths of a second can have a significant impact on achieving excellent sporting results. (Macovei, S., Lambu, E., Lambu, I., & Heba, L. (2013).

Types of reaction time: In experimental cognitive psychology, there are 3 types of reaction time: (Grice, G. R., Nullmeyer, R., & Spiker, V. A. (1982).

a) Simple reaction time

b) Choice reaction time

c) Complex reaction time

SIMPLE REACTION TIME: The simple reaction time task measures the basic cognitive processes of perception and response execution. In the case of simple reaction time, a single response is produced when a single stimulus is presented. In other words, there is only one stimulus, and when it occurs, we must respond with the only available response. (St. Xavier's College, Jaipur. (n.d.).

CHOICE REACTION TIME: The reaction time for a task in which each response to be given is associated with a different stimulus. There are multiple stimuli, and each stimulus requires a different response. In 1868, the Dutch physiologist Donders devised the choice reaction time experiment and found that this reaction time was approximately 100 ms longer than the simple reaction time. (St. Xavier's College, Jaipur. (n.d.).

COMPLEX REACTION TIME: In complex reaction time, the body has to react to one of two or more stimuli. The discriminative reaction time is much longer than the simple reaction time. (St. Xavier's College, Jaipur. (n.d.).

Living in the age of technology, there are numerous opportunities to develop new training methods to support students, one of which is the use of VR headsets. This technology enables the creation of realistic training environments, enhances the development of practitioners' skills, and facilitates the assessment of performance. Immersing themselves in realistic virtual environments allows students to practise and refine their techniques in situations that closely resemble real competitive scenarios. VR training is used to improve practitioners' response to various karate-specific attacks, while also positively influencing the reaction time required to act. (Lygouras, D., & Tsinakos, A. (2024).

Another type of technology that has gained popularity recently, particularly in combat sports, is that which enhances cognitive skills by stimulating rapid motor responses to visual stimuli. (Ezhov, A., Zakharova, A., & Kachalov, D. (2021). These systems use a set of touch-sensitive wireless lights (light pods) that work in conjunction with a mobile device, lighting up randomly or following a specific sequence and switching off as quickly as possible when the user touches them. Often referred to as Light Sport Training Systems, they are used in training to assess reaction time and coordination in various sports disciplines. This category includes the FitLight Trainer and BlazePod systems. As this technology evolves, research indicates its significant potential in supporting the training process. The BlazePod is being used increasingly by coaches across various sports disciplines, thanks to its user-friendly interface, ease of use and affordable price. (Zekailiche, Y., et al. (2024). Depending on the number of modules available, the BlazePod can be used for individual or group sessions, and even to incorporate competitive elements. It enables the exercise parameters to be adjusted to the athletes' abilities and can be used at various training levels. Such training can influence reaction speed by shaping the ability to initiate and execute purposeful motor actions in response to a light stimulus, engaging the whole body or parts of it. In addition to training applications, the BlazePod also enables the assessment of reaction speed to both simple and complex stimuli while performing movement patterns characteristic of various combat sports. (Polechoński, J., Pilch, J., Langer, A., Prończuk, M., Markowski, J., & Maszczyk, A. (2025). Studies have been conducted on various martial arts disciplines, such as MMA (Mixed Martial Arts) and Taekwondo, with positive results, which supports the claim that the use of BlazePod technology can improve the reaction time and coordination. (Hsieh, W.-L., et al. (2025); (Polechoński, J., Pilch, J., Langer, A., Prończuk, M., Markowski, J., & Maszczyk, A. (2025).

The study's hypothesis was based on the assumption that, by adapting and practising a specific exercise programme using BlazePod digital technology, reaction time and the ability to combine reactive movements can be improved in students practising traditional karate.

2. Materials and Methods

The study was conducted from November 2025 to February 2026, with pupils participating in this after-school activity in the sports hall of the 'Dr. Bernady Gyorgy' Secondary School, and included an initial one-week testing phase (IT), followed by the implementation of an experimental programme to develop reaction speed over a period of 12 weeks, and concluding with a final one-week testing phase (FT). Bernády György" Secondary School, and included an initial testing phase (IT) lasting one week, followed by the implementation of an experimental programme to develop reaction speed over a period of 12 weeks, and finally concluding with a final testing phase (FT) lasting one week. The experimental programme for developing reaction speed consisted of karate-specific exercises using BlazePod technology. This programme was practised only by the experimental group. The control group followed a programme designed by their teacher, which did not involve the use of digital technologies. The experimental group carried out the experimental programme twice a week, with each training session lasting 60 minutes (plus a dedicated 15-minute warm-up). Throughout this study, all groups (experimental and control) trained three times a week for 60 minutes per session, with two of these sessions dedicated to developing reaction speed and technical training.

The research used the Blazepod Training System (Figure 1), a technology designed to improve reaction time, decision speed and visual-motor coordination. The system consists of a set of wireless light modules ('pods') equipped with touch sensors and multi-coloured LEDs that emit programmed visual stimuli. The pods are powered by internal rechargeable batteries and connect via Bluetooth to a dedicated app installed on a mobile device (smartphone or tablet).

The Blazepod App allows for the complete configuration of the training session: selecting the number of pods, choosing the colours, setting the reaction time, the activation sequence, the frequency, and the type of exercise. The app's interface provides instant feedback on the user's performance, automatically recording the reaction time for each visual stimulus and generating progress reports.

For the system to function correctly, each Blazepod pod must be synchronised with the mobile app via Bluetooth, which has a range of approximately 40 metres. The devices can be placed on the floor, on walls or on dedicated stands, depending on the nature of the exercises and the training objectives. In this research, the pods were positioned at various heights and in different directions, in line with techniques specific to traditional karate.

The Blazepod system offers the advantage of an objective and precise measurement of reaction time, eliminating human timing errors. Furthermore, the ability to customise exercises and the provision of real-time feedback enable the training intensity to be adapted to the level of each participant, thereby increasing their motivation and engagement.

In addition to the Blazepod system, the research also used auxiliary equipment such as stands for the light modules, cones to mark out the training area, and the mobile device used to operate the application (an Android smartphone).



Figure 1. Blazepods

2.1. Participants

This study included 40 male students who are practicing traditional karate in afterschool programmes, divided into two groups: an experimental group with 20 subjects (EG) and a control group with 20 subjects (CG). In this study, the subjects were randomly assigned to the two groups. All subjects participated voluntarily, based on informed consent from their parents, and this study adhered to the principles set out in the Declaration of Helsinki.

2.2. Procedures

Only two assessments were conducted: an initial assessment (IA) at the start of the experiment and a final assessment (FA) after the 12-week period during which the experimental programme was implemented. No interim assessments were recorded. We administered five tests, four of which aimed to assess RT (the Simple Reaction Time Test and the Choice Reaction Time Test), and one of which also aimed to assess visual reaction time and hand–eye coordination. As we used specific light spots linked to the BlazePod technology, all these components of coordinative ability focused on aspects of reactivity to visual, tactile, and kinesthetic stimuli. Each test consisted of 2 attempts, and the best result was quantified. When one light spot was switched off, the next one switched on at one-second intervals.

Simple Reaction Test (Figure 2): Four light spots were placed in a line on a table, 10 cm apart, on a bench with a height of 65 cm. Pupils were required to touch the BlazePods that lit up randomly in blue. Twenty spots were set to light up during the test, and the software recorded the reaction time in seconds.



Figure 2. Blazepods Reaction test for upper body

Choice Reaction Test: This test was identical to the previous one, but visual stimuli of different colours were added. If the BlazePod spot lit up in red, the subjects had to touch the illuminated spot with their right hand, whereas if it lit up in blue, they had to touch it with their left hand. This test required not only a rapid reaction, but also a decision based on the colour of the light stimulus. The BlazePod spotlight lit up 20 times, and the software recorded the reaction time in seconds.

The two aforementioned tests were also performed for the lower limbs, with the BlazePod spots placed on the floor at the same distance of 10 cm. In the third test, which measured the simple reaction time, the students had to touch the light spot with their foot as quickly as possible, while in the fourth test, measuring the choice reaction time, when the red spot lit up, it had to be touched with the right foot, and when the blue spot lit up, it had to be touched with the left foot. The BlazePod spotlight lit up 20 times, and the software recorded the reaction time in seconds.(Figure 3)



Figure 3. Blazepods Reaction test for lower body

In the final test, which is the karate-specific complex reaction test, four BlazePods were placed on a wall in the shape of a cross(Figure 4) and the student was required to perform karate-specific defence techniques from a standing position as follows: if the BlazePod at head level lit up, the student performed an age-uke technique (head block); if one of the two spots at chest level lit up, the student performed a uchi-uke technique (chest block), depending on which side lit up (right/left); and if the lowest spot lit up, the student performed a gedan barai technique (lower-body block). The BlazePod spotlight lit up 20 times, and the software recorded the reaction time in seconds.



Figure 4. Blazepods Reaction test specific for karate

2.3. Statistical Analysis

For the present research SPSS 26 was used to highlight descriptive statistics of the collected data and showcase the significance of the students progress within dependent student t test. Also the independent student t test was used for comparing the experimental and control groups.

3. Results

Table 1 shows that both the experimental group and the control group included 20 subjects in all five tests, at both the initial and final assessment. In the experimental group, the mean values decreased from initial to final testing in all tests, which indicates an improvement in reaction time. The largest reductions in the experimental group were observed in T4, where the mean decreased from 0.942 to 0.752, and in T5, where it decreased from 0.710 to 0.553. Similar improvements were also observed in the control group, although the decreases in mean values were smaller in all tests. For example, in the control group,

T4 decreased from 0.858 to 0.798, and T5 from 0.694 to 0.606. The standard deviation values were generally lower at final testing in both groups, suggesting a tendency toward greater group homogeneity after the intervention. In the experimental group, variability remained higher in T3 and especially T4 compared with the other tests. The minimum and maximum values also tended to decrease from initial to final testing, supporting the overall improvement in performance. Kurtosis values in the control group remained close to normal limits, while in the experimental group, T3 and especially T4 showed high positive kurtosis, indicating less normal distributions and more peaked score clustering. Overall, the descriptive results suggest progress in both groups, but the improvements were more pronounced in the experimental group across all five tests.

Tabel 1. Descriptive statistics

						Kurtosis	
	N	Minimum	Maximum	Mean	Std. Deviation	Statistic	Std. Error
T1 It EG	20	0.37	0.70	0.513	0.097	-0.705	0.992
T1 Ft EG	20	0.33	0.54	0.431	0.063	-1.129	0.992
T2 It EG	20	0.52	1.01	0.701	0.147	-0.138	0.992
T2 Ft EG	20	0.43	0.78	0.561	0.096	0.357	0.992
T3 It EG	20	0.54	1.08	0.687	0.128	3.383	0.992
T3 Ft EG	20	0.45	0.83	0.562	0.086	4.300	0.992
T4 It EG	20	0.74	1.56	0.942	0.185	6.157	0.992
T4 Ft EG	20	0.62	1.21	0.752	0.130	7.930	0.992
T5 It EG	20	0.54	0.86	0.710	0.079	0.132	0.992
T5 Ft EG	20	0.43	0.64	0.553	0.051	0.652	0.992
T1 It CG	20	0.42	0.71	0.510	0.083	0.817	0.992
T1 Ft CG	20	0.40	0.66	0.486	0.078	0.953	0.992
T2 It CG	20	0.57	0.90	0.663	0.109	-0.473	0.992
T2 Ft CG	20	0.53	0.83	0.619	0.096	-0.338	0.992
T3 It CG	20	0.54	0.83	0.629	0.086	0.322	0.992
T3 Ft CG	20	0.51	0.77	0.591	0.076	0.145	0.992
T4 It CG	20	0.76	1.00	0.858	0.067	-0.447	0.992
T4 Ft CG	20	0.71	0.91	0.798	0.054	-0.346	0.992
T5 It CG	20	0.54	0.80	0.694	0.070	0.164	0.992
T5 Ft CG	20	0.48	0.69	0.606	0.054	0.391	0.992

Table 2 presents the results of the dependent (paired) Student's t-test, highlighting the differences between initial and final testing within each group. In the experimental group, all five tests show statistically significant improvements, with p values reported as 0.000 ($p < 0.001$). The mean differences indicate substantial reductions in reaction time, with the largest improvement observed in T4 (0.189), followed by T5 (0.157) and T2 (0.140). The high t values (ranging from 8.298 to 20.474) confirm strong effects of the intervention. In the control group, all tests also show statistically significant improvements ($p < 0.001$), but the mean differences are consistently smaller compared to the experimental group. The largest improvement in the control group is seen in T5 (0.089), followed by T4 (0.060). Confidence intervals for all tests in both groups do not cross zero, supporting the reliability of these changes. Overall, both groups improved over time, but the magnitude of improvement was clearly greater in the experimental group across all five tests.

Table 2. dependent student t test

		Mean	Std. dev.	Std. er. Mean	Lower	Upper	t	df	p
T1 EG	Ti-Tf	0.082	0.039	0.009	0.064	0.100	9.483	19	0.000
T2 EG	Ti-Tf	0.140	0.076	0.017	0.105	0.175	8.298	19	0.000
T3 EG	Ti-Tf	0.125	0.050	0.011	0.102	0.149	11.165	19	0.000
T4 EG	Ti-Tf	0.189	0.061	0.014	0.161	0.218	13.969	19	0.000
T5 EG	Ti-Tf	0.157	0.034	0.008	0.141	0.173	20.474	19	0.000
T1 CG	Ti-Tf	0.024	0.023	0.005	0.013	0.035	4.604	19	0.000
T2 CG	Ti-Tf	0.044	0.015	0.003	0.037	0.051	13.485	19	0.000
T3 CG	Ti-Tf	0.038	0.012	0.003	0.032	0.044	13.721	19	0.000
T4 CG	Ti-Tf	0.060	0.014	0.003	0.054	0.067	19.831	19	0.000
T5 CG	Ti-Tf	0.089	0.026	0.006	0.076	0.101	15.127	19	0.000

Tabel 3. independent student t test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% C.I.	
	F	p	t	df	p	Mean dif,	Std. er. Mean	Lower	Upper
T1 It EG	0.824	0.370	0.114	38	0.910	0.003	0.028	-0.054	0.061
T1 Ft EG	0.106	0.747	-2.453	38	0.019	-0.055	0.022	-0.100	-0.010
T2 It EG	1.896	0.177	0.926	38	0.360	0.038	0.041	-0.045	0.120
T2 Ft EG	0.085	0.772	-1.911	38	0.064	-0.058	0.030	-0.120	0.003
T3 It EG	1.007	0.322	1.666	38	0.104	0.057	0.034	-0.012	0.127
T3 Ft EG	0.014	0.906	-1.153	38	0.256	-0.030	0.026	-0.082	0.022
T4 It EG	4.442	0.042	1.912	38	0.063	0.084	0.044	-0.005	0.173
T4 Ft EG	2.795	0.103	-1.434	38	0.160	-0.045	0.031	-0.109	0.019
T5 It EG	0.245	0.623	0.644	38	0.523	0.015	0.024	-0.033	0.063
T5 Ft EG	0.018	0.893	-3.204	38	0.003	-0.053	0.017	-0.086	-0.019

Table 3 presents the results of the independent Student's t-test, comparing the experimental and control groups at both initial and final testing. At the initial assessment, no statistically significant differences were observed between groups in any of the five tests (all $p > 0.05$), indicating that the groups were comparable at baseline. Levene's test showed homogeneity of variances in most cases, with the exception of T4 initial testing ($p = 0.042$), suggesting some variance inequality for that variable.

At the final assessment, statistically significant differences between groups were identified in T1 ($p = 0.019$) and T5 ($p = 0.003$), where the experimental group showed better performance (lower reaction times) compared to the control group. For T2 ($p = 0.064$), T3 ($p = 0.256$), and T4 ($p = 0.160$), no statistically significant differences were found, although mean differences favored the experimental group. The confidence intervals for T1 and T5 at final testing do not include zero, confirming the significance of these differences, while for the other tests the intervals cross zero, indicating non-significant results.

Overall, the combined analysis of descriptive statistics and inferential tests indicates that both groups improved their reaction time over the course of the study, confirming the effect of regular training. However, the experimental group demonstrated consistently greater improvements across all five tests, as reflected in larger mean differences and stronger t-values. While within-group analyses showed significant progress in both groups, the between-group comparisons revealed statistically significant

advantages for the experimental group only in T1 and T5 at final testing. This suggests that the implementation of BlazePod-based training had a selective but meaningful impact, particularly on simple upper-limb reaction time and karate-specific complex reactions. Therefore, the results partially support the research hypothesis, indicating that the use of modern technology can enhance certain components of reaction performance beyond traditional training alone.

4. Discussion

The results of this research show a significant improvement in reaction time among traditional karate trainees following the incorporation of a training programme based on BlazePod technology. These findings support the idea that exercises involving rapid reactions to visual stimuli can contribute to the development of reaction speed and neuromotor coordination, which are fundamental elements in martial arts.

Previous research by Cremasco et al. (2024), demonstrated significant effects on reducing reaction time following a similar intervention using the BlazePod and Microgate systems in adolescent athletes. The authors reported a mean decrease from approximately 3,770 ms to 3,108 ms, with a large statistical effect, confirming the effectiveness of the technology in promoting rapid responses to visual stimuli. (Timea, B. M., Carmen, C.-B., Nicolae, O. M., Nicola, M., Teodor, G. V., Maria, S. A., Cornelia, P., Hervás-Gómez, C., Florina, G. E., & Dan, M. (2025). Furthermore, research by Çağın (2024) demonstrated the validity and reliability of reaction time tests performed using the BlazePod, revealing strong correlations ($r > 0.70$, $p < 0.05$) between reaction time tests for the upper and lower limbs, which supports the use of this technology in both experimental and applied settings in the field of sport. (Çağın, M., Çimen Polat, S., Orhan, Ö., Çetin, E. (2024).

However, the literature is not entirely in agreement regarding the effectiveness of these tools. Savenkov et al. (2021) highlight certain technical limitations of the BlazePod system, noting the absence of a dedicated photosensor for accurately measuring reaction time, which may affect the precision of results obtained in standardised tests (Ezhov, A., Zakharova, A., & Kachalov, D. (2021). Therefore, the observed improvements should be interpreted with caution, especially when seeking a direct link to sporting performance.

Furthermore, Scanlan et al. (2024) demonstrated that reactions to light stimuli measured under controlled conditions do not necessarily have a significant correlation with reactive agility demonstrated in real-game contexts, such as in team sports (Broodryk, A., Skala, F., & Broodryk, R. (2025). This finding can also be extended to martial arts, where an effective reaction does not consist solely of responding to a simple visual stimulus, but involves complex processes of anticipation, perception, decision-making and execution. Therefore, although BlazePod technology contributes to the development of reaction speed, the transfer of this improvement to performance in kumite or other combat situations remains a contentious issue.

Similarly, Kaur et al. (2022), in a systematic review, highlighted that most reaction tests used in sport are not sufficiently specific to the discipline under study, as they lack the decision-making element that defines the actual reaction in competition. (Janicijevic, D., & Garcia-Ramos, A. (2022). Feasibility of Volitional Reaction Time Tests in Athletes: A Systematic Review. Motor Control, 26(2), 291–314.) This observation supports the idea that training with the BlazePod can be considered a complementary method, designed to improve a specific aspect of motor performance, without replacing training based on direct interaction with an opponent.

In conclusion, BlazePod technology has been shown to be an effective tool for improving visual-motor reaction time in traditional karate practitioners, but the results should be interpreted with caution,

taking into account methodological limitations and the need to correlate these improvements with actual sporting performance.

5. Conclusions

This study showed that reaction time improved in both groups over the training period, but the progress was greater in the group that used BlazePod technology. The experimental group obtained better results in all five tests, with statistically significant advantages at final testing in simple upper-limb reaction time and in the karate-specific complex reaction test. These findings suggest that BlazePod-based exercises can be a useful complementary method in traditional karate training, especially for developing rapid responses to visual stimuli and improving sport-specific reactive actions. At the same time, the results should be interpreted with caution, and future studies on larger samples are needed to clarify the extent to which these improvements transfer to actual combat performance.

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Students' Beliefs About Talent and Effort as Predictors of Performance in Physical Education

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Abstract

Background: Mindset has been widely studied as a key factor influencing learning and performance across various domains, including education and sport. However, its role in physical performance and task efficiency remains less explored.

Objectives: The aim of this study was to examine the relationship between growth mindset and performance in a physical task. The following hypotheses were proposed: H1: Participants with a growth mindset will demonstrate higher success rates compared to those with lower mindset scores. H2: Participants with a growth mindset will perform more efficiently, requiring fewer attempts to achieve success. H3: Participants with a growth mindset will report lower levels of anxiety during task performance.

Methods: Thirty first-year Physical Education and Sport students (26 males, 4 females) participated in the study. Mindset was assessed using a questionnaire based on beliefs about effort and ability. Participants then performed a gymnastics task (supported headstand), during which the number of attempts, task success, duration, and anxiety levels were recorded.

Results: Participants with higher mindset scores showed a significantly higher success rate ($p = 0.00024$). Although they appeared to require fewer attempts, this difference did not reach statistical significance ($p = 0.12$). No significant differences were found in anxiety levels ($p = 0.78$).

Conclusions: The findings of this study suggest that mindset is associated with the likelihood of success in a physical task, as participants with higher mindset scores demonstrated significantly higher success rates. Although individuals with a higher mindset appeared to perform more efficiently, this difference did not reach statistical significance. No significant differences were found in anxiety levels between groups. These results highlight the potential importance of fostering a growth-oriented mindset in physical education and sport settings to support performance and learning outcomes.

Keywords: growth mindset; physical performance; task efficiency; physical education; gymnastics;

1. Introduction

Mindset has been widely studied as a key psychological factor influencing learning, motivation, and performance. According to Dweck (2006), individuals with a growth mindset believe that abilities can be developed through effort, practice, and feedback, whereas those with a fixed mindset tend to view abilities as static. In addition, previous research has highlighted the role of mindset in fostering resilience and adaptive responses to failure. Yeager and Dweck (2012) showed that individuals who believe that personal

characteristics can be developed are more likely to persist in the face of challenges and recover more effectively after setbacks. In sport contexts, Biddle et al. (2003) found that athletes who endorse incremental beliefs about ability (growth mindset) display higher intrinsic motivation and are more likely to engage in challenging tasks.

Furthermore, Cumming et al. (2017) demonstrated that growth mindset is associated with task-oriented goals and improved performance, as athletes focus more on skill development and learning processes rather than solely on outcomes. This distinction has been shown to affect how individuals respond to challenges, failure, and learning opportunities. Supporting this perspective, Vella et al. (2016), in a systematic review and meta-analysis, found that a growth mindset is consistently associated with greater effort, persistence, and intrinsic motivation in sport and physical activity contexts, although its relationship with performance is generally moderate.

Recent research has extended these findings to sport contexts. For example, Deng et al. (2025) found that athletes with a growth mindset demonstrated higher levels of competitive motivation, partly due to lower stress and greater satisfaction of basic psychological needs. Similarly, McNeil et al. (2023) showed that athletes with a high-growth and low-fixed mindset profile achieved higher levels of performance, with this relationship being explained by stronger coping abilities. In addition, Batucan et al. (2025) highlighted the mediating role of sports emotions, showing that growth mindset is associated with more positive emotional responses, which in turn enhance mental toughness, whereas fixed mindset is linked to negative emotions such as anxiety and dejection. More broadly, psychological and emotional factors play a critical role in sport performance. A recent systematic review (Frontiers in Psychology, 2025) showed that student-athletes are exposed to multiple stressors, including training demands, competition pressure, and academic challenges, which can negatively impact emotional well-being and performance. The study also emphasized that effective coping strategies and emotional regulation are essential for maintaining performance and mental health. These findings further support the idea that performance in sport is influenced not only by physical ability, but also by psychological and emotional processes.

In addition, theories of skill acquisition emphasize the importance of learning from errors and adapting performance over time. Ericsson and Pool (2016) highlight that effective performance improvement is driven by deliberate practice, which involves actively using feedback to refine execution. Individuals with a growth mindset may be more likely to engage in such adaptive processes, leading to more efficient performance. Despite these insights, there is limited research directly examining the relationship between mindset and performance efficiency in physical tasks. Most studies rely on self-reported measures or focus on long-term development, rather than immediate performance in a controlled setting. Therefore, further investigation is needed to better understand how mindset influences both success and efficiency in real physical activities. The aim of this study was to examine the relationship between growth mindset and performance in a physical task. The following hypotheses were proposed:

H1: Participants with a growth mindset will demonstrate higher success rates.

H2: Participants with a growth mindset will perform more efficiently, requiring fewer attempts to achieve success.

H3: Participants with a growth mindset will report lower levels of anxiety during task performance.

2. Materials and Methods

This study employed a cross-sectional observational design with a performance-based assessment conducted in a physical education setting. The aim was to examine the association between students mindset (beliefs about effort and ability) and their performance in a motor task. Data were collected during a single session, in which participants first completed a questionnaire assessing mindset, followed by the execution of a gymnastics task. Performance outcomes included task success, number of

attempts required to achieve success, and self-reported anxiety levels prior to each attempt. The study design allows for the examination of relationships between psychological factors and performance outcomes, but does not permit causal inferences.

2.1. Participants

Participants were recruited on a voluntary basis from a first-year Physical Education and Sports cohort. The study initially included 38 participants (students who answered the questionnaire), but only 30 participants also participated in the physical study. The final sample consisted of 26 males and 4 females, first-year Physical Education and Sports students. Their age ranged from 18 to 44, but most of them were between 19 and 21. They had no prior training for this specific task. Participants with injuries or medical conditions affecting physical performance were excluded. All participants provided informed consent prior to participation.

2.2. Procedure

Participants first completed a brief questionnaire assessing their beliefs about talent and effort in physical education. The questionnaire included items evaluating whether students believed they could improve their performance within a single class and whether they considered effort more important than talent. The questionnaire was given to them a couple of days before the actual physical task.

The questionnaire consisted of 8 items, 6 of them were rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).The questionnaire was developed for the purpose of this study and included the following items: 1.''The most important factor for sports success is talent.'' 2. "Continuous and systematic practice is the most important factor in success in sports." 3. "If I don't succeed on the first try, but I keep trying, eventually I will succeed." 4. "Some students are naturally good at sports, while others cannot improve their abilities very much, no matter how much they practice." 5. "When a physical exercise is difficult, I usually want to try again." 6. "I try to avoid mistakes as much as possible." and two other items that were not rated on the Likert scale: "Do you think that in just one hour of sports practice you can become better at a certain exercise?" and "What do you think is more important for being good at sports?". The item regarding fixed ability beliefs was reverse scored. A total mindset score was calculated for each participant. Following the completion of the questionnaire, participants took part in a practical session involving a gymnastics task. Initially, participants were asked to perform a vault, starting at a basic level of difficulty, which progressively increased. They were informed that they could attempt the task as many times as they wished until they either successfully completed it or chose to stop. However, as all participants successfully completed the vault on their first attempt, the task was considered insufficiently challenging to differentiate performance. Consequently, a second, more demanding task was introduced. Participants were instructed to perform a supported headstand (with palms on the floor) and maintain the position for 10 seconds. Participants were again allowed to make multiple attempts or withdraw from the task at any time. Prior to each attempt, participants reported their level of anxiety using a 5-point scale (1 = very low anxiety, 5 = very high anxiety). For each participant, the following variables were recorded: task completion (defined as maintaining the position for 10 seconds), number of attempts, anxiety level prior to each attempt. The tasks were performed using standard physical education equipment, including a vaulting horse and safety mats. Additionally, participants reported whether they had prior experience with the vaulting task or any previous experience in gymnastics.

2.3. Statistical Analysis

Data were analysed using Microsoft Excel. Descriptive statistics (means and standard deviations) were calculated for all main variables, including mindset scores, number of attempts, and anxiety levels.

Correlation analyses were conducted to examine the relationships between mindset and performance-related variables, including number of attempts and anxiety levels. Due to the nature of the data, Pearson correlation coefficients were used. Additionally, participants were grouped based on task success (successful vs. unsuccessful), and comparisons were made between groups in terms of mindset scores, number of attempts, and anxiety levels.

The level of statistical significance was set at $p < 0.05$.

3. Results

Table 1. Task Succes by Mindset Group.

Variable	High Mindset(>22)	Low/Avg Mindset(≤22)	P
Success rate (%)	91.7	22.2	0.00024
Number of Attempts	5.58 ± 10.95	3.89 ± 2.81	0.27
Number of Attempts*	2.45 ± 1.51	3.89 ± 2.81	0.12
Anxiety level	1.42 ± 0.90	1.50 ± 0.86	0.78

Number of attempts (excluding outlier)*

Out of the total sample, 15 participants successfully completed the task, while 15 participants did not. The mean mindset score was 21.97 (M = 21.97). The average number of attempts was 4.57 (M = 4.57). The mean reported anxiety level was 1.47 (M = 1.47). Participants were divided into two groups based on their mindset scores, using the sample mean (M = 22) as a threshold.

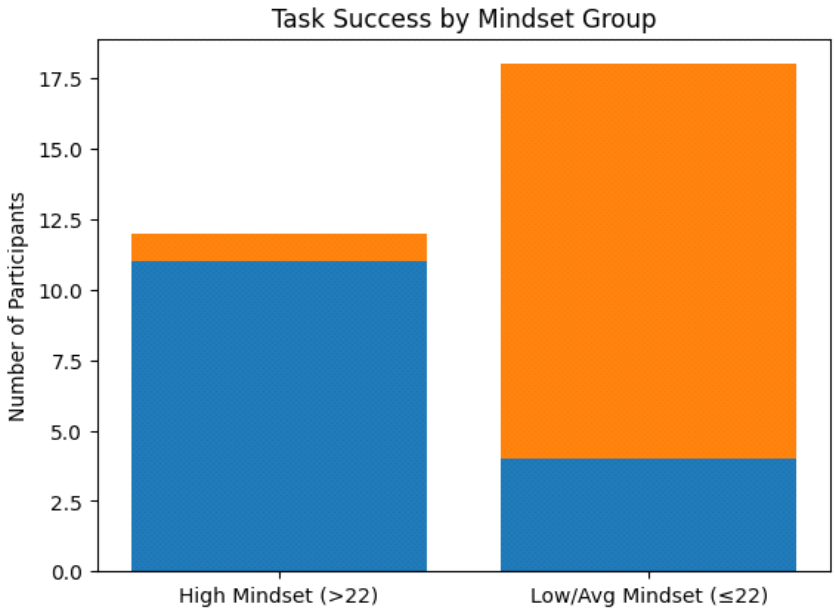


Figure 1. Task Succes by Mindset Group

Among participants with above-average mindset scores (>22), 11 out of 12 successfully completed the task (92%). In contrast, among those with average or below-average mindset scores (≤22), only 4 out of 18 participants succeeded (22%). The difference between groups was statistically significant (Fisher's Exact Test, $p = 0.00024$), indicating a significantly higher success rate in the high mindset group. Participants were also grouped based on their combined score for the two persistence-related items. Those with high scores (9-10) showed a higher success rate (60.0%) compared to participants with medium

scores (7-8; 30.0%). Specifically, 12 out of 20 participants in the high-score group successfully completed the task, whereas 3 out of 10 participants in the medium-score group achieved success. Although participants with higher persistence scores showed a higher success rate, this difference was not statistically significant, possibly due to the small sample size.

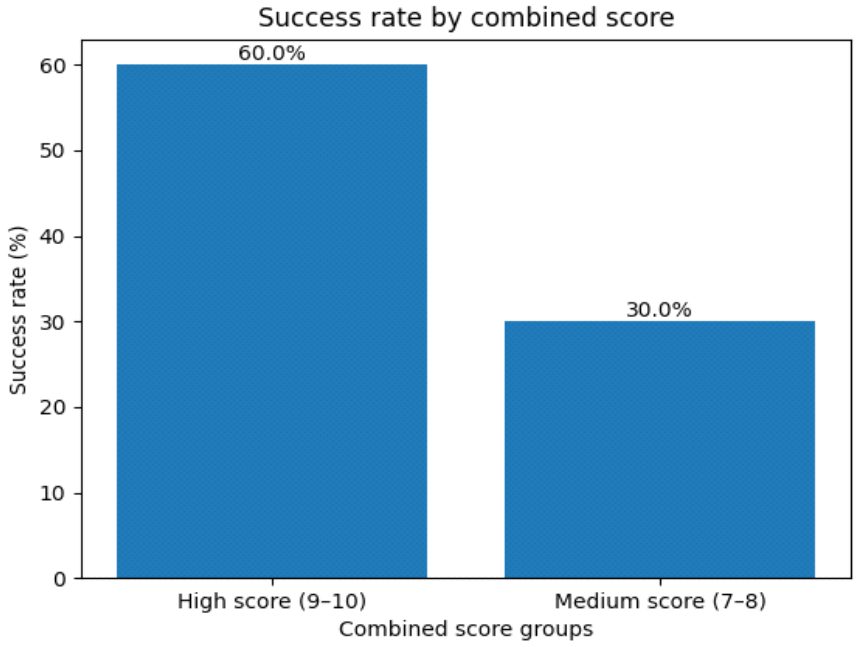


Figure 2. Succes rate by combined score

The mean anxiety level for participants with above-average mindset scores (>22) was 1.42, while for those with average or below-average mindset scores (≤22), it was 1.50. No significant differences were found in anxiety levels between participants with higher and lower mindset scores. (Mann–Whitney U test, p = 0.78).

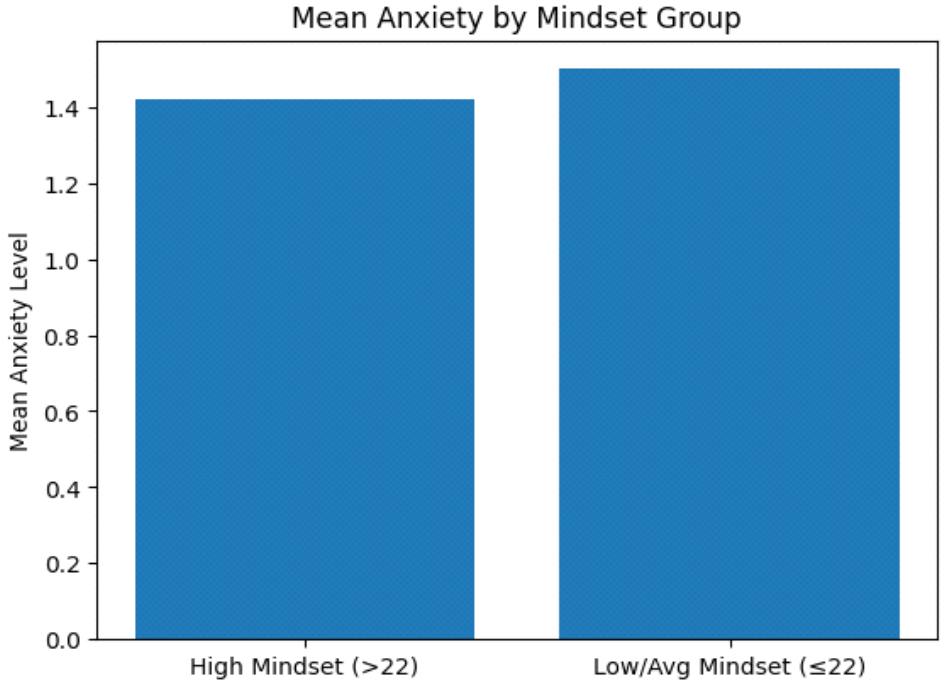


Figure 3. Mean Anxiety by Mindset Group

Participants with above-average mindset scores (>22) had a higher mean number of attempts (M = 5.58) than participants with average or below-average mindset scores (≤22), whose mean number of attempts was 3.89. When excluding an extreme value (participant with 40 attempts), the mean number of attempts for the high mindset group (>22) decreased to 2.45. This is lower than the mean of 3.89 observed in the average and below-average mindset group (≤22), suggesting that the initial difference was influenced by an outlier.

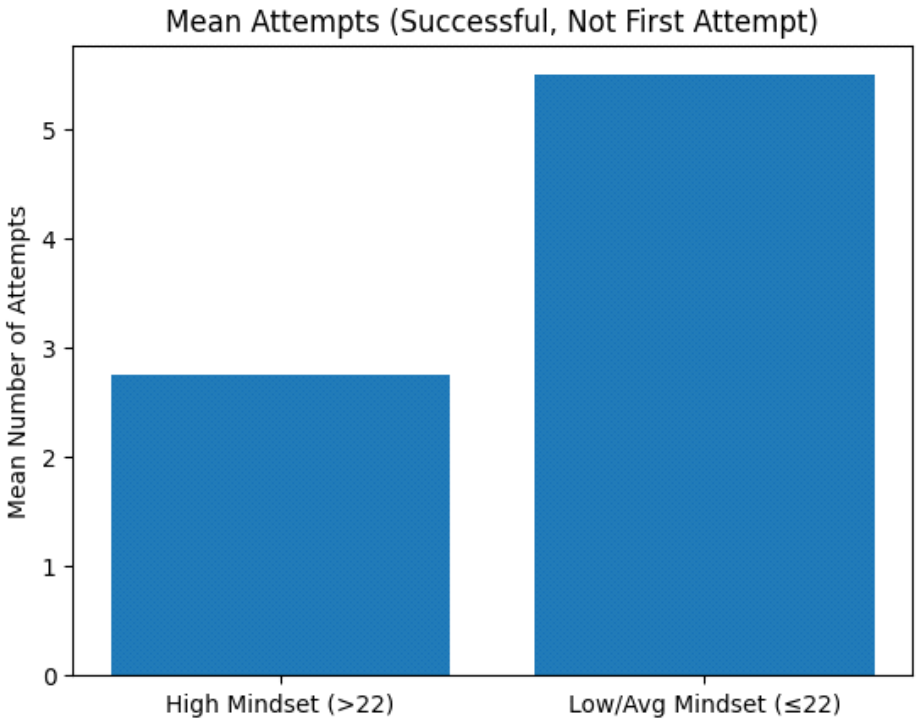


Figure 4. Mean Anxiety by Mindset Group

Among participants who eventually succeeded but not on their first attempt, those with a higher mindset required fewer attempts on average (2.75) compared to those with lower or average mindset (5.5). This graph is excluding the outlier (participant with 40 attempts) Although the difference did not reach statistical significance ($p = 0.12$), the results showed a tendency for participants with higher mindset scores to require fewer attempts.

4. Discussion

The results of this study suggest that mindset may play an important role in physical performance. Participants with a higher mindset were significantly more likely to successfully complete the task; however, although they appeared to perform more efficiently, requiring fewer attempts to reach success, this difference did not reach statistical significance. One possible explanation for these findings is that individuals with a higher mindset are better able to learn from unsuccessful attempts and adjust their performance accordingly. Rather than simply repeating the task, they may use feedback from previous attempts to refine their execution, leading to faster improvement. These findings are consistent with Dweck's theory of growth mindset, which suggests that individuals who believe abilities can be developed are more likely to persist and adapt in the face of challenges. Additionally, the results align with Ericsson's concept of deliberate practice, which emphasizes the importance of learning from errors and making continuous adjustments to improve performance. Anxiety levels were similar across both groups, and no

statistically significant differences were found, suggesting that performance differences were not primarily driven by emotional factors, but rather by cognitive and behavioural processes. A novel aspect of this study is the use of a real physical task to assess performance, rather than relying solely on self-reported measures. Furthermore, the study highlights not only differences in success rates, but also in efficiency, showing that mindset may influence how quickly individuals achieve success, not just whether they succeed. The findings of this study provide partial support for the proposed hypotheses.

The first hypothesis, stating that individuals with a more flexible mindset would demonstrate a higher success rate, was clearly supported. Participants with above-average mindset scores showed a substantially higher rate of task completion compared to those with lower scores.

The second hypothesis, suggesting that individuals with a more flexible mindset would be more efficient in their attempts, was not statistically supported. Although participants with higher mindset scores appeared to require fewer attempts to achieve success, this difference did not reach statistical significance ($p = 0.12$). This pattern suggests a tendency in the expected direction, but the results should be interpreted with caution. It is possible that individuals with higher mindset scores also possessed better physical abilities, such as balance, strength, or coordination, which may have contributed to their performance. Therefore, the observed differences in efficiency may not be solely attributable to cognitive or motivational factors, but also to underlying physical capabilities.

In contrast, the third hypothesis, which predicted lower levels of anxiety among individuals with a more flexible mindset, was not supported. No statistically significant differences were found in anxiety levels between groups ($p = 0.78$), with both groups reporting similarly low levels of anxiety. This suggests that performance differences were not primarily driven by anxiety in the present study. However, the absence of a significant effect does not necessarily indicate that mindset is unrelated to anxiety in physical performance contexts. One possible explanation is that the task may not have been sufficiently demanding or stressful to elicit meaningful differences in anxiety between participants.

Future research could investigate this relationship using a more challenging task, a larger and more balanced sample, and more sensitive measures of anxiety. It would also be useful to examine performance in situations involving greater pressure, such as time constraints, evaluation by peers, or competitive settings. Under such conditions, differences in anxiety related to mindset may become more apparent. This study presents several strengths. One important strength is the use of a real physical task to assess performance, rather than relying solely on self-reported data. This allowed for the observation of actual behaviour, including number of attempts and task success. Additionally, the study examined not only whether participants succeeded, but also how efficiently they achieved success, providing a more detailed understanding of performance. However, several limitations should be acknowledged. First, the sample size was relatively small and not gender-balanced, which may limit the generalizability of the findings. Furthermore, physical ability was not directly measured, which means that differences in performance may have been influenced by factors other than mindset, such as strength, coordination, or prior experience. Finally, the task may not have been sufficiently stressful to produce meaningful differences in anxiety levels, which could explain why the third hypothesis was not supported. Future research could further explore the relationship between mindset and physical performance by addressing the limitations of the present study. One important direction would be to use more challenging and stressful tasks in order to better assess the role of anxiety in performance. Increasing the level of difficulty or introducing competitive elements may create conditions in which differences in emotional responses become more evident. Additionally, future studies should include larger and more diverse samples to improve the generalizability of the findings. Measuring participants' physical abilities more directly would also be beneficial, as this would help distinguish the effects of mindset from those of physical skill. Another important improvement would be the use of a more comprehensive and validated questionnaire to assess

mindset. A more detailed instrument could capture subtle differences between participants and provide a more accurate representation of their mindset orientation. Another valuable approach would be to use a longitudinal design, examining how mindset influences learning and performance over time. This could provide deeper insight into how individuals adapt and improve with repeated practice.

5. Conclusions

The findings of this study indicate that mindset plays a significant role in physical performance. Participants with a higher (more flexible) mindset demonstrated a substantially higher success rate compared to those with lower mindset scores. In addition, individuals with a higher mindset tended to achieve success more efficiently, often requiring fewer attempts; however, this difference did not reach statistical significance. No meaningful differences were observed in anxiety levels between groups, suggesting that performance differences were not primarily driven by emotional factors. These findings highlight the importance of fostering a growth-oriented mindset in physical education and sport settings. Encouraging individuals to view effort, feedback, and mistakes as opportunities for improvement may enhance both performance outcomes and learning efficiency. The results should be interpreted as associations rather than causal relationships.

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IJMS Journal 2026, Vol. 1, Article 18

Reality of English Linguistic Competencies of Physical Education Teachers in International Schools Across Egypt

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Article type	Conference track	Language and length
Original Research Article	Movement Science and Human Performance	English, 4 pages

Abstract

Background: English linguistic competence is essential for physical education teachers who work in international school settings, where lesson planning, instruction, and assessment must often be conducted in English.

Objective: This study aimed to identify the level of English linguistic competence among pre-service physical education teachers at the Faculty of Sports Sciences, Capital University, and in-service physical education teachers working in international schools in Egypt, specifically in Cairo, Alexandria, and Giza. The study also examined the statistical differences between the two groups.

Results: The study population included 30 pre-service teachers and 28 in-service teachers from international schools. An observation card was used to collect data on English language use during lesson planning, implementation, and assessment. The results showed that the level of English linguistic competence among pre-service teachers was medium, while in-service teachers demonstrated a high level. Significant differences were identified in favor of the in-service teachers.

Conclusions: The findings suggest the need to design a physical education teacher preparation program delivered entirely in English, in order to prepare graduates who can teach and work effectively in international schools across Egypt.

Keywords: English linguistic competence, physical education teachers, pre-service teachers, in-service teachers, international schools.

1. Introduction

The rapid expansion of international schools in Egypt has created a growing demand for physical education teachers who are proficient in English, the primary medium of instruction in these schools. However, most physical education teacher preparation programs in Egyptian universities, including the Faculty of Sports Sciences at Capital University, are delivered in Arabic. This creates a significant gap between graduate competencies and labor market needs (British Council Egypt, 2023; International Schools Consultancy, 2024).

Observations during teaching practice at Capital University revealed that pre-service physical education teachers struggle to use English effectively in planning, implementing, and assessing PE lessons. Meanwhile, in-service teachers already working in international schools appear to have developed stronger English linguistic competencies through on-the-job exposure and professional development.

According to reports from the Egyptian Ministry of Education and international school associations (2020–2025), many newly graduated PE teachers are unable to write lesson plans in English, give instructions during activities, or assess students using English terminology. This problem is rooted in the absence of English-medium PE programs in Egyptian universities.

This study is the first in Egypt to investigate English linguistic competencies specifically among PE teachers in international schools and to propose an English-medium teacher preparation program at Capital University.

The main purpose is to:

(1) identify the extent of English linguistic competencies possessed by pre-service and in-service PE teachers.

(2) identify any statistical differences between the two groups.

(3) propose a framework for an English-medium PE teacher preparation program at Capital University. The research questions guiding the study were:

(a) To what extent do pre-service and in-service PE teachers possess English linguistic competencies in planning, implementation, and assessment?

(b) Are there statistically significant differences between the two groups?

(c) What is the proposed framework for an English-medium PE program?

2. Materials and Methods

A descriptive study design was used. Data were collected using an observation card instrument designed to assess English linguistic competencies across three teaching dimensions: lesson planning, lesson implementation, and lesson assessment.

2.1. Participants

The study population consisted of two groups. The pre-service group included 30 physical education students in their final year of the bachelor's program at the Faculty of Sports Sciences, Capital University (mean age = 21.4 ± 0.6 years). The in-service group included 28 physical education teachers currently working in accredited international schools across Cairo, Alexandria, and Giza governorates (mean teaching experience = 5.2 ± 2.8 years). All participants volunteered and provided informed consent. The study was approved by the Research Ethics Committee of Capital University (protocol No. CAPU-PE-2025-014).

2.2. Procedure

The observation card included 25 English linguistic competency items distributed as follows: planning (8 items), implementation (12 items), and assessment (5 items). Examples include: writing lesson objectives in English, using correct grammar and punctuation in lesson plans, giving instructions in English, using appropriate vocabulary for PE activities, writing assessment criteria in English, and providing written feedback in English. Each participant was observed over three separate physical education lessons. A panel of five experts in English language teaching, PE pedagogy, and international school education validated the instrument. Reliability was calculated using Cronbach's alpha, yielding an overall coefficient of 0.92 (planning = 0.90, implementation = 0.93, assessment = 0.94).

2.3. Statistical Analysis

Data were analyzed using SPSS version 26. Descriptive statistics (means and standard deviations) were calculated for each competent field. An independent samples t-test was used to compare the mean scores of pre-service and in-service teachers. The significance level was set at $\alpha < 0.05$. Effect sizes (Cohen's d) were computed post-hoc.

3. Results

Table 1 presents the means and standard deviations for English linguistic competencies in the three fields. Pre-service teachers showed medium competency in planning (M = 2.73, SD = 0.320) and assessment (M = 2.80, SD = 0.519), but high competency in implementation (M = 3.01, SD = 0.356). In-service teachers demonstrated high competency in all three fields (planning: M = 3.45, SD = 0.410; implementation: M = 3.59, SD = 0.349; assessment: M = 3.52, SD = 0.475).

Table 1. Means and standard deviations for English linguistic competencies

Group	Planning (M)	Planning (SD)	Implementation (M)	Implementation (SD)	Assessment (M)	Assessment (SD)
Pre-service (Capital Univ.)	2.73	0.320	3.01	0.356	2.80	0.519
In-service (International schools)	3.45	0.410	3.59	0.349	3.52	0.475

Table 2. t-test results for differences between groups

Field	Mean (Pre)	Mean (In)	t-value	p-value	Cohen's d
Lesson Planning	2.73	3.45	7.537	<0.001	1.95
Lesson Implementation	3.01	3.59	6.202	<0.001	1.64
Lesson Assessment	2.80	3.52	5.501	<0.001	1.45

Table 2 shows the independent t-test results. Statistically significant differences were found in favor of in-service teachers for all three fields: planning ($t = 7.537$, $p < 0.05$, $d = 1.95$), implementation ($t = 6.202$, $p < 0.05$, $d = 1.64$), and assessment ($t = 5.501$, $p < 0.05$, $d = 1.45$). These large effect sizes confirm that current pre-service training is insufficient for preparing teachers to work in English-medium international schools.

4. Discussion

The main finding of this study is that pre-service PE teachers at Capital University possess only medium-level English linguistic competencies, whereas their in-service counterparts in international schools demonstrate high proficiency. The significant gap in all three teaching domains (planning, implementation, assessment) indicates that the current Arabic-medium teacher preparation program does not equip graduates with the English skills required for employment in international schools.

The high implementation scores among pre-service teachers (M = 3.01) suggest that basic oral instruction in English (e.g., giving commands, demonstrating activities) may be easier to acquire, possibly

due to the practical nature of PE lessons. However, the lower scores in planning and assessment, which involve written English, align with previous findings that written academic language develops more slowly than oral communicative language (Al-Tawel & Al Jaafreh, 2017). In-service teachers' higher scores likely result from sustained English use in international school environments, ongoing professional development, and feedback from supervisors (Stojanovic & Zdravkovic, 2012).

These findings have important practical implications. First, they highlight a clear labor market mismatch: international schools in Egypt urgently need PE teachers fluent in English, yet universities continue to train teachers in Arabic. Second, the results support the need for a structural curriculum reform at Capital University, specifically an English-medium PE program that integrates language and content learning. Similar recommendations have been made for other disciplines in the Arab region (British Council Egypt, 2023).

Limitations of this study include the relatively small sample (n = 58) and the focus on one university. Future research should include larger samples, other Egyptian universities, and experimental studies comparing English-medium versus Arabic-medium PE programs on graduate employability.

5. Conclusions

This study confirms that pre-service PE teachers at Capital University lack sufficient English linguistic competencies for teaching in international schools, while in-service teachers in those schools demonstrate high proficiency. A significant performance gap exists in planning, implementation, and assessment. Therefore, we conclude that an English-medium PE teacher preparation program is urgently needed at Capital University. Such a program would graduate students fully prepared to teach and work in international schools across Egypt, thereby meeting a critical labor market demand.

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Physical Activity in Europe vs Romania: Participation, HEPA Targets, and Policy Implications

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Article type	Conference track	Language and length
Original Research Article	Movement Science and Human Performance	English, 6 pages

Abstract

Background: Physical inactivity and sedentary behavior remain major determinants of non-communicable disease risk in Europe, despite EU- and WHO-level frameworks promoting health-enhancing physical activity (HEPA).

Objectives: To compare EU27 and Romania using harmonized secondary surveillance sources and derive policy-relevant implications aligned with HEPA governance frameworks. Methods: Narrative review and descriptive secondary analysis of (i) Special Eurobarometer 525 (Apr–May 2022) for self-reported sport/exercise frequency; (ii) Eurostat/European Health Interview Survey (EHIS wave 3, around 2019) for aerobic physical activity thresholds; (iii) WHO/Europe HEPA Monitoring Framework reporting (2015–2024) for EU policy implementation trends; and (iv) WHO country profiling outputs for Romania.

Results: In EU27, 38% reported exercising or playing sport at least weekly (6% ≥5×/week; 32% 1–4×/week) and 45% reported never exercising; in Romania, 20% reported at least weekly participation (2% ≥5×/week; 18% 1–4×/week) and 62% reported never exercising. Eurostat EHIS reporting indicates that about one third of Europeans achieved ≥150 min/week of non-work-related aerobic activity, whereas Romania reported 8%. WHO/Europe reports increasing average achievement of EU HEPA monitoring indicators from 64.7% (2015) to 81.8% (2024).

Conclusions: Romania shows a marked participation gap compared with EU averages. Strengthening surveillance, cross-sectoral implementation, and evidence-based interventions consistent with EU guidelines and WHO recommendations is essential to improve population-level activity.

Keywords: physical activity, HEPA, Eurobarometer, EHIS, Romania and European Union

1. Introduction

Regular physical activity across the life course lowers the risk of cardiovascular disease and metabolic disorders, supports musculoskeletal health, and is associated with substantial benefits for mental health and overall well-being (World Health Organization [WHO], 2020, 2022). According to WHO guidelines, adults should accumulate at least 150–300 minutes of moderate-intensity aerobic physical activity per week, or an equivalent combination of moderate- and vigorous-intensity activity, while also reducing sedentary time (WHO, 2020). Despite the well-established effectiveness of these recommendations, physical inactivity remains prevalent across Europe, generating significant health and economic burdens (OECD & WHO Regional Office for Europe, 2023).

Within the European Union, the promotion of health-enhancing physical activity (HEPA) has been embedded in cross-sectoral policy frameworks and monitoring mechanisms, most notably through the Council Recommendation on HEPA across sectors and the EU Physical Activity Guidelines (Council of the European Union, 2013; European Commission, 2008). Recent WHO/Europe monitoring indicates gradual improvements in policy implementation across EU Member States; however, progress remains uneven, and substantial disparities persist between countries (WHO Regional Office for Europe, 2024). Population-level participation in sport and physical activity continues to vary widely, as evidenced by Eurobarometer surveys and European Health Interview Survey (EHIS) data (European Commission & Kantar, 2022; Eurostat, 2022).

Comparative surveillance is therefore essential to identify gaps between policy intent and actual physical activity behaviors. Evidence from Eurobarometer data highlights persistent inequalities in participation and sedentary behavior trends across European populations (Beller et al., 2023; European Commission, 2022). Furthermore, country-level profiling conducted by WHO reveals that Romania continues to face structural challenges in physical activity surveillance and participation compared with the EU average (WHO, 2022; European Observatory on Health Systems and Policies, 2023).

Against this background, the present manuscript provides a comparative analysis of physical activity participation indicators between the EU27 average and Romania, drawing on Eurobarometer and Eurostat/EHIS surveillance outputs, complemented by WHO/Europe HEPA monitoring reports and WHO country profile data. This integrated approach aims to contextualize Romania's position within the broader European HEPA policy and surveillance landscape and to inform evidence-based policy discussion.

The aim of this study is to compare selected physical activity participation indicators between the EU27 and Romania and to discuss the implications for HEPA implementation in alignment with European Union and World Health Organization policy frameworks (Council of the European Union, 2013; WHO Regional Office for Europe, 2024).

2. Materials and Methods

Study design: Narrative review with descriptive secondary analysis of publicly available surveillance and policy monitoring reports.

Data sources and indicators:

1. Special Eurobarometer 525 (Apr–May 2022) measured self-reported frequency of exercising/playing sport using categories: regularly (≥5 times/week), with some regularity (1–4 times/week), seldom (≤3 times/month), and never. EU27 weighted average and Romania country results were extracted.

2. Eurostat (EHIS wave 3, around 2019) reported time spent in health-enhancing non-work-related aerobic physical activity, including the benchmark ≥150 minutes/week, and weekly participation in sport/fitness/leisure physical activities.

3. WHO/Europe report on the HEPA Monitoring Framework provided EU-level average achievement across 23 monitoring indicators for 2015, 2018, 2021 and 2024.

4. WHO country profiling documents for Romania (2021 factsheet and 2022 country profile) were consulted for surveillance context.

Analysis: Values were summarized descriptively and presented in tables and figures. No new statistical testing was performed.

3. Results

Eurobarometer 525 (Apr–May 2022) included 26,578 respondents across the 27 EU Member States, using face-to-face interviewing in 17 Member States and mixed face-to-face/online approaches in others, and provides EU27 weighted estimates. The distribution of exercise/sport frequency shows that in EU27, 45% reported never exercising or playing sport, 17% reported exercising seldom, 32% reported doing so 1–

4 times/week, and 6% reported exercising regularly (≥5 times/week). Romania displayed a less favourable profile: 62% reported never exercising or playing sport, 18% reported seldom, 18% reported 1–4 times/week, and 2% reported ≥5 times/week.

At EU level, supplementary Eurobarometer findings reported that 13% of respondents did not walk for 10 minutes at a time at all in a typical week and 11% reported sitting for more than 8 hours and 30 minutes on a usual day. The Commission press release accompanying the survey reported an age gradient: respondents aged 15–24 years were the most likely to exercise or play sport with some regularity (54%), decreasing to 21% among those aged 55 and over.

Eurostat EHIS reporting on non-work-related aerobic activity provides an additional, health-focused benchmark. Eurostat notes that about one third of Europeans achieved at least 150 minutes/week of non-work-related aerobic activity in 2019, whereas Romania reported 8%. Eurostat also reports that overall weekly participation in sport/fitness/leisure-time physical activities at least once per week was 44% in 2019 at EU level, with higher participation among men (47%) than women (42%). The Eurostat summary explicitly notes that in Bulgaria and Romania, few people practiced sport in general and the percentage of men was double that of women.

Romania-specific country profiling from WHO/Europe reports estimated prevalence of sufficient physical activity levels of 30.0% among adults and 28.0% among adolescents (11–15 years), based on adult data collected in Special Eurobarometer 472 (2017) and adolescent data from the Health Behavior in School-aged Children survey (2017–2018). WHO also published a dedicated Romania physical activity country profile in 2022, supporting country-level monitoring and policy reporting.

WHO/Europe HEPA Monitoring Framework reporting indicates an EU-wide strengthening in policy implementation capacity over time. The average proportion of the 23 HEPA monitoring indicators achieved by Member States increased from 64.7% (2015) to 74.5% (2018), 76.5% (2021), and 81.8% (2024).

Beyond prevalence, WHO and OECD emphasize the health and economic burden of insufficient activity in Europe. A WHO news release on the OECD/WHO report ‘Step up!’ states that, in the EU, 45% of people say they never exercise or play sport and every third person has insufficient levels of physical activity; it further states that meeting WHO recommended levels could prevent more than 10,000 premature deaths each year and reduce health expenditure, and that the report estimates prevention of 11.5 million new cases of noncommunicable diseases by 2050 if minimum recommended levels are achieved.

Table 1. Frequency of exercising/playing sport in EU27 vs Romania (Special Eurobarometer 525, 2022).

Frequency category	EU27 (%)	Romania (%)
Regularly (≥5×/week)	6	2
With some regularity (1–4×/week)	32	18
Seldom (≤3×/month)	17	18
Never	45	62

Table 2. Aerobic physical activity benchmark (EHIS 2019) and EU-level context indicators.

Indicator	EU (source)	Romania (source)
≥150 min/week non-work-related aerobic PA (2019)	About one third (Eurostat EHIS)	8% (Eurostat EHIS)
Sport/fitness/leisure PA ≥1×/week (2019)	44% (Eurostat EHIS)	Not specified in the Eurostat summary extract
Never exercise/play sport (2022)	45% (Eurobarometer 525)	62% (Eurobarometer 525)

No 10-min walk in a typical week (2022)	13% (Eurobarometer 525)	Not specified in the Eurobarometer summary extract
Sitting >8h30 on a usual day (2022)	11% (Eurobarometer 525)	Not specified in the Eurobarometer summary extract
Sufficient physical activity, adults (WHO/Europe factsheet)	Not provided as EU aggregate in the factsheet	30.0% (WHO/Europe factsheet, 2021)
Sufficient physical activity, adolescents 11–15 (WHO/Europe factsheet)	Not provided as EU aggregate in the factsheet	28.0% (WHO/Europe factsheet, 2021)

Table 3. EU-level HEPA monitoring indicator achievement (WHO/Europe, 2015–2024).

Year	Average proportion of indicators achieved (%)
2015	64.7
2018	74.5
2021	76.5
2024	81.8

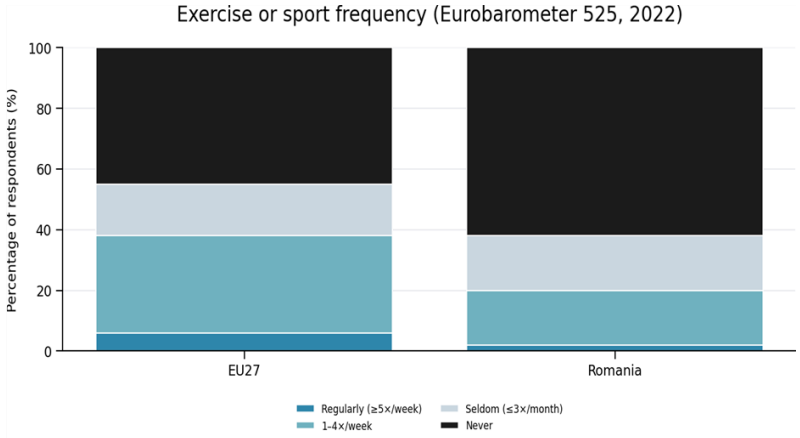


Figure 1. Exercise or sport frequency in EU27 vs Romania (Special Eurobarometer 525, 2022).

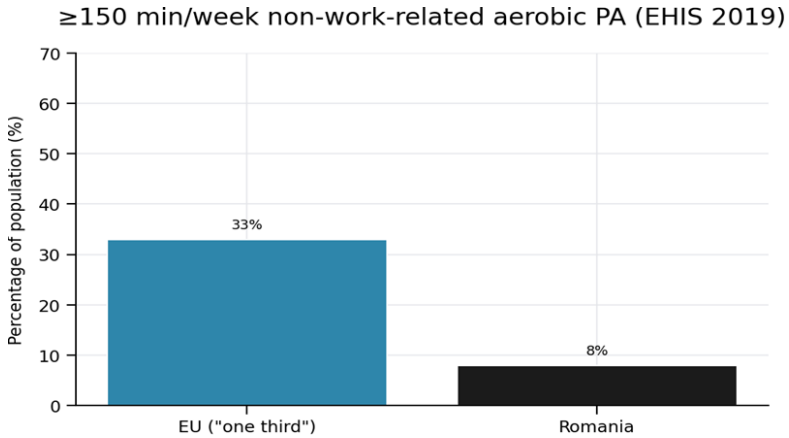


Figure 2. Share achieving ≥150 min/week non-work-related aerobic activity (Eurostat EHIS 2019): EU “one third” vs Romania (8%).

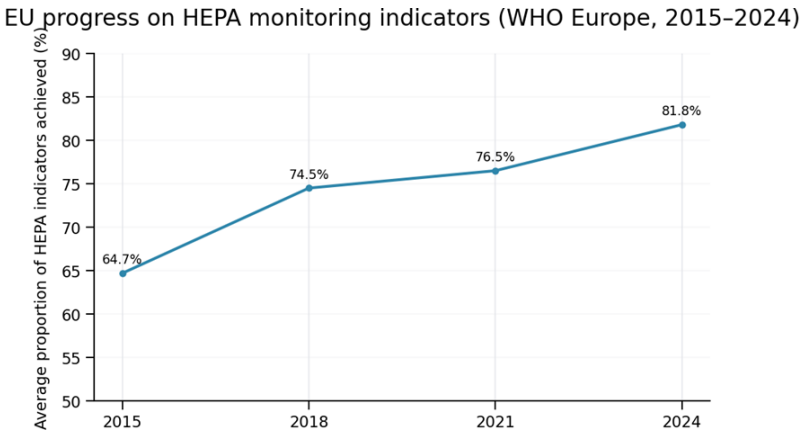


Figure 3. EU progress in average achievement of HEPA monitoring indicators (WHO/Europe: 2015–2024).

4. Discussion

This synthesis shows consistent evidence of a participation gap between Romania and EU27 across complementary surveillance instruments. Eurobarometer 525 indicates that the share reporting 'never' exercising or playing sport is markedly higher in Romania (62%) than in EU27 (45), and weekly participation is lower in Romania (20%) than in EU27 (38%). EHIS-based Eurostat reporting further indicates that Romania has a very low share (8%) achieving the ≥150 minutes/week benchmark of non-work-related aerobic activity compared with an EU-wide statement of about one third. These results collectively suggest that Romania's gap is present both in sport participation and in broader health-enhancing activity levels.

A key interpretation point is that policy capacity can improve even when behavioral outcomes remain uneven. WHO/Europe reports increasing average achievement of HEPA monitoring indicators across Member States from 2015 to 2024, which indicates strengthened governance and implementation infrastructure at EU level. However, Eurobarometer still shows that nearly half of EU citizens report never exercising or playing sport, underscoring the challenge of translating policy frameworks into sustained behavior change. The OECD/WHO report 'Step up!' frames insufficient physical activity as a major public health and economic burden and links meeting recommended activity levels to prevention of premature deaths and reductions in NCD incidence.

Strengths of this manuscript include reliance on authoritative, comparable European surveillance outputs and policy monitoring reports. Limitations include reliance on self-report measures and differences in constructs across data sources (e.g., 'exercise or sport frequency' vs 'aerobic activity minutes'). Future research should include evaluation studies of implementation mechanisms and interventions in Romania aligned to cross-sector HEPA frameworks.

5. Conclusions

1. Romania shows substantially lower self-reported sport/exercise participation than EU27, with 62% reporting 'never' exercising versus 45% in EU27 (Eurobarometer 525, 2022).

2. Romania's share achieving ≥150 min/week of non-work-related aerobic activity is 8% versus an EU-wide statement of about one third (Eurostat EHIS, 2019).

3. WHO/Europe country profiling reports sufficient physical activity prevalence estimates of 30.0% in adults and 28.0% in adolescents in Romania (WHO/Europe factsheet, 2021).

4. EU-level HEPA policy monitoring indicates improved implementation capacity from 2015 to 2024, but behavioural outcomes remain uneven across countries.

5. Closing the EU–Romania gap will require strengthened surveillance and cross-sector implementation aligned with EU guidelines and WHO recommendations.

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IJMS Journal 2026, Vol. 1, Article 20

Effects of Greek Folk Dance on Coordination and Performance in International Dance Competitions

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Article type	**Conference track**	**Language and length**
Original Research Article	Movement Science and Human Performance	English, 4 pages

Abstract

Background: Greek folk dances represent a valuable component of cultural heritage and are increasingly integrated into contemporary competitive dance contexts. Dance forms such as Syrtaki and Cretan dances involve complex rhythmic structures, coordinated footwork, and expressive movement patterns that may influence technical and artistic performance.

Objectives: This study aimed to examine the effects of a structured Greek folk dance training program on coordination, agility, and performance quality in an international dance competition setting.

Methods: A longitudinal case study was conducted on one female dancer (22 years old), who followed a 12-week structured training program including Syrtaki and Cretan dance. The intervention incorporated rhythm training, synchronization exercises, and choreographic sequences. Performance outcomes were assessed pre- and post-intervention through quantitative measures (coordination, heart rate, perceived exertion) and qualitative evaluation (judges' scoring and video analysis).

Results: The results indicated a 15% improvement in coordination, along with significant enhancements in cardiovascular response ($p < 0.05$) and reduced perceived exertion. Syrtaki training improved synchronization and movement fluidity, while Cretan dance enhanced agility and footwork precision. Judges' evaluations reported high artistic expression and cultural authenticity, with an average score of 9.2/10.

Conclusions: Greek folk dance training contributes to both technical and expressive performance in competitive dance. The integration of traditional dance elements may enhance motor abilities and enrich artistic execution in international competitions.

Keywords: Greek folk dance, Syrtaki, Cretan dance, coordination, performance, agility

1. Introduction

Dance performance represents a complex integration of physical, technical, and expressive components, requiring the coordinated interaction of neuromuscular, cognitive, and emotional processes. Within this framework, coordination and agility are considered fundamental motor abilities that support both technical execution and artistic interpretation (Koutedakis & Jamurtas, 2004).

In recent years, there has been an increasing interest in the use of traditional dance forms as complementary training tools in competitive dance. Greek folk dances, such as Syrtaki and Cretan dances, are characterized by structured rhythmic patterns, complex footwork, and synchronized group movements. These characteristics make them particularly relevant for enhancing coordination, rhythm perception, and movement precision (Papadopoulos, 2020).

From a motor learning perspective, traditional dances involve repetitive yet variable movement sequences, which stimulate motor adaptability and improve sensorimotor integration. Moreover, their

strong cultural and expressive component may contribute to the development of artistic performance, a key evaluation criterion in international dance competitions.

Despite these potential benefits, the scientific literature remains limited regarding the direct impact of Greek folk dance training on performance outcomes in competitive environments. Most existing studies focus on general motor development or cultural aspects, without addressing their applicability in high-level dance performance.

Therefore, the aim of this study was to investigate the effects of a structured Greek folk dance training program on coordination, agility, and performance quality in an international dance competition. It was hypothesized that systematic training in Syrtaki and Cretan dance would lead to significant improvements in both motor and expressive performance indicators.

2. Materials and Methods

Study design: Observational case study.

The present research employed a longitudinal observational case study design, aimed at analyzing performance changes following a structured intervention. Although limited in generalizability, this design allows for an in-depth analysis of motor and performance adaptations.

2.1. Participants

The participant was a 22-year-old female dancer, clinically healthy, with prior experience in dance training but without participation in international competitions. Informed consent was obtained prior to participation, and the study followed ethical standards for human research.

2.3. Training Protocol

The intervention consisted of a 12-week structured training program, with a frequency of five sessions per week (approximately 60–90 minutes per session). The training protocol included:

- Syrtaki training Focused on rhythmic accuracy, group synchronization, and upper body expressivity. Exercises emphasized timing consistency, tempo adaptation, and coordinated movement sequences.
- Cretan dance training (Pentozali) Focused on agility, rapid directional changes, and complex footwork. Exercises included dynamic weight transfers, acceleration-deceleration patterns, and multi-planar movements.
- Complementary exercises Included coordination drills, balance exercises, and rhythm training using auditory cues.

2.4 Assessment Methods

Performance evaluation was conducted pre- and post-intervention using:

Quantitative measures

Coordination scores (based on movement accuracy and timing)

Heart rate (resting, post-effort, recovery at 3 minutes)

Rating of perceived exertion (RPE scale 6–20)

Qualitative measures

Judges' scoring during the International Dance Cup (scale 1–10)

Video analysis assessing timing accuracy, synchronization, and expressive quality

2.3. Statistical Analysis

Descriptive statistics (mean ± standard deviation) were used to summarize the data. Differences between pre- and post-training values were analyzed using paired comparisons. Statistical significance was set at $p < 0.05$.

3. Results

The results indicate a consistent improvement across both physiological and performance-related parameters.

Coordination improved by 15%, reflecting enhanced motor control and timing precision. This improvement was particularly evident in synchronized sequences and rhythm-based movements.

Heart rate responses showed improved cardiovascular efficiency. Post-dance heart rate values were significantly lower after training ($p = 0.002$), and recovery heart rate at 3 minutes improved significantly ($p = 0.03$), indicating better recovery capacity.

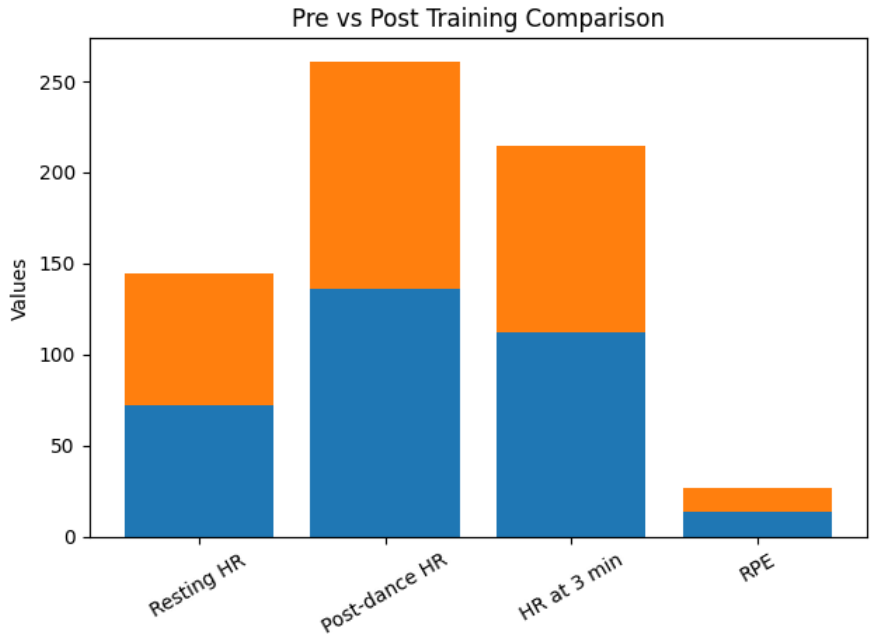
Perceived exertion decreased significantly ($p = 0.01$), suggesting improved effort management and adaptation to training demands.

From a qualitative perspective, judges' scores averaged 9.2/10, highlighting high levels of artistic expression, cultural authenticity, and technical execution. Video analysis confirmed improvements in movement fluidity, timing accuracy, and overall performance coherence.

Table 1. Coordination scores before and after training

Variable	Syrtaki Mean ± SD	Pentozali Mean ± SD	t	p
Resting HR (bpm)	72.4 ± 8.6	71.9 ± 7.9	0.45	0.65
Post-dance HR (bpm)	136.2 ± 14.8	124.4 ± 13.1	3.54	0.002*
HR at 3 min (bpm)	112.3 ± 12.5	102.7 ± 11.9	2.34	0.03*
RPE (6-20)	14.1 ± 1.9	12.7 ± 1.8	2.81	0.01*

Note: HR = heart rate, RPE = rating of perceived exertion, *$p < 0.05$.



Grafic 1. Comparison of Physiological Parameters Before and After Training

4. Discussion

The findings of this study support the hypothesis that Greek folk dance training contributes to both motor and artistic performance improvements in competitive dance contexts.

The observed increase in coordination can be explained through the repetitive yet rhythmically complex movement patterns inherent in Syrtaki. These patterns require continuous synchronization with external auditory stimuli, facilitating the development of temporal coordination and sensorimotor

integration. Similar findings have been reported in studies examining rhythm-based training and motor performance (Koutedakis & Jamurtas, 2004).

The agility improvements associated with Cretan dance are likely due to the high demands placed on rapid footwork execution and dynamic balance control. These movements stimulate proprioceptive mechanisms and enhance neuromuscular responsiveness, which are essential for complex dance routines (Angioi et al., 2009).

Physiological adaptations, including reduced heart rate and perceived exertion, indicate an improvement in aerobic efficiency and energy utilization. This suggests that traditional dance training can also contribute to conditioning, not only technical skill development.

An important contribution of this study is the emphasis on artistic expression. Judges' evaluations confirmed that cultural authenticity and expressive quality were significantly enhanced. This supports the idea that traditional dance forms enrich movement repertoire and provide a deeper expressive framework, which is increasingly valued in international competitions.

However, several limitations must be acknowledged. The single-participant design limits external validity, and the absence of a control group prevents causal inferences. Additionally, the relatively short intervention period does not allow for long-term adaptation analysis.

Future research should adopt experimental designs with larger samples, include biomechanical and kinematic analyses, and compare traditional dance training with other conditioning methods. Such approaches would provide a more comprehensive understanding of the role of cultural dance forms in performance optimization.

5. Conclusions

Greek folk dance training represents an effective method for enhancing both technical and artistic components of dance performance.

The results demonstrate that coordination, timing accuracy, and movement precision can be significantly improved through structured training in Syrtaki and Cretan dance. Additionally, these dance forms contribute to agility development and improved physiological efficiency.

Beyond physical benefits, traditional dances enhance artistic expression and cultural authenticity, which are critical factors in competitive evaluation.

Although preliminary, these findings suggest that integrating traditional dance elements into training programs may provide a multidimensional advantage for dancers. Coaches and choreographers are encouraged to incorporate such practices to optimize performance outcomes.

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Integrating Physical and Psychological Well-Being in Higher Education: An Interdisciplinary Approach to Student Development

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Article type	Conference track	Language and length
Original article	Movement Science and Human Performance	English, 18 pages

Abstract

Background: Student well-being is an increasing global priority, with rising psychological distress among university populations. However, physical and psychological dimensions are frequently examined in isolation, limiting a comprehensive understanding of their combined influence on academic functioning.
Objectives: This study investigates the associations between physical activity, psychological well-being, and academic performance, hypothesizing that higher physical activity levels predict enhanced psychological functioning and academic motivation.
Methods: A cross-sectional study was conducted among university students from multiple disciplines. Psychological constructs were assessed using validated instruments (WHO-5, WHOQOL-BREF, Academic Motivation Scale, CD-RISC-10, PSQI). Physical activity was measured via IPAQ-SF and complemented by objective fitness indicators (handgrip strength, sit-and-reach). Data analysis included Pearson correlations, group comparisons (active vs. sedentary), and regression models.
Results: Higher physical activity levels were significantly associated with greater psychological well-being, resilience, and academic motivation ($p < 0.05$), as well as improved sleep quality and overall quality of life.
Conclusions: Findings support a biopsychosocial framework of student development and highlight the need for integrated institutional strategies targeting both physical and mental health to enhance academic outcomes.

Keywords: student well-being, physical activity, psychological well-being, academic performance, higher education, resilience.

1. Introduction

In recent decades, universities around the world have paid increasing attention to student well-being, recognizing that academic success depends not only on cognitive skills, but also on students' overall physical and psychological health. Student well-being is essential for academic success, as it is a complex and interdependent construct shaped by adaptation to the university environment and by factors such as physical activity, stress management, and health-related behaviors. Recent research shows that student well-being is associated with academic success, social integration, and the development of long-term healthy behaviors (Sanci et al., 2022).

A growing body of literature suggests that physical activity plays an important role in this broader framework of student development. A recent meta-analysis showed that physical exercise can produce significant effects on psychological well-being, including increased well-being and reduced symptoms of anxiety, depression, and stress among students (Avalos-Ramos & Martinez, 2022; Liu et al., 2025). More recent systematic evidence has also shown that physical activity interventions can improve mental health outcomes in undergraduate students, although the methodological quality of interventions remains uneven (Huang et al., 2024). In parallel, broader review evidence indicates that physical activity benefits mental health through multiple pathways, including affect regulation, self-perceptions, self-efficacy, and social mechanisms (White et al., 2024).

Physical education is one of the oldest forms of formative action. This component of education encompasses a set of activities that contribute to human development by cultivating and enhancing the psychophysical dimension of the individual, maintaining a balance between the physical and the psychological, as well as between psychomotor abilities and intellect, will, and emotionality (Cucoș, 2024, pp. 192–193).

Empirical studies further show that physical exercise contributes to emotional regulation and to the strengthening of personal competence, factors that may support adaptation to the demands of the university environment (Hu & Liu, 2025). Research also indicates that physical activity may have positive effects on concentration, cognitive functions, and academic performance, suggesting a complex relationship between physical health, psychological well-being, and academic success (Barbosa et al., 2020; Chaput et al., 2020; Comachio et al., 2025; Pan et al., 2025). At the same time, recent studies among college students have emphasized that social support and self-efficacy may mediate the relationship between physical activity and subjective well-being, highlighting that the benefits of movement are both physiological and psychosocial (Guo et al., 2024).

Although research highlights the benefits of integrating these dimensions, many universities still approach them in a fragmented way, which reduces the effectiveness of interventions designed to support students. This problem is especially relevant in higher education, where mental health concerns, sedentary behavior, academic overload, and sleep difficulties often coexist.

The guidelines developed by the World Health Organization highlight that regular physical activity contributes to the prevention of cardiovascular, metabolic, and oncological diseases, as well as to the improvement of general functionality (Bull et al., 2020). These conclusions are supported by large epidemiological studies demonstrating a dose-response relationship between physical activity and the reduction of morbidity and mortality risk (Garcia et al., 2023; Markozannes et al., 2024; Ribeiro et al., 2023).

In this context, physical activity is increasingly used as a therapeutic and preventive intervention in the management of chronic diseases. In the case of type 2 diabetes, physical exercise contributes to improved glycemic control and insulin sensitivity (Hayden et al., 2021). Similarly, in the case of chronic low back pain, physical exercise is recommended as a first-line intervention, with demonstrated effects on pain reduction and improved functionality (Comachio et al., 2025; Hayden et al., 2021). At the same time, the

relationship between physical activity and health can be explained through a biopsychosocial model, in which biological, behavioral, and psychological factors interact dynamically (Comachio et al., 2025; Hayden et al., 2021).

Regarding the benefits of physical activity, the literature also highlights several important gaps. First, there is substantial variability in results between studies due to methodological differences and the diversity of interventions used (Alalawi et al., 2024; Alley et al., 2024). Second, the lack of standardization of exercise protocols makes it difficult to identify an optimal dose of physical activity (Comachio et al., 2025; Hayden et al., 2021). In addition, the mechanisms through which physical activity simultaneously influences physical and mental health are not yet fully elucidated, and the role of psychological factors is often insufficiently investigated experimentally (Comachio et al., 2025; Hayden et al., 2021; Rahmati et al., 2024). Recent synthesis studies reinforce this point by showing that the pathways linking physical activity to mental health are complex and still underexplored in applied educational contexts (White et al., 2024).

Most available studies are also short-term, which limits understanding of the sustainability of long-term effects, especially for digital and educational interventions (Alley et al., 2024). This limitation raises important questions about the maintenance of active behavior and the role of motivational factors in adherence to physical activity programs. Recent work on university populations has also shown that barriers to physical activity remain common, including lack of time, academic pressure, low motivation, and environmental constraints, all of which may weaken the continuity of healthy behaviors in student life (Elmahgoub et al., 2025).

Despite recognition of the importance of integrating physical and psychological well-being in higher education, research remains limited by a lack of longitudinal and experimental studies, insufficient implementation of interdisciplinary programs, limited exploration of diversity and equity, and insufficient attention to institutional or environmental factors. Many studies use cross-sectional designs, leaving gaps in understanding the long-term effects and sustainability of interdisciplinary interventions on student well-being (Salois et al., 2025; Mudlo-Glagolska & Larionow, 2025; Pap et al., 2023). Longitudinal and experimental studies conducted in diverse institutions and student populations are still rare, which limits the formulation of causal relationships and the generalizability of results (Joggyah & Tyler, 2025).

Although physical and psychological well-being are recognized as essential, most interventions are still specific to a single discipline, and truly interdisciplinary models integrated into the curriculum are rarely implemented or evaluated on a larger scale (Salgado Medina et al., 2024; Bardini et al., 2024; Joggyah & Tyler, 2025; Wang et al., 2025). It is therefore necessary to develop comprehensive programs that intentionally connect the physical, psychological, and academic domains across faculties. In addition, recent evidence suggests that physical activity may also influence sleep quality indirectly through health literacy and life satisfaction, which further supports the need for integrated approaches that do not isolate physical, emotional, and behavioral dimensions of student health (He et al., 2025).

Research also pays limited attention to how interdisciplinary well-being interventions affect different groups of students, including differences related to field of study, gender, socioeconomic status, and cultural context (Yang et al., 2026; Wang et al., 2025; Tomas-Gallego et al., 2024). The differential impact of these interventions and the specific barriers faced by vulnerable groups remain poorly documented (Severino-Gonzalez et al., 2025). Most studies focus on individual behaviors or immediate academic outcomes, with little attention to institutional, organizational, or policy factors that influence the effectiveness of interdisciplinary well-being initiatives (Suditu & Safta, 2025; Severino-Gonzalez et al., 2025; Bardini et al., 2024). All these aspects, taken together, indicate a clear scientific gap in understanding how university policies, campus culture, and administrative support facilitate or hinder the integration of physical and psychological well-being into student development.

As a result, there is a need for research that addresses physical activity from an integrated perspective, including the interaction between physical and psychological dimensions, through collaboration between education, psychology, and sports sciences, in order to support the holistic development of students. Therefore, the purpose of this paper is to analyze the role of integrating physical and psychological well-being in higher education and to highlight the importance of an interdisciplinary approach to student development. More specifically, the study aims to investigate the relationship between physical activity levels, psychological well-being, adaptation, and academic performance in university students. Based on the literature, it is expected that higher levels of physical activity and better functional capacity will be associated with more favorable psychological outcomes and better academic adjustment.

2. Materials and Methods

2.1. Study Design

This study employed a quantitative, cross-sectional, correlational design aimed at examining the associations between physical activity, functional capacity, psychological well-being, quality of life, and academic motivation in university students. The interdisciplinary framework integrated perspectives from movement science, psychology, and public health. Given its cross-sectional nature, the study was designed to identify associations between variables without inferring causality.

2.2. Participants

The study sample consisted of 327 students enrolled at Lucian Blaga University of Sibiu, recruited through a convenience sampling strategy. Participants were aged between 18 and 30 years and represented different academic disciplines. Socio-demographic variables, including sex, year of study, and academic field, were also collected in order to describe the sample and explore potential confounding influences.

2.3. Eligibility Criteria

Inclusion criteria were: age between 18 and 30 years, active student status, provision of written informed consent, and medical clearance for participation in physical effort.

Exclusion criteria were: the presence of musculoskeletal or cardiovascular conditions limiting physical effort and incomplete questionnaire responses exceeding 10% missing data.

To control for potential confounding variables, socio-demographic data such as sex, year of study, and academic field were collected.

2.4. Ethical Considerations

Inclusion criteria were: age between 18 and 30 years, active student status, provision of written informed consent, and medical clearance for participation in physical effort. Exclusion criteria were: the presence of musculoskeletal or cardiovascular conditions limiting physical effort and incomplete questionnaire responses exceeding 10% missing data.

2.5. Instruments and Variables

A multidimensional assessment approach was employed, combining internationally validated self-report instruments with objective physical fitness measurements.

Psychological well-being was assessed using the WHO-5 Well-Being Index, a validated instrument measuring the frequency of positive affect experienced over the previous two weeks, with higher scores reflecting greater well-being.

Quality of life was evaluated through the WHOQOL-BREF, which captures subjective perceptions across four domains: physical health, psychological well-being, social relationships, and environmental context.

Academic motivation was measured using the Academic Motivation Scale (AMS), allowing differentiation between intrinsic motivation, extrinsic motivation, and amotivation, thus providing a nuanced understanding of students' engagement in academic activities.

Physical activity levels were assessed using the International Physical Activity Questionnaire – Short Form (IPAQ-SF), which quantifies the frequency and duration of physical activities across intensity levels, as well as sedentary behavior over the previous seven days.

To complement the self-reported data, two objective physical fitness tests were administered in order to evaluate functional capacity and explore its relationship with psychological and behavioral variables.

Muscular strength was assessed using a calibrated handgrip dynamometer, following standardized testing protocols. Participants were evaluated in a standing position, with the arm positioned alongside the body and without external support. Two trials were performed for each hand, and the highest value (kg) was retained for analysis.

Flexibility of the posterior kinetic chain was assessed using the sit-and-reach test, performed with a standardized measurement box. Participants executed maximal forward trunk flexion from a seated position, with knees fully extended. Two trials were conducted, and the best performance (cm) was recorded.

Tabel 1. Psychological and Behavioral Measures

No.	Assessed Domain	Instrument	Measured Variable	Assessment Protocol	Unit of Measurement
1	Psychological well-being	WHO-5	Subjective well-being	Five items rated on a Likert scale referring to the last two weeks	Total score (0–100)
2	Quality of life	WHOQOL-BREF	Multidimensional quality of life	Assessment across four domains: physical, psychological, social, and environmental	Domain scores (1–5)
3	Academic motivation	AMS	Types of motivation	Intrinsic motivation, extrinsic motivation, and amotivation	Likert scale (1–7)
4	Physical activity level	IPAQ-SF	Physical activity level	Frequency and duration of physical activity (vigorous, moderate, walking)	Minutes/week

2.6. Functional Capacity Assessments

To complement self-reported measures, objective assessments of functional capacity were conducted using standardized field tests commonly applied in exercise science research. These tests

provide valid indicators of muscular strength and flexibility, relevant for evaluating physical fitness in young adult populations.

Tabel 2. Functional Capacity Measures

No.	Assessed Domain	Instrument	Measured Variable	Assessment Protocol	Unit of Measurement
1	Muscular strength	Handgrip dynamometry	Maximal grip strength	Two trials per hand performed in standing position; the highest value was recorded	Kilograms (kg)
2	Flexibility	Sit-and-Reach test	Posterior chain flexibility	Two trials from a seated position; the best performance was retained	Centimeters (cm)
3	Flexibility	Sit-and-Reach test	Posterior chain flexibility	Two trials from a seated position; the best performance was retained	Centimeters (cm)



Figure 1. Handgrip test



Figure 2. Sit and Reach Test

2.7. Procedure

Data collection was conducted in two consecutive stages under standardized conditions. In the first stage, participants completed the self-report questionnaires online after receiving standardized instructions and study information. In the second stage, they underwent physical assessments in a controlled indoor sports facility under the supervision of trained evaluators. The order of testing, environmental conditions, equipment, and verbal instructions were kept constant for all participants.

In the first stage, participants completed the self-report questionnaires online. Prior to participation, all individuals were informed about the purpose of the study and provided written informed consent. Standardized instructions were provided to all participants to minimize variability in item interpretation and response patterns.

In the second stage, participants underwent physical assessments in a controlled indoor sports facility. All measurements were conducted under the supervision of trained evaluators, following standardized testing protocols. The order of test administration was kept consistent across all participants to avoid potential order effects. Environmental conditions, equipment, and verbal instructions were uniform for all assessments.

This two-stage procedure enabled the integration of subjective (self-reported) and objective (performance-based) data within a unified methodological framework, thereby enhancing the reliability and internal validity of the study while minimizing potential sources of measurement error.

2.3. Statistical Analysis

Descriptive statistics were calculated for all variables. To examine differences in psychological well-being, quality of life, and academic motivation according to physical performance, the sample was divided into two groups based on the median values of right handgrip strength, left handgrip strength, and sit-and-reach performance. Group differences were then tested using inferential statistics. The section should also specify the statistical software, significance threshold, and effect size reporting.

To investigate the associations between physical activity, psychological well-being and academic performance, we verified the significance of the differences between the mean scores obtained by respondents on the three self-report questionnaires: WHO-5, WHOQOL-BREF, Academic Motivation Scale. For this statistical analysis, we divided the group of students according to the results of the physical measurements performed: Right and Left handgrip strength (kg) and Sit and Reach (cm).

Tabel 3. Descriptives statistics

Variable	n	Mean	SD	Min	P50	Max
Age	327	20.08	2.936	18	19	44
Well-Being Index (WHO-5)	327	67.14	18.143	0	68	100
Physical Health (WHOQOL)	327	27.44	4.114	14	28	35
Psychological Health (WHOQOL)	327	23.19	4.164	7	24	30
Intrinsic motivation (AMS)	327	59.28	13.512	12	61	82
Extrinsic motivation (AMS)	327	67.87	11.944	16	71	88
Right handgrip strength (kg)	327	32.39	11.178	14.30	28.60	70.90
Left handgrip strength (kg)	327	30.49	10.489	14.10	26.80	74.30
Sit and Reach (cm)	327	20.43	8.158	2	20	43

The two independent groups were formed by referring to the median values (P50 indicator in Table 1) of the three variables describing functional capacity assessment: Right and Left handgrip strength (kg) and Sit and Reach (cm). Of course, we did not neglect the results of the IPAQ-SF either, but following the statistical analyses we did not obtain data that would support our starting hypothesis (Figure 3).

However, the assumption that higher levels of physical activity predict improved psychological functioning and academic motivation was partially confirmed by the significant differences in the means of the two groups formed by dividing the sample according to the median value (P50).

Tabel 4. Differences between Right handgrip strength (kg) on five psychological variables

Right handgrip strength (kg)	< 28,60 n = 163 Mean (SD)	>= 28,60 n = 164 Mean (SD)	df	t	p
Well-Being Index	63.24 (16.663)	71.02 (18.762)	325	3.966	.001
Physical Health	26.63 (3.941)	28.26 (4.134)	325	3.650	.001
Psychological Health	22.53 (4.010)	23.84 (4.226)	325	2.857	.005
Intrinsic motivation	58.77 (13.373)	59.78 (13.672)	325	.674	.501
Extrinsic motivation	68.48 (11.463)	67.26 (12.408)	325	-.925	.356

Considering the variable Right handgrip strength (table 4), we compared students with high Right handgrip strength (M=71.02, SD=18.76) with those with low Right handgrip strength (M=63.24, SD=16.66) and obtained significant differences in terms of Well-Being Index ($t(325)=3.966$; $p < .001$). The same significant difference is also observed for Physical Health ($t(325)=3.650$; $p < .001$) and Psychological Health ($t(325)=2.857$; $p = .005$). The differences in terms of academic motivation measured with the Academic Motivation Scale (AMS) are not conclusive.

Tabel 5. Differences between Left handgrip strength (kg) on five psychological variables

Left handgrip strength (kg)	< 26,80 n = 162 Mean (SD)	>= 26,80 n = 165 Mean (SD)	df	t	p
Well-Being Index	63.56 (16.853)	70.67 (18.717)	325	3.608	.001
Physical Health	26.67 (3.997)	28.10 (4.133)	325	2.960	.003
Psychological Health	22.47 (4.124)	23.89 (4.095)	325	3.128	.002
Intrinsic motivation	60.17 (12.652)	58.41 (14.292)	325	-1.179	.239
Extrinsic motivation	69.22 (11.213)	66.55 (12.513)	325	-2.036	.043

We can report similar results when we refer to Left handgrip strength (table 5). Comparing students with high Left handgrip strength (M=70.67, SD=18.72) with those with low Left handgrip strength (M=63.56, SD=16.85) we obtained significant differences in terms of Well-Being Index ($t(325)=3.608$; $p < .001$). The same significant difference is also observed for Physical Health ($t(325)=2.960$; $p = .003$) and Psychological Health ($t(325)=3.128$; $p = .002$). In addition, regarding extrinsic academic motivation, measured with the Academic Motivation Scale (AMS), there is a slightly significant difference in the means of the two analyzed groups ($t(325)=-2.036$; $p = .043$).

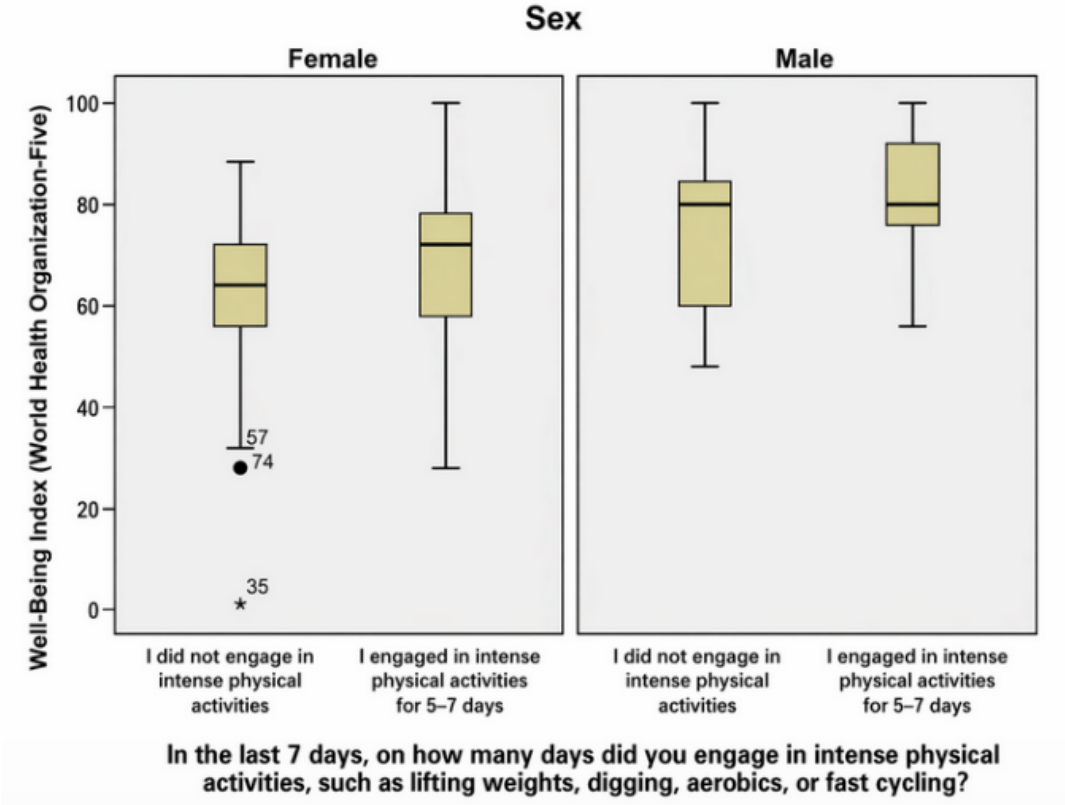


Figure 3. Box plot of Well-Being Index by frequency of physical activity and gender.

3. Results

3.1. Sample Characteristics and Descriptive Statistics

A total of 327 university students were included in the analysis. Participants had a mean age of 20.08 years (SD = 2.94). Descriptive statistics for the main study variables are presented in Table 3. The mean score for the WHO-5 Well-Being Index was 67.14 (SD = 18.14). Mean physical health and psychological health scores, assessed through the WHOQOL-BREF, were 27.44 (SD = 4.11) and 23.19 (SD = 4.16), respectively. The mean intrinsic motivation score was 59.28 (SD = 13.51), while the mean extrinsic motivation score was 67.87 (SD = 11.94). Regarding the physical indicators, the mean right handgrip strength was 32.39 kg (SD = 11.18), the mean left handgrip strength was 30.49 kg (SD = 10.49), and the mean sit-and-reach score was 20.43 cm (SD = 8.16).

3.2. Group Differences According to Right Handgrip Strength

To examine whether psychological outcomes differed according to functional strength, the sample was divided into two groups based on the median value of right handgrip strength, < 28.60 kg and ≥ 28.60 kg. The results are presented in Table 4. Students with higher right handgrip strength reported significantly better well-being than those with lower right handgrip strength. The mean WHO-5 score was 71.02 (SD = 18.76) in the higher-strength group and 63.24 (SD = 16.66) in the lower-strength group, $t(325) = 3.966$, $p = .001$. Significant differences were also observed for physical health, with higher scores in the stronger group, 28.26 (SD = 4.13) versus 26.63 (SD = 3.94), $t(325) = 3.650$, $p = .001$, and for psychological health, 23.84 (SD = 4.23) versus 22.53 (SD = 4.01), $t(325) = 2.857$, $p = .005$. No statistically significant differences were found for intrinsic motivation, $t(325) = 0.674$, $p = .501$, or extrinsic motivation, $t(325) = -0.925$, $p = .356$.

Report findings in a clear order that mirrors the methods and the study aims. Every table and figure should be introduced in the text before it appears. Present the essential values, not only p values. Include means, standard deviations, percentages, confidence intervals, or effect sizes where appropriate. Do not interpret the meaning of the results extensively here, reserve interpretation for the Discussion.

A practical structure for the discussion is: principal finding, comparison with previous research, possible mechanisms, applied meaning, strengths, limitations, and future research. When findings differ from prior studies, explain plausible reasons such as sample characteristics, intervention design, competitive level, season timing, measurement tools, or statistical approach.

3.3. Group Differences According to Left Handgrip Strength

A similar analysis was performed using the median value of left handgrip strength, < 26.80 kg and ≥ 26.80 kg. The results are shown in Table 5. Students with higher left handgrip strength obtained significantly higher scores on the WHO-5 Well-Being Index than those with lower left handgrip strength, with mean values of 70.67 (SD = 18.72) and 63.56 (SD = 16.85), respectively, $t(325) = 3.608$, $p = .001$. Significant differences were also observed for physical health, 28.10 (SD = 4.13) versus 26.67 (SD = 4.00), $t(325) = 2.960$, $p = .003$, and for psychological health, 23.89 (SD = 4.10) versus 22.47 (SD = 4.12), $t(325) = 3.128$, $p = .002$. In the case of academic motivation, no significant difference was identified for intrinsic motivation, $t(325) = -1.179$, $p = .239$. However, a statistically significant difference was found for extrinsic motivation, with the lower-strength group showing slightly higher mean values than the higher-strength group, 69.22 (SD = 11.21) versus 66.55 (SD = 12.51), $t(325) = -2.036$, $p = .043$.

3.4. Physical Activity Frequency and Well-Being by Sex

Figure 3 illustrates the distribution of WHO-5 well-being scores according to the frequency of intense physical activity during the previous seven days, analyzed separately for female and male students. In both sex groups, students who reported engaging in intense physical activity for 5 to 7 days tended to show higher median well-being scores than those who reported no intense physical activity. This pattern appeared more visible among female students, where greater variability and several low outlier values were also observed. Overall, the figure suggests a tendency toward better well-being among students with a higher frequency of intense physical activity.

3.5. Summary of the Main Findings

Taken together, the results indicate that muscular strength was more consistently associated with psychological well-being and perceived health than with academic motivation. Both right and left handgrip strength differentiated students in terms of well-being, physical health, and psychological health. By contrast, the associations with motivation were limited, with no significant differences for intrinsic motivation and only a small difference for extrinsic motivation in relation to left handgrip strength. In addition, although the visual inspection of Figure 3 suggests a more favorable well-being profile among students reporting frequent intense physical activity, the statistical analyses based on IPAQ-SF variables did not provide sufficiently strong evidence to fully support the initial hypothesis.

4. Discussion

The present study examined the relationship between physical activity, functional capacity, psychological well-being, quality of life, and academic motivation in a sample of university students. The main finding was that students with higher levels of muscular strength, reflected by both right and left handgrip performance, showed significantly better scores for well-being, physical health, and

psychological health. By contrast, the associations with academic motivation were weaker and less consistent, while the self-reported physical activity indicators did not provide sufficiently strong statistical support for the initial hypothesis. These findings suggest that, in this student sample, objective indicators of functional fitness were more closely related to psychological well-being than self-reported activity level alone.

This pattern is broadly consistent with recent literature showing that physical activity and physical fitness are positively associated with mental well-being in university students. A recent systematic review focused specifically on college students concluded that physical activity is generally associated with better self-esteem, lower depressive symptoms, and more favorable subjective well-being outcomes, although the strength of the evidence varies across study designs and measures (Li et al., 2025). Similarly, a systematic review of interventions in undergraduate populations reported that physical activity programs tend to reduce anxiety, depression, and stress, while also showing potential to improve well-being, although methodological heterogeneity remains substantial (Huang et al., 2024). Recent work has also emphasized that the link between movement and mental health is often mediated by self-efficacy, emotion regulation, social support, and related psychosocial mechanisms rather than by energy expenditure alone (White et al., 2024; Guo et al., 2024; Hu & Liu, 2025).

Our findings also align with recent studies suggesting that the quality of psychological functioning may be more closely tied to the broader psychosocial effects of exercise than to simple frequency counts of activity. For example, Guo et al. (2024) found that physical activity was linked to subjective well-being through self-efficacy and social support, while Zhong (2024) reported meaningful relationships between physical activity motivation profiles and dimensions of psychological well-being among university students. In a similar direction, Hu and Liu (2025) showed that self-efficacy and emotion regulation help explain the positive association between physical exercise and mental health in college students. This may help explain why the objective fitness indicators in our study, especially handgrip strength, showed clearer relationships with well-being than the IPAQ-SF-based analysis. Functional capacity may reflect not only recent activity but also cumulative adaptation, physical confidence, and behavioral consistency.

Another important result of the present study is that the associations with academic motivation were limited. Intrinsic motivation did not differ significantly across the handgrip-based groups, and only a small difference emerged for extrinsic motivation in relation to left handgrip strength. This more cautious pattern is worth emphasizing, because the relationship between physical activity and academic motivation appears to be more complex than the relationship with psychological well-being. Recent evidence supports the existence of such a link, but also suggests that it is often indirect. For instance, Ma et al. (2026) reported that mental health mediated the association between physical activity and academic motivation, while Duong et al. (2025) found that academic motivation was associated with mental health and quality of life among medical students. Taken together, these findings suggest that movement-related behaviors may support academic motivation, but usually through broader psychological mechanisms rather than through a simple direct effect.

The fact that our IPAQ-SF-based analyses did not strongly confirm the starting hypothesis also deserves attention. This does not necessarily contradict the wider literature. Rather, it may reflect a known limitation of self-report measures of physical activity, which are sensitive to recall bias, social desirability, and imprecise estimation of intensity or duration. Several recent studies in university populations have shown that the effects of physical activity on well-being may depend not only on how often students are active, but also on why they are active, how they regulate emotions, how much social support they perceive, and whether their activity patterns are stable over time (White et al., 2024; Zhong, 2024; Elmahgoub et al., 2025). In this context, the stronger findings for handgrip strength in our study are

scientifically meaningful, because they suggest that objective physical functioning may be a more robust correlate of student well-being than self-reported activity frequency alone.

The current findings are also relevant in light of recent work linking physical activity with other dimensions of student adjustment, including sleep, resilience, life satisfaction, and emotional regulation. Recent studies have shown that physical exercise may improve sleep quality through pathways involving health literacy and life satisfaction, and may also support life satisfaction through resilience and reduced negative emotions (He et al., 2025; Huang et al., 2025). Other studies have reported that physical activity is positively associated with subjective well-being through self-esteem, resilience, and perceived social support (Pan et al., 2025). Although these variables were not all tested directly in the present study, they help situate our results within a larger biopsychosocial framework, where physical functioning, emotional balance, and adaptive academic behavior are interconnected rather than isolated domains.

A key contribution of the present article lies in its interdisciplinary design and in the combination of subjective and objective indicators within the same student sample. Many recent studies focus either on self-reported physical activity or on mental health outcomes alone. By contrast, the present study brought together WHO-5, WHOQOL-BREF, Academic Motivation Scale, IPAQ-SF, and objective functional measures such as handgrip strength and sit-and-reach performance in a single framework. This is an important point of novelty, because it allows a more integrated perspective on student development, one that includes physical, psychological, and educational dimensions simultaneously. At the same time, the results suggest that simple self-report activity measures may not capture the full functional and psychosocial profile relevant to student well-being.

A second element of novelty is that this study highlights the specific relevance of muscular strength as a correlate of student well-being in a higher education context. Much of the recent literature emphasizes general physical activity or exercise participation, but fewer studies in university populations compare psychological outcomes according to objective strength markers. In our data, both right and left handgrip strength consistently differentiated students in terms of well-being and perceived health. This gives the study applied value, because handgrip testing is simple, low-cost, and easy to integrate into university screening or health promotion settings. It also supports the idea that student well-being programs may benefit from including not only counseling and health education, but also opportunities for structured physical training and physical fitness monitoring.

The study also has limitations that should be stated clearly. First, the cross-sectional design does not allow causal inference. Second, the sample was drawn from a single university, which limits generalizability. Third, the discrepancy between the weaker IPAQ-SF findings and the stronger handgrip findings suggests that different physical indicators may reflect different aspects of behavior and adaptation. Fourth, academic motivation appears to be influenced by a broader set of academic, social, and psychological factors than those captured here. For these reasons, future studies should use longitudinal and multivariable designs, test mediation pathways more explicitly, and compare subjective and objective activity indicators in a more detailed way. Recent studies using mediation models, latent profiles, and large student samples suggest that this direction is both feasible and valuable for the field (Ma et al., 2026; Chen et al., 2026; Zhang et al., 2025).

In order for all students to achieve their full potential, the traditional, transmissive approach to educational relationships and the teaching process must be replaced by one that allows students to actively engage and participate. Creating a cooperative partnership between students and teachers through which to value diversity, learning and personal development can be the solution to this challenging period in academic education (Mag, A. in Abegglen et al., 2023, p. 139).

Overall, the present findings strengthen the view that student well-being in higher education should be approached through an integrated biopsychosocial lens. The article adds evidence that objective

physical fitness, especially muscular strength, is meaningfully associated with psychological well-being and perceived quality of life in university students. It also adds nuance by showing that the relationship with academic motivation is less direct and that self-reported physical activity alone may not fully explain variation in student well-being. This combination of confirmation and nuance represents the main scientific value of the study and supports the development of more comprehensive, interdisciplinary student support strategies.

5. Conclusions

This study examined the relationship between physical activity, functional capacity, psychological well-being, quality of life, and academic motivation in a sample of university students. The findings showed that muscular strength, assessed through both right and left handgrip performance, was consistently associated with higher levels of well-being, better perceived physical health, and better psychological health. In contrast, the associations with academic motivation were weaker and less consistent, while the self-reported physical activity indicators did not provide sufficiently strong evidence to fully support the initial hypothesis.

These results support the view that student well-being in higher education should be approached from an integrated perspective that includes both physical and psychological dimensions. The study also suggests that objective indicators of functional fitness may offer more robust information about student well-being than self-reported physical activity alone. In this respect, muscular strength appears to be a relevant and practical marker in the assessment of student health and adaptation.

The main contribution of the present research lies in its interdisciplinary framework and in the combined use of validated psychological instruments and objective physical fitness measures within the same student sample. By linking physical, psychological, and academic dimensions, the study adds a more comprehensive perspective on student development in higher education.

At the same time, the findings should be interpreted in light of several limitations. The cross-sectional design does not allow causal inferences, the sample was drawn from a single university, and some variables were based on self-report measures, which may be affected by recall and response bias. Future research should use longitudinal and experimental designs, include more diverse student populations, and further explore the mechanisms through which physical fitness and physical activity influence psychological well-being and academic functioning.

Overall, the present study highlights the importance of integrating physical and psychological well-being in university settings and supports the development of interdisciplinary strategies aimed at improving student health, adaptation, and quality of life.

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