Multivariate Training Programs During Physical Education Classes

Avelino Silva

Tese para obtenção do Grau de Doutor em
Ciências do Desporto
(3º ciclo de estudos)

Orientador: Prof. Doutor Daniel Almeida Marinho
Coorientador: Prof. Doutor Ricardo Manuel Pires Ferraz

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Eu, Avelino Silva, que abaixo assino, estudante com o número de inscrição (D2605) do 3º Ciclo de Estudo da Faculdade de Ciências Sociais e Humanas, declaro ter desenvolvido o presente trabalho e elaborado o presente texto em total consonância com o **Código de Integridades da Universidade da Beira Interior**.

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Avelino da Silva

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List of Publications

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Abstract

Physical education plays a fundamental role in the integral development of the student, allowing cognitive, psychomotor, and affective development, while stimulating healthy lifestyles, socialization, team spirit, and sports practice. One of the strategies that can increase its effectiveness, and which has been implemented in the school context, is the multivariate training program, which, duly adapted, allows the inclusion of different contents and the development of different individual skills, as well as improving the practice of physical, technical, and tactical exercises. However, a lack of evidence has been reported on this topic. The main purpose of this thesis was to analyze the effects of the multivariate training program in game performance and physical fitness during physical education classes. In addition, for a more in-depth analysis, the effect of the multivariate training program on the relationship between the components (physical fitness and game performance) and the variables of each component considered was also studied. To accomplish these objectives, the following sequence was used: (i) to review the available literature; (ii) to investigate the effects of a multivariate training program on physical fitness and tactical performance during physical education classes (iii) to determine the magnitude of the correlation between the physical fitness and game performance components before and after the application of the aforementioned training program.

Keywords

Physical Education, Multivariate Training Program, Physical Fitness, Game Performance.

Resumo

A Educação Física desempenha um papel fundamental no desenvolvimento integral do aluno, permitindo o desenvolvimento cognitivo, psicomotor e afetivo, estimulando estilos de vida saudáveis, a socialização, o espírito de equipa e a prática desportiva. Uma das estratégias que pode aumentar a sua eficácia, e que tem vindo a ser implementada em contexto escolar, é a utilização de programas de treino multivariados, que, devidamente desenhados, permitem a inclusão de diferentes conteúdos e o desenvolvimento de diferentes competências individuais, bem como a melhoria da prática de exercícios físicos, técnicos e táticos. No entanto, há falta de evidência experimental sobre este tópico. O principal objetivo desta tese foi analisar os efeitos do programa de treinamento multivariado no desempenho de jogo e na aptidão física durante as aulas de educação física. Além disso, para uma análise mais aprofundada, também foi estudado o efeito do programa de treino multivariado na relação entre as componentes (aptidão física e desempenho no jogo) e as variáveis de cada componente consideradas. Para atingir esses objetivos, a seguinte sequência foi utilizada: (i) revisão da literatura disponível; (ii) investigar os efeitos de um programa de treino multivariado na aptidão física e no desempenho tático durante as aulas de educação física (iii) determinar a magnitude da correlação entre as componentes da aptidão física e do desempenho de jogo antes e após a aplicação do referido programa de treino.

Palavras-chave

Educação Física, Programa de Treino Multivariado, Aptidão Física, Desempenho em Jogo.

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List of Abbreviations

AA	Appropriate action
AI	Adaptability index
AS	Abdominal strength
BS	Basic school
CG	Control group
CI	Confidence interval
D	Cohen d
DMI	Decision making index
ES	Effect Sizes
FITescola	Programa FITescola
FMS	Fundamental motor skills
GI	Game involvement
GP	Game performance
GPAI	Game Performance Assessment Instrument
HI	Horizontal impulse
HS	High school
IA	Inappropriate action
IG	Intervention group
PE	Physical Education
PICOS	Population-Intervention-Comparators-Outcomes
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QS	Qualitative effect size
R	Repetitions
S	Sessions
SD	Standard deviation
SCA	Student-Centered Approach
SE	Sports education
SEI	Skill execution index
SI	Support Actions index
SSGs	Small-sided basketball games
T	T-test
TGFU	Teaching Games for Understanding
TL	Training Load

Chapter 1. General Introduction

Framework of Physical Education

The European Union encouraged Member States to promote physical activity through the Sports Work Plan (2014-2017). The plan aimed to improve physical education in schools by prioritizing the development of motor skills during childhood. It emphasized daily play, games, and sports participation to develop vital skills. The curriculum offered a variety of activities, including outdoor sports and extracurricular opportunities. Key principles included ethical education, teamwork, and social inclusion while avoiding stereotypes. The integration of health education concepts and the promotion of interdisciplinary cooperation were also encouraged. Inclusivity has been given priority, with adapted approaches for people with disabilities. It was also recommended that mandatory time for physical education be increased to 5 hours per week, with specific developmental goals. Assessment of individual progress, feedback, teacher qualifications, enhanced training, extracurricular activities, community partnerships, accessible facilities, professional development, parental involvement, adherence to safety guidelines, monitoring and evaluation, integration with health education, awareness campaigns, and policy support were considered critical to fostering an active school environment (European Council, 2011).

The curriculum for the first four years of schooling in Portugal focuses on three key areas: Skills and Manipulations, Movements and Balance, and Games. These areas are designed to develop motor skills, encourage physical exploration, and promote interactive play among young students. As students move into their third and fourth years, additional blocks such as gymnastics are introduced. Students also have the opportunity to choose activities such as nature exploration, skating, nature trails, or swimming to enhance their learning experience. During early elementary education, students work on motor skill development, coordination, and physical well-being through activities such as Skills and Manipulations and Movements and Balance. As they progress, they continue to perfect these skills and explore similar areas to increase the focus on games. Gymnastics is introduced in the third year and additional activity options are available in the fourth year. These activities contribute to the acquisition of motor and coordination skills and lay the foundation for a healthy lifestyle. In the second and third cycles of primary and secondary education, physical education is divided into its three main areas. The first is physical activity, which includes several domains such as physical and motor activities, rhythmic expressive activities, nature exploration activities, and traditional games. These domains cover a wide range of sub-areas, including specific subjects such as team sports, gymnastics, track and field, volleyball, and ballroom dancing. The second area is Physical Fitness, which focuses on assessing and demonstrating physical performance and fitness levels based on the FIT escola. Students are encouraged to participate in activities that improve physical fitness and contribute to overall health. Finally, there is Knowledge. Students acquire knowledge to improve and maintain physical fitness and understand the social structure and phenomena related to physical activity. They also learn about the processes involved in improving physical fitness and gain insight into the social aspects of engaging in physical activity (Ministério da Educação da República Portuguesa, 2018).

Physical Education Advantages

Physical education plays an important role in the development of children's gross motor skills and physical abilities. It provides opportunities to use large muscle groups and improve coordination and body control (Olrich, 2002). Research shows a strong link between basic movement skills and engagement in physical activity. The preschool and primary school years are critical for acquiring and refining these skills through practice and reinforcement (Bailey, 2006). Motor skill proficiency in childhood has long-term implications for physical activity levels in adolescence and adulthood. Difficulties in mastering motor skills may discourage future participation in sports and physical activity. Therefore, establishing a strong foundation of basic body control skills and fostering motivation are critical to promoting a lifelong commitment to a healthy and active lifestyle (Williams et al., 2008; Robinson et al., 2012; Morgan et al., 2008).

Teacher communication and enforcement of rules has a tremendous impact on student behavior that extends beyond the classroom to their homes and other environments. In addition, teachers' competence plays an important role in shaping students' character by effectively answering questions and using their extensive knowledge and experience. By promoting intimate connections with their students, physical education teachers engage in interactive methodologies that involve playful and physical activities. By consistently integrating these activities and relevant resources, they actively contribute to the development of students' character. Research supports the integration of character development into elementary physical education. Collaboration between teachers and parents is essential to effectively monitor student behavior at home. However, challenges arise from the lack of coordination and cooperation within the education system. It is up to teachers to be positive role models because their behavior has a significant impact on students' attitudes and actions. Therefore, schools and physical education teachers should conscientiously strive to foster character development in their students (Suherman, 2018).

Perceived physical self has a significant impact on youth's physical activity, as evidenced by studies linking it to activity levels (e.g., high/low, active/nonactive) (Fox, 1989; Kipp & Weiss, 2013; Raudsepp et al., 2002) and fitness (Grubber, 1986). In addition, perceived competence, a key component of physical self-perception, correlates with both activity behavior and actual motor skill performance (Jones et al., 2010; Raudsepp & Liblik, 2002). This perception plays a central role in shaping self-esteem, a multidimensional construct that includes social, physical, and cognitive aspects that contribute to overall self-worth (Harter, 1978, 1981, 1982). Based on Harter's model, which is rooted in the "effectance" theory, individuals engage in behaviors to understand and influence their environment, ultimately stimulating a sense of efficacy (White, 1959). Regular physical activity provides significant health benefits to young people, including both their mental and physical well-being (Horst et al., 2007, Sallis et al., 2000). Conversely, inadequate physical activity and poor fitness levels are associated with increased risk factors for cardiovascular disease in adolescents. Physical activity levels are inextricably linked to fitness levels, and recent studies have highlighted the relationship between cardiorespiratory fitness and obesity and cardiovascular disease indicators (Church al., 2007; Ortega et al., 2008). However, as children transition into adolescence, their participation in physical activity tends to decline, resulting in a subsequent decline in cardiorespiratory fitness (Nader et al., 2008; Dollman & Olds, 2007). Therefore, identifying factors that influence activity and fitness is of paramount importance in developing strategies to improve the health of young people (Barnett et al., 2008).

The important role of the physical education teacher

The primary responsibilities of a physical education teacher include facilitating maximum physical activity during class time, teaching skills that can be applied outside the physical education setting, motivating students to be physically active, and assuming the school’s role as a provider of physical activity. Providing additional opportunities throughout the school day is important to ensure that students receive and practice adequate physical activity. Several factors contribute to maximizing physical activity in the classroom, such as organizing space effectively, ensuring sufficient equipment for all students, and planning structured activities with high participation rates. It can be said that by prioritizing the quality and quantity of physical activity, students can improve their skills, knowledge, and physical fitness (Rink et al., 2010).

Another important aspect of the physical education teacher's role is to teach skills and activities that transfer to physical play beyond the classroom. The skills learned in physical education can directly influence a child's participation in a variety of physical activities, from tag games in kindergarten to jump rope in second grade to kickball in later years. Confidence in one's own abilities positively influences engagement in group activities, whereas lower ability students, especially in the upper grades, may be reluctant due to fear of failure or peer judgment. Equipping students with the necessary skills is essential for their active participation in physical activity (Rink et al., 2010). In the field of physical education, teacher instruction includes the art of delivering quality task presentations and establishing a structured framework prior to activities. Second, it involves providing timely corrective feedback or structural guidance during the activities. It is crucial that this feedback is accepted and perceived as legitimate by the learners. These instructional behaviors, such as task presentation and corrective feedback, are of immense importance in the field of physical education. They serve as variables that can significantly predict pedagogical effectiveness and ensure improved student-learning outcomes. As a result, it is imperative that teachers develop the ability to present tasks in a way that empowers students to embark on their learning journey with confidence. In addition, providing corrective feedback that builds students' confidence in their ability to correct mistakes is paramount (Mouratidis et al., 2010; Vergara-Torres et al., 2020). This approach effectively reduces feelings of incompetence associated with task performance, even as corrective feedback addresses areas of poor execution. By using these sophisticated instructional strategies, teachers can create an environment conducive to learning and growth (Garza-Adame et al., 2017). And by using eloquent language and appropriate delivery techniques, teachers can instill a sense of belief and motivation in students to excel at their tasks. Ultimately, this approach, as advocated by these scholars, not only improves students' overall performance, but also fosters a positive and constructive learning atmosphere (Vergara-Torres et al., 2021).

The role of the physical education teacher in motivating children to be active is critical. They can promote community activities, assign physical activity-related homework or fun assignments, take an interest in students' physical activity outside of class, and lead by example. Awareness of community-based physical activity opportunities such as recreational sports, dance classes, gymnastics programs, and martial arts can be promoted through bulletin boards, school websites, and regular announcements. By promoting physical activity and fostering an active environment, teachers inspire students to lead active lifestyles (Rink et al., 2010).

The decisive role of a well-organized physical education class

The teacher planning process begins with asking outcome-based questions: "What do I want students to know and be able to do?" (Rubio, 2017). A mastery objective is then set to guide students toward reaching the desired outcome. Saphier et al. (2008) suggest that linking involvement, activity, and coverage leads to purposeful planning and the creation of mastery goals. In addition, thinking skills goals help students transfer their skills to different situations. When planning for student learning, some authors recommend that teachers first identify mastery goals and then apply the five levels of teacher thinking. Referencing national standards and grade-level outcomes helps teachers design lessons that enable students to successfully achieve their grade-level goals. It is important to note that while student enjoyment and engagement are critical, instruction must be linked to mastery objectives to ensure consistent and predictable outcomes (Saphier et al., 2008).

To promote the transfer of learning and meaning beyond the classroom, students should practice mental processes in a variety of contexts. Learning and practicing skills in only one context can hinder their application and relevance elsewhere. When planning lessons, teachers should first identify the specific thinking skill and then provide opportunities to use it in different contexts. For example, elementary school students can engage in a variety of aerobic movements and games to improve cardiorespiratory endurance. Middle school students can calculate heart rate zones and participate in appropriate activities. High school students can create personalized fitness plans that include a variety of exercises. By designing thinking skills objectives, students can transfer knowledge and adapt to different situations (Wiggins & McTighe, 2008). When designing lessons, it is important for teachers to consider student enjoyment, engagement, and participation. Saphier et al. (2008, p. 374) refer to this as involvement thinking, which focuses on making the learning experience inviting and accessible to all students. According to Placek (1983), student enjoyment, behavior, and misbehavior have a significant impact on teacher planning. However, it is important for teachers to strike a balance between class participation and student learning outcomes. Selecting activities based solely on ensuring whole-class participation and fun may prioritize participation over meaningful learning. Instead, teachers should use involvement thinking as a form of differentiated instruction. This means providing activities that give students choices, involve different levels of participation, use different types of equipment, and include tasks of varying difficulty. This allows teachers to meet individual student needs and promote engagement and learning. Lesson planning involves selecting activities that are aligned with learning objectives and grade-level outcomes. Well-planned lessons prioritize deliberate practice, mastery goals, and achievement of desired outcomes. This approach, called activity thinking, emphasizes learning over mere engagement. Clearly identified outcomes guide student learning while communicating the purpose of the lesson and the knowledge and skills expected. Adding thinking skills and mastery objectives enhances the lesson. Presenting mastery goals in the classroom using age-appropriate language serves as a roadmap for student learning. It helps students understand expectations, assess their progress, and make connections between goals and planned activities (Saphier et al., 2008).

Effective teacher planning goes beyond classroom activities and considers the application of knowledge outside of school. It begins with clear mastery and thinking objectives for the specific learning domain, then incorporates coverage, activities, and engagement. Using lesson hooks and essential questions that relate to physical activity outside of school is critical to engaging students from the start. It is important to continually check for understanding and progress toward the mastery goal throughout the lesson and to encourage students to apply their skills outside of school, emphasizing the practical relevance of physical education for lifelong physical activity. In summary, effective teacher planning involves engaging students with essential questions and hooks, monitoring understanding, and promoting the application of skills beyond the classroom (El-Sherif, 2021).

Physical education class preparation

Research in physical education has demonstrated the importance of effective lesson planning in relation to teacher effectiveness and evaluation. Several studies have underscored the importance of careful planning in the teaching of physical education. Accomplished physical education teachers exhibit certain characteristics in their planning process. They have a clear understanding of the goals they want to achieve and the strategies they will use to attain them. They also take into account the abilities and individual needs of their students and tailor appropriate learning experiences accordingly. These teachers meticulously structure their lessons and provide clear and appropriate instruction. They set realistic yet challenging goals that facilitate learning for all students. Skillful questioning techniques are used to increase student understanding and engagement. In addition, effective teachers use appropriate classroom organization and management strategies to improve useful class time and foster a positive and productive learning environment. Finally, they have contingency plans to deal with unforeseen circumstances and emergencies (Kyrgyridis et al., 2006; O'Sullivan & Tsangaridou, 1992; Chen et al., 2011; Kyrgiridis et al., 2014).

The Multivariate Training Programs

In the area of physical education, one strategy that has shown promise in increasing its effectiveness is the implementation of a multivariate and comprehensive training program. This program, when properly tailored, allows for the incorporation of diverse content and the cultivation of various individual skills, ultimately promoting improved physical training and game performance. This approach includes the integration of strength and skill-based training, interventions rooted in physical education principles, sports-based training programs, and lifestyle interventions focused on physical activity. Through the use of this multifaceted methodology, physical education classes are designed to provide students with a holistic and well-rounded educational experience that enhances their overall development and promotes a healthy and active lifestyle (Weaving et al., 2017).

Multivariate training programs offer the opportunity to improve not only physical fitness, but also motor skills and creativity. This type of program may also have some social and psychological benefits for youth, such as improving their self-esteem and reducing depressive symptoms (Borbón-Castro et al., 2019). According to the results obtained, the multivariate training program tested seems to be an excellent tool and a pedagogical alternative for the integrated development of tactical indicators such as understanding, interpretation and technical/tactical execution of the game.

In the traditional model, a physical education class uses reproductive (rather than discovery) teaching methods that prioritize efficient knowledge transfer. These classes focus on teaching basic skills and techniques within a highly structured lesson (Rink, 1993). Therefore, students are expected to be attentive, well-behaved, and disciplined, with their attention focused primarily on motor rather than cognitive tasks (Rosado & Mesquita, 2009; Rosenshine, 1979). Early research on the impact of this teaching approach suggests its effectiveness in improving students' skill performance, particularly in less complex skills and at younger ages (Brady, 1998; Rink, 1993). However, a commonly identified weakness of this controlling teaching style is that it undermines students' ability to construct their own learning, leading to a decrease in their autonomy, decision-making skills, and cognitive and social processes (Ennis, 2014; Metzler, 2017; Siedentop et al. 2020). In other words, skills related to the tactical component may be lost with this approach. According to Lusianti (2015), in the traditional warm-up, there are two main types of heating during warm-up activities: static heating and dynamic heating (commonly referred to as jogging). These activities are traditional but can become repetitive and boring for students. Therefore, it is important to find ways to make warm-up exercises more engaging and keep students interested. Previous research has explored the use of games in warm-up routines and found that incorporating games can help eliminate boredom and disinterest among students (Lusianti, 2015). In addition, warming up with games has been shown to significantly increase student enjoyment by up to 91.5% and increase their heart rate to the optimal training zone (Astiati et al., 2021).These game-based warm-up activities are particularly appropriate for elementary school students because they not only make the warm-up process more enjoyable, but also increase their comprehension, self-confidence, and motivation to learn (Zakaria, 2021).

In today's era of increasingly challenging and engaging environments, one would expect a greater emphasis on the early development of motor, social, and cognitive skills (Brown, 2010; Osorio-Valencia et al., 2017). However, the current situation presents a contrasting reality, characterized by a rapid increase in sedentary lifestyles, interpersonal problems, and decreased exposure to nature. These factors pose a significant threat to the development of children's motor skills (Duncan et al., 2019; Flynn et al., 2006). There is evidence to suggest that beginning this type of training during adolescence is highly beneficial, as it allows the body to be trained during a period of accelerated musculoskeletal growth, coinciding with a decline in balance and coordination due to this growth (Zolotarjova et al., 2018; Janssen & LeBlanc, 2010). Therefore, in the 1990s, several scholars introduced alternative approaches to traditional teaching methods in physical education. These alternatives, according to Ennis (2014), are considered the second generation of models and include sports education (SE) (Siedentop et al., 2020), teaching games for understanding (Bunker & Thorpe, 1982), and teaching personal and social responsibility (Hellison, 2011). A common aspect of these models is the requirement that students act autonomously, responsibly, and competently in the face of challenges, risks, and opportunities. These models adopt a "Student-Centered Approach" (SCA) based on constructivist and social learning theories (Chandler & Mitchell, 1991) to promote tactical and social skills such as problem-solving and decision-making, and to allow for an active role in knowledge construction and the development of autonomy and responsibility skills (Lynch, 2019). Laakso et al. (2022)

stated that coaches and physical education teachers should strategically create and manipulate small-sided games for players and students to develop their tactical, technical, physical, and social skills. In this way, they can increase the opportunities for players to explore and develop synergistic relationships with their teammates. Through these deliberate interventions, players can develop new skills and effectively explore competitive environments from multiple perspectives, transcending the limitations of early specialization. Furthermore, this approach allows players to acquire skills of individual and collective performance as they try to restore the spatio-temporal balance in relation to the ball's position. In addition, Gunawan et al. (2023) demonstrated that the implementation of game-based warm-up not only increases students' motivation to actively participate in warm-up activities, but also contributes to their holistic development, which includes skill improvement, social interaction, and knowledge acquisition, as opposed to traditional warm-up.

Physiological systems are highly complex and are influenced by a variety of factors that affect training outcomes. Each exercise or training session presents unique physiological, biomechanical, and psychological demands. These requirements differ not only based on prescribed parameters such as sets, repetitions, and duration, but also based on the type of exercise, such as strength training or sport-specific training (Soligard et al., 2016; Cardinale and Varley, 2017). As a result, relying solely on a single independent variable to measure Training Load (TL), whether internal or external, is unlikely to be sufficient. To address this challenge, researchers have proposed a comprehensive representation of TL (Cardinale and Varley, 2017). This approach recognizes the limitations of a univariate approach, as well as the potential loss of important information that could help explain the correlations between imposed TL and changes in fitness, performance, or injury. The simultaneous collection of numerous TL variables has become common practice because recent research has shown that a single TL variable does not explain a significant amount of the variance explained by multiple internal and external TL factors. This is particularly evident when considering different training modes, such as technical-tactical training, high-intensity interval training, or sprint training (Weaving et al., 2014, 2017).

Although there is a significant amount of research discussing different teaching models and pedagogical approaches in education, there is a noticeable lack of literature when it comes to the effects of implementing multivariate programs in physical education classes, regardless of the specific teaching models or pedagogical practices utilized. There is a clear research gap in the literature that requires further investigation and empirical studies to deepen our understanding of the potential benefits and outcomes associated with incorporating multivariate programs into physical education.

Further research on the effects of multivariate programs in physical education could provide useful data on how multivariate programs affect students' physical, cognitive, and social development. This will help to better understand the possible synergies and overall effectiveness of these programs by incorporating different components such as aerobic exercise, strength training, flexibility exercises, and skill-based activities. In addition, studying the long-term effects of multivariate programs will shed light on the impact of multivariate programs on students' overall health, fitness, and lifelong physical activity habits. This study could aid in the development of a comprehensive physical education program that focuses on the long-term well-being of students.

In conclusion, despite extensive studies on educational instructional models and pedagogical techniques, more research is needed on the influence of multivariate program implementation in physical education. Therefore, more research is needed to examine the potential benefits, outcomes, and long-term effects of these initiatives to fill this knowledge gap. This commitment will enable the promotion of evidence-based practice in physical education, thereby improving the overall educational experience for students.

Considering the above, the main purpose of this thesis is to fully analyze the effects of the multivariate training program on two different but very important components to be developed during physical education classes: game performance and physical fitness. Moreover, for a more in-depth analysis, it will be interesting to study the effects of the multivariate training program on the relationship between the components (physical fitness and game performance) and the variables of each component considered.
It was hypothesized that the use of multivariate training programs will have a positive effect on physical fitness and tactical performance and that there may be a positive correlation between physical fitness and game performance, which may further support the use of multivariate training programs in physical education classes and especially in place of traditional warm-ups.

This thesis is organized and developed in the following order:

- Chapter 2 presents the literature review and a review study of the theoretical basis of the multivariate training program (Study 1).

- Chapter 3 presents the experimental study developed to investigate the effects of a multivariate training program during physical education classes (Study 2).

- Chapter 4 presents the correlational study that was designed to verify the magnitude of the association between tactical performance and physical fitness levels in young school students during the teaching of the didactic unit of basketball, before and after the application of a multivariate training program (Study 3).

- Chapter 5 presents the main conclusions of the thesis.

- Chapter 6 presents practical applications and suggestions for future research.

Chapter 2. Literature Review

Multivariate Training Programs during Physical Education Classes in School Context: Theoretical Considerations and Future Perspectives

Introduction

Physical education plays a fundamental role in the integral development of the student, enabling cognitive, psychomotor, and affective development, while stimulating healthy lifestyles, socialization, team spirit, and sports practice (Bailey, 2006; Ferraz et al., 2020). In fact, the benefits of regular physical activity are numerous, with a focus on improving cardiovascular and respiratory function, reducing levels of anxiety and depression, increasing feelings of well-being, and developing cognitive and social skills (Warburton & Bredin, 2017; Ács et al., 2020). In contrast, sedentary lifestyles are associated with decreased functional capacity, increased morbidity and mortality, and increased prevalence of chronic diseases in adulthood (González-Gross & Meléndez, 2013). Therefore, it is essential to promote healthy lifestyles and physical activity in childhood, which can play a key role in preventing physical inactivity in adolescence and adulthood and have a positive impact on overall health (Kumar et al., 2015). Today, due to the existence of an increasingly challenging and stimulating world, it would be expected that there would be a concern for the development of motor, social, and cognitive skills from an early age (Brown, 2010; Osorio-Valencia et al., 2018). However, the reality is different, with an exponential increase in sedentary lifestyles, interaction problems, and reduced contact with nature, which puts the development of children's motor skills at risk (Flynn et al., 2006; Sarmento et al., 2018).

In particular, with regard to physical education, one of the strategies that can increase its effectiveness, and which has been implemented in the school context, is the multivariate training program, which, duly adapted, allows the inclusion of different contents and the development of different individual skills, as well as improving the practice of physical exercise (Flynn et al., 2006; Sarmento et al., 2018; Couturier et al., 2014; Biddle & Mutrie, 2007). This methodology has been used in physical education classes to integrate strength- and skill-based training, physical education-based interventions, sports-based training programs, and physical activity-based lifestyle interventions (Fox & Riddoch, 2000; Faigenbaum & Mediate, 2006; Zolotarjova et al., 2018). However, a lack of evidence on the characteristics of multivariate training programs has been reported due to variability present in the application of the methods in different contexts (Janssen & LeBlanc, 2010). Furthermore, there are different methodological proposals in this sense, with different objectives and duration, which still do not reach a consensus on their application, and therefore more research is needed on this subject. Multivariate training program have been conceptualized in some studies as a physical education-based strategy by applying an integrated evidence of teaching-learning methods for school-age children and youth.

This narrative review highlights the potential benefits of using multivariate programs on physical fitness, motor proficiency and creativity in children and young people during physical education classes. Ultimately, a review is needed to summarize the findings and emerging evidence on the effects of using multivariate programs in young populations.

Materials and Methods

Literature Search Strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the Population-Intervention-Comparators-Outcomes (PICOS) design were followed to search for studies included in the current narrative review. To conduct this narrative review, the available literature was examined through a structured and exploratory search of the Web of Science (Core Collection: Citation Indexes), PubMed, and SPORTDiscus electronic databases. Articles published in 2021 or earlier were considered. The search strategy included search terms that combined one of two primary keywords ("multivariate training programs" and "physical education"), with a second keyword ("children", "youth", "physical fitness") and a third keyword ("motor proficiency", "creativity"), using the Boolean operator.

Inclusion criteria for these articles were: (1) relevant data on the use of multivariate training programs; (2) effects of multivariate training programs on motor proficiency and creativity. Studies were excluded if: (1) They did not include data relevant to this study; and (2) were conference abstracts. A validated protocol was used to assess the quality of the studies (Sarmento et al., 2018; Teixeira et al., 2021). Articles were screened by evaluating the title and abstract. All articles that did not focus on the study were excluded. A total of 97 articles were considered relevant for this review. All articles were read in detail and assessed for relevance and quality by two senior researchers with experience and relevant publications in the field. Disagreements between the authors on the selection of the studies were resolved with the assistance of a third reviewer. The authors did not prioritize authors or journals. All articles that did not meet the criteria were excluded. A total of 144 duplicate records were removed and 100 articles were removed based on the title and abstract according to the inclusion and exclusion criteria. After this procedure, 68 articles remained for analysis using the PRISMA flowchart (Figure 1).

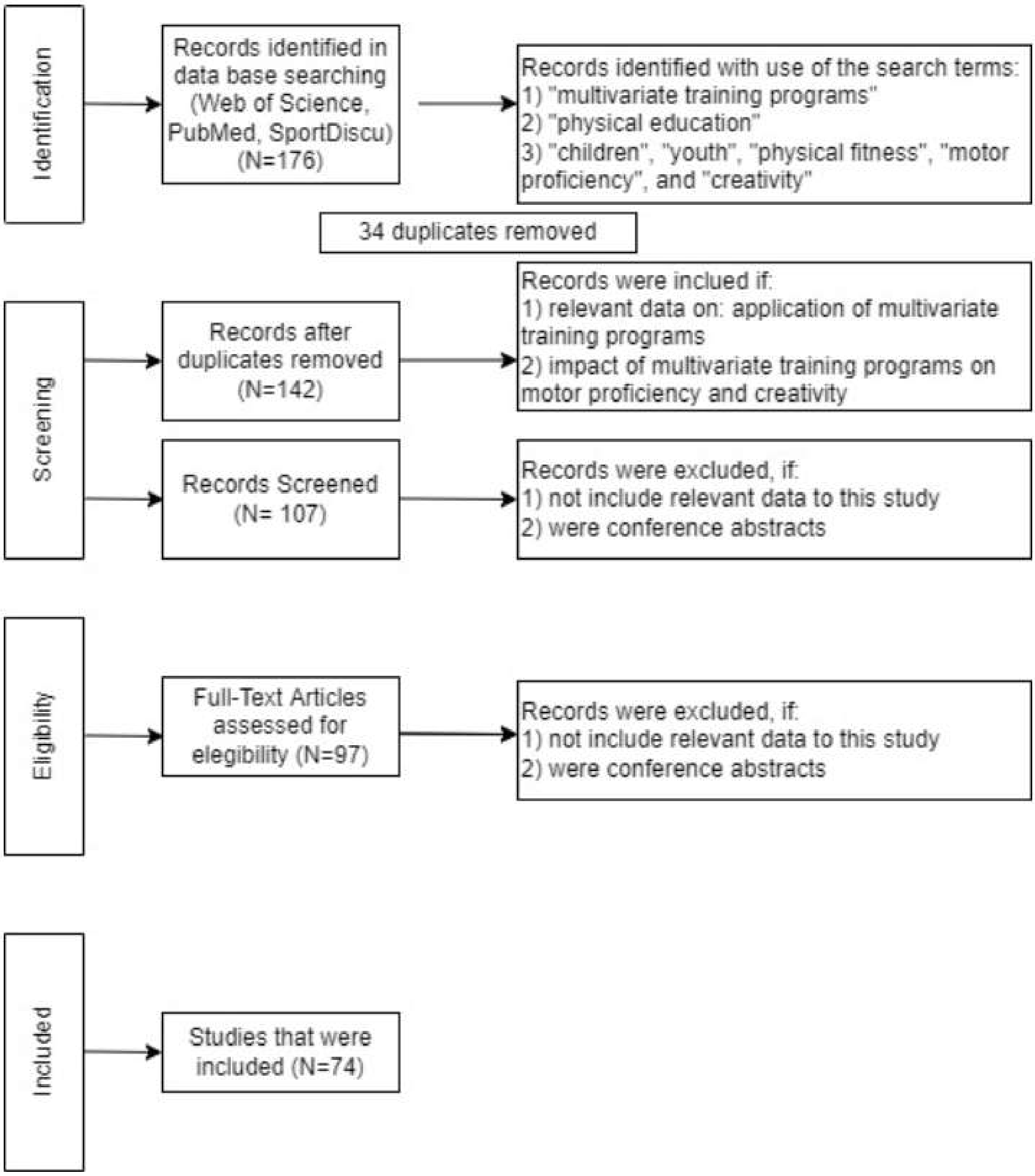


Figure 1. Prisma 2009 flowchart**.**

Quality Assessment and Narrative Revision

The current narrative review was based on the methodological quality by the CONSORT stands for the Consolidated Standards of Reporting Trial (Cuschieri, 2019). Subsequently, a survey and narrative interpretation were conducted to examine the theoretical considerations and future perspectives of multivariate training programs in physical education classes. The summary of previous research was organized into: (a) theoretical background; (b) research gaps and issues. *Physical Education classes* and *Multivariate Training Programs* were further analyzed to reveal the explanation of the subject matter, as well as the practical application and suggestions for further research.

Summary of Previous Research

Theoretical Background

Regular participation in physical education classes has the potential to develop physically literate individuals and can stimulate the skills and confidence to engage in physical activity as a lifestyle choice from an early age (Couturier et al., 2017). In addition, a substantial body of research has shown that physical activity in children can influence a number of physiological and psychological variables (Biddle & Mutrie, 2007; Fox & Riddoch, 2000). For this reason, there has been a growing interest in the knowledge derived from the application of multivariate training programs to children, highlighting the significant benefits that have been reported previously (Faigenbaum & Mediate, 2006; Zolotarjova et al., 2018). In fact, according to previous research (Janssen & LeBlanc, 2010), these types of programs are beneficial for younger populations as long as they are prescribed in sufficient amounts and with functional loads that allow them to exceed their usual muscular activity in accordance with the methodological recommendations for training in children and young people. However, previous research on the use of multivariate training programs in the context of physical education classes is inconclusive and shows conflicting results (Strong et al., 2005; Hajihosseini, 2016; Zachopoulou et al., 2006; Nielsen et al., 2019; Mura et al., 2015; Kokkonen et al., 2018; Spanaki et al., 2016). In general, this type of program consists of several stations designed to improve strength, balance, resistance, and coordination (Spanaki et al., 2016). According to Strong et al. (2005), school-aged children and adolescents should participate in moderate to vigorous intensity exercise for 60 minutes or more per day. The authors also concluded that physical activity needs to be developed through appropriate, enjoyable, and varied activities (Spanaki et al., 2016). Strength training sessions should be performed at least twice a week in a non-consecutive sequence

(Strong et al., 2005; Hajihosseini, 2016). Hajihosseini (2016) advocated that school-based interventions need to be a multi-component approach that simultaneously targets curriculum, school environment and policies, as well as community linkages to promote physical activity and motor development. Kokkonen et al. (2018) have mentioned that creative physical education-based approaches can increase students' perceptions of a task-supportive physical activity climate, which predicts their subsequent motivation for leisure-time physical activity outside the school context and overall physical activity.

Recent studies suggest that children and adolescents may benefit from this type of program in a school context (Ferraz et al., 2020; Duncan et al., 2019; Faigenbaum & Mediate, 2006; Errisuriz et al., 2018), and that its use may also simultaneously enhance the development of motor proficiency (Pan et al., 2014) and creativity (Zachopoulou et al., 2006). In this regard, several studies have concluded that physical activity has beneficial effects on cognitive processes (Román et al., 2018; Kashihara et al., 2009; Vanhelst et al., 2016) and that physical education classes are an ideal place to stimulate creativity in children (Doron, 2016). However, the actual effect of physical activity on cognitive processes depends on several factors, including environment, type, duration, and intensity (Davies et al., 2013, Pesce et al., 2009; Kamijo et al., 2007). A recent review (Davies et al., 2013) described the possible insights and strategies that physical education teachers and educators should explore in the following ways: (i) flexible use of space and time; (ii) appropriate materials; (iii) strategies for working outside the classroom/school; (iv) 'playful' or 'game-based' approaches with a degree of learner autonomy; (v) respectful relationships between teachers and learners; (vi) opportunities for peer collaboration; (vii) partnerships with external agencies; (viii) awareness of learners' needs; (ix) non-prescriptive planning. The review also described the impact of creative environments and the implementation of teaching-learning processes (Pesce et al., 2009). This becomes even more important when considering that exercise induced uncorrelated changes in cognition within changes in mood or anxiety, suggesting a separate effect for each component in the neural systems (Hopkins et al., 2012). Different types of exercise are known to have different effects on cognition (Hopkins et al., 2012; Davidson et al., 2006); however, little is known about the most effective type of intervention and/or exercise to promote creativity in children and young people, and this information is crucial and in need of further clarification. In fact, this is valuable information for a more adequate planning of physical education classes and for the formulation of multivariate training programs that allow the simultaneous and effective development of motor proficiency, physical fitness, and creativity.

Research Gaps and Issues

Although one of the most important goals of physical education should be the development of motor skills (Barnett et al., 2009; Hardy et al., 2012) and physical fitness (Oliveira et al., 2017; Pangrazi & Beighle, 2019), it is also important to improve cognitive processes, especially creativity. Low competence in FMS was strongly associated with lower cardiorespiratory fitness and physical activity levels in childhood and adolescence (Hardy et al., 2012). Moreover, children with good motor control and skills are more likely to become active adolescents and adults (Barnett et al., 2009 ; Oliveira et al., 2017). Motor skill development should be a key strategy in childhood interventions aimed at promoting long-term physical activity (Kokkonen et al., 2018; Errisuriz et al., 2017; Pan et al., 2014). In fact, there is evidence of a causal relationship between physical fitness and brain vitality (Tomporowski et al, 2007). In particular, cardiorespiratory fitness and motor proficiency play an active role in cognitive development during childhood and youth (Haapala et al., 2014), so increasing physical fitness may be beneficial for the cognitive development in children and young people (Buck et al., 2008). In addition, physical education programs also aimed to promote health through physical fitness, including improving cardiometabolic indicators and musculoskeletal health in students (Oliveira et al., 2017). Nowadays, the environment created for children in the school context limits their creative potential instead of stimulating their thinking, originality, curiosity, and daring (McDonald & Gray, 2019). In this sense, recent research has proposed principles according to which training programs for children and young people should follow the stimulation of their creativity (Davies et al., 2013; McDonald & Gray, 2019; Konstantinidou et al., 2014). The educational benefits of physical education and school sport have been extended to improve children's concentration and alertness, which may indirectly benefit academic performance (Bailey et al., 2009). However, the interplay between the two learning contexts, physical education and sport, can be further explored. The literature is equally sparse on the use of qualitative methodology, which can complement quantitative data with greater depth and sensitivity (Warburton & Bredin, 2017; Sarmento et al., 2018; Mura et al., 2015). Quantitative and qualitative data allow valid information to be collected for pre- and post-program evaluation (Hajihosseini, 2016).

The impact of training programs applied in the context of physical education classes on improving motor skills and physical fitness is widely accepted in the literature; however, little is known about the potential of these types of programs to develop creativity. Despite the apparent complexity of the concept, the results suggest that creativity is a disposition that can be improved by optimizing the environment and developing appropriate training programs (Runco, 2014; Ma, 2006), so the physical education classroom context seems to be the ideal environment. Few studies have examined the relationship between creativity and physical fitness (Gallahue & Donnelly, 2007). Previous studies have shown that exercise, such as aerobic exercise, can enhance creativity (Rodríguez-Negro et al., 2020; Santos et al., 2017; Tan et al., 2012; Memmert, 2015; Lucas et al., 2013; Blanchette et al., 2005), and this idea has been supported by research using game-based programs in physical education classes (Tomporowski et al., 2007; Gallotta et al., 2014). Following a different training approach, a previous study (Santos et al., 2017) conducted with elementary school children examined the effects of applying a multivariate training program based on creative thinking, diversified practice, and physical and educational literacy over a 5-month period and concluded that it was effective in improving children's creativity, basic motor skills, agility, and speed (Lucas et al., 2013; Blanchette et al., 2005). Over the decades, various teachers have applied different conceptions of teaching and learning in physical education, but multivariate training programs have been evolved from a teacher-centered approach to a more student-centered approach to promote problem-solving skills and critical and autonomous thinking (Tan et al., 2012; Lucas et al., 2013). Teaching Games for Understanding (TGfU) (Tan et al., 2012), teaching tactical creativity in sports (Santos et al., 2017; Memmert, 2015), nonlinear pedagogy (Runco, 2014; Tan et al., 2012), and physical literacy (Pangrazi & Beighle, 2019; Lloyd & Oliver, 2012) are topics that should be explored when considering the use of a multivariate training program.

Explanation of Subject Matter

Physical Education Classes

Physical education is a critical factor in motor development (Gallahue & Donnelly, 2007), as it is often the only place where children are exposed to the practice of vigorous physical activity. Therefore, teaching must include stimuli that provide a variety of experiences, that are compatible with the child's overall development (Bailey, 2006). It is essential that physical education takes place in a favorable context that allows for a high number of motor experiences that enable a progressive development of the child's motor behavior, so the teacher must ensure a progression in the complexity and diversification of the activities performed in class (Errisuriz et al., 2018; Bailey et al., 2009; Woodson-Smith et al., 2015). Developing physical fitness in a school setting through physical education classes promotes health through changes in body composition, reduced susceptibility to disease, and improved physical fitness (Strong et al., 2005). In this regard, some studies have reported successful intervention programs in the context of physical education classes, mainly through the application of strength training programs

(Faigenbaum & Mediate, 2006; Faigenbaum & Myer, 2010; Herman et al., 2021). In addition to improving motor skills and increasing muscular strength and endurance, frequent participation in a strength training program in young people triggers relevant health benefits (Faigenbaum & Mediate, 2006; Faigenbaum & Myer, 2010; Herman et al., 2021) and improves body composition and motor coordination (Faigenbaum & Myer, 2010). Furthermore, this type of training (Stricker, 2002) also improves mental health and muscle strength, which has been shown to be positively associated with academic performance (Coe et al., 2012). Given these benefits, there are several health-related recommendations aimed at increasing the number of children and adolescents participating in training programs that incorporate muscle strengthening (Myer, Faigenbaum, Chu et al., 2011). For all of these reasons, muscle strength should be a priority in any sports development program (Lloyd & Oliver, 2012).

Physical education and sport are expressed as positive contexts and experiences in schools, leading to enjoyment, variety and engagement with increased physical activity and participation (Bailey, 2006). In addition, the application of physical education programs during the elementary school years improves the learning of movement skills, fitness conditioning, and cognitive skills such as creativity and critical thinking (Pesce et al., 2009). Galhahue et al. (2007) examined the relationship between content standard, performance standard, and performance benchmark. It is a behavior that represents the progress toward the goal, and the expected level of achievement expresses the benchmark and standard of performance. Pesce et al. (2009) mentioned that acute and submaximal exercise performed by students during physical education classes may facilitate memory storage. On this basis, the content standard is characterized by the baseline that the student should be a physically educated person (Pesce et al., 2009; Gallahue & Donnelly, 2007). Learning contexts vary widely by education level, gender, and prior experience (Kokkonen et al., 2018; Oliveira et al., 2017). Physical education is the gateway to promoting appropriate levels of physical activity in childhood, and healthy habits and active lifestyles in adulthood are linked to childhood practices (Kokkonen et al., 2018; Errisuriz et al., 2018; Pangrazi & Beighle, 2019). In fact, Errisuriz et al. (2018) emphasize that physical education-based interventions are a popular method for targeting physical activity, body composition, and fitness in children. However, this will only be effective if creative physical education, student perceptions, motivational climate, dynamic physical education lessons, and recreational time physical activity are empowering (Kokkonen et al., 2018; Errisuriz et al., 2018).

In addition, a creative classroom environment in elementary school plays a key role in creativity, critical thinking, and future decision-making and problem-solving skills

(Konstantinidou et al., 2014; Santos et al., 2017). The exchange between physical education interventions and sports-based creative behavior training programs should also not be overlooked (Santos et al., 2017). Improvements in motor and cognitive development lead to improvements in children's self-esteem, self-confidence, phonic skills, handwriting, and participation in sports (Brown, 2010). In addition, psychomotor and motor proficiency games improve athletic performance (Santos et al., 2017), as well as skills in other areas of knowledge, such as literacy and mathematics (Osorio-Valencia et al., 2018). The effects of gender on children's cognitive and motor development have also been reported in the literature (Herman et al., 2021). Creating a positive learning environment for female students in physical education classes using positive teaching strategies can help understand female students' attitudes toward physical activity, sport performance, and participation/retention (Woodson-Smith et al., 2015; Herman et al., 2021; Myer et al., 2005). Evidence-based physical activity for school-aged children and youth includes a variety of delivery methods, including strength- and skill-based training (Faigenbaum et al., 2015), physical education-based interventions (Hajihosseini, 2016; Nielsen et al., 2019; Santos et al., 2017), sports-based exercise programs (Ferraz et al., 2020; Tan et al., 2012), and physical activity-based lifestyle interventions (Janssen & LeBlanc, 2010; Strong et al., 2005; Hajihosseini, 2016). Thus, multivariate training programs have become increasingly important in the training of educators and teachers, in the sense of aggregating all the approaches previously reported using multidisciplinary interventions (Ferraz et al., 2020; Zolotarjova et al., 2018).

Multivariate Training Programs

The literature has shown that multivariate training programs can be effective in promoting health and improving physical fitness indicators in children and young people (Ferraz et al., 2020; Faigenbaum et al., 2015). In this regard, integrated neuromuscular training that includes general activities (i.e., basic movements), specific activities (i.e., exercises to improve motor deficits), and strength and conditioning exercises (i.e., resistance, dynamic stability, plyometric and agility) has been recommended (Myer, Faigenbaum, Fort et al., 2011; Fort-Vanmeerhaeghe et al., 2016). This type of approach allows children and young people to experience mastery of basic movement skills such as locomotion, stability, and manipulation skills (Fort-Vanmeerhaeghe et al., 2016). Integrative training is defined by Fort-Vanmeerhaeghe et al. (2016) as a multivariate training program or plan that incorporates general and specific strength and conditioning activities with congruent goals, such as health and skill-related components. Moreover, Fort-Vanmeerhaeghe et al. (2016) express the need to apply an integrative neuromuscular training in order to improve injury resilience and to enhance athletic and motor performance abilities in youth populations. This is critical because the effects of sedentary lifestyles during childhood and adolescence on lifelong pathological processes appear to extend into adulthood if unhealthy behaviors are not managed and prevented during this vulnerable period of life (Fort-Vanmeerhaeghe et al., 2016). In addition, other studies have reported gains in muscle strength and improvements in movement mechanics (Myer et al., 2005; Myer et al., 2012). This type of multivariate program has been recognized as an innovative approach (Faigenbaum et al., 2011) that can be implemented in a physical education classroom context (Myer et al., 2015). A previous study reported improvements in basic motor skills and physical fitness after 8 weeks of an integrated neuromuscular training program in the initial phase of the physical education class (i.e., 15 m) (Faigenbaum et al., 2011). Similar conclusions were reported in a recent study (Duncan et al., 2019) that examined the effects of 10 weeks of integrated neuromuscular training in a school context, while another study (Malar & Maniazhagu, 2020) examined the effects of integrated neuromuscular training combined with yoga and varied stretching.

Another multivariate training program was tested on young students during 20 physical education classes with the goal of developing creativity (Zachopoulou et al., 2006). The applied training program consisted of exercises that: (i) relied on the use and modification of movement elements; (ii) developed creative thinking during movement activities through exploration; (iii) used movement to learn concepts from different subject areas of teaching; and (iv) developed critical thinking during movement activities. The results presented improvements in creative fluency as a result of participation in the training program during physical education classes. According to Nielson et al. (2019), the acquisition of training, new perspectives, and teaching methods for the physical education teachers can enable the implementation of the program. In fact, Mura et al. (2015) report that schools are an ideal setting for implementing physical activity programs in order to improve youths' learning, intellectual abilities, and health habits. At the same time, multivariate training programs have been associated with improvements in cognitive skills and academic performance (Tomporowski et al., 2007; Haapala et al., 2014; Bailey et al., 2009). Several studies included multiple intervention components and also demonstrated improvements in children's physical activity, fitness, and body composition, typically with multiple components implemented simultaneously (Errisuriz et al., 2018). Bailey et al. (2009) suggest that future physical education and school sport programs should incorporate another evaluation research strategy as qualitative methods. This would allow for an in-depth assessment of affective benefits (Kokkonen et al., 2018; Ma, 2006). Affective variables can be characterized as psychological, mental, and emotional well-being and can assess mental health, positive self-esteem, coping skills, conflict resolution skills, mastery motivation, a sense of autonomy, moral character, and self-confidence (Bailey et al., 2009). Aggregation of psychomotor training programs with multivariate training programs can also explore motor and cognitive skills (Spanaki et al., 2016).

Although physical activity has been shown to be an effective tool for enhancing and developing students' creativity (Tomporowski et al., 2007; Haapala et al., 2014; Buck et al., 2008), other multidisciplinary approaches have also been shown to be effective (Zachopoulou et al., 2006; Santos et al., 2017). Finally, there are several types of training programs that have been shown to be effective in developing physical and cognitive skills individually or simultaneously (McDonald & Gray, 2019; Runco, 2014). However, the focus of physical activity counseling and physical education classes on exercise quantity may limit qualitative features of multivariate training programs, such as skill development, socialization, and enjoyment of exercise (Myer et al., 2012). The timing of brain development and the neuroplasticity associated with motor skill learning make the preadolescent period a critical time to develop and strengthen basic movement skills in both boys and girls (Osorio-Valencia et al., 2018; Mura et al., 2015; Hopkins et al., 2012). Santos et al. (2017) report that sport is an ideal environment for fostering creative behavior, arguing that a higher order disposition can differentiate a child's everyday life. In fact, creativity can be defined by another dimensional definition such as strength, breadth, and depth (Lucas et al., 2013). Various types of training (e.g., aerobic, strength, circuit, flexibility, and balance training) and sports- and exercise-based interventions have been reported to have a high capacity to enhance creativity and motor development (Ferraz et al., 2020; Santos et al., 2017; Tan et al., 2012; Memmert, 2015; Lucas et al., 2013). For this reason, the type of training program that is most congruent with the simultaneous development of creativity, motor skills, and physical fitness in the context of physical education classes remains to be clarified.

Practical Applications and Suggestions for Further Research

In general, previous studies have verified the benefits of applying different training programs in numerous variables (i.e., physical fitness, motor proficiency and creativity). However, current data show that there is a lack of consensus on the best strategy to improve each of these variables, so there is a need to clarify this and to develop a multivariate training program that allows for the simultaneous improvement of all of the variables examined in this review (i.e., motor proficiency, physical fitness, and creativity). Several authors have made suggestions for further research. Tomporowski et al. (2007) recommended that a systematic review should be conducted to analyze the type of physical activity children engage in and the task challenges that help understand the influence of cognitive development during physical activity. Ma (2006) noted the lack of meta-analysis of scientific creativity theory. The authors supported their assumptions by arguing that the effectiveness of the key components of the training was confirmed by the creativity strategies, which not only made the training more effective, but also made the process of creative thinking clearer. Otherwise, Rodriguez-Negro et al. (2020) pointed out that the short-term effects of different training lesson content on motor and cognitive development should be studied using a long-term approach. Santos et al. (2017) made several important points such as: (i) coaches and educators can apply enrichment training to children's dispositions and critical thinking; (ii) sports-based training is ideally suited to foster creative behavior; (iii) the training program possessed the basic motor and play skills. Tan et al. (2012) presented several pathways for further research using TGflU and nonlinear pedagogy, including: (i) investigating the relative effectiveness of teacher instruction on specific movement patterns; (ii) analyzing the affective (e.g., motivation) and physical (e.g., activity level) consequences of this approach on motor skills. Combining these different teaching-learning methods may also provide new directions for understanding and creating new perspectives for the multivariate training program (Ferraz et al., 2020).

Following an emerging research trend and responding to gaps in the literature, future research can focus on multivariate training programs that allow for the simultaneous development of physical fitness, motor proficiency, and creativity. Although there is agreement on the potential benefits of applying strength training programs in a school context, there is still no consensus in the literature on the best strategies (i.e., type of program, duration, intensity) for improving motor proficiency and creativity in the context of physical education classes. It may be relevant to validate a multivariate training program that attempts to answer open-ended questions. Some of the findings may provide new insights for researchers and teachers to enhance the development of multivariate training programs in a physical education classroom context.

Conclusions

This study allows to conclude that multivariate training programs can be considered a valid strategy for physical education classes. Through this brief review, the benefits of applying multivariate training programs during physical education classes on indicators of physical fitness, motor proficiency, and creativity were critically analyzed. The results found seem to indicate that this type of multivariate training programs could be used more effectively in a school context and suggest that this type of training is a useful tool for the simultaneous development of physical fitness, motor proficiency, and creativity. However, there is still no consensus on specific recommendations for this type of program and more research is needed. In the same vein, future research should attempt to understand the differences in the application of multivariate training programs when applied in different contexts (i.e., school, recreational physical activity, and sport environments).

Chapter 3. Experimental Study

Effects of applying a multivariate training program on physical fitness and tactical performance in a team sport taught in physical education classes.

Introduction

Today, physical education plays a key role in promoting active lifestyles through physical activity (Drijvers et al., 2022; Khairuddin et al., 2023). This discipline brings together many areas of knowledge, such as the development of athletic performance, the acquisition of specific technical skills, and the promotion of health by encouraging more active and healthier lifestyles (Branquinho et al., 2022; Kirk, 2009). In fact, the benefits of regular practice of physical activity are many and varied, focusing on improving cardiovascular and respiratory function, reducing levels of anxiety and depression, increasing well-being and developing cognitive and social skills (Ács et al., 2020; Warburton, n.d.). In addition to the opportunity to express their motor skills, many students also emphasize the potential of physical education to meet their psychological needs through its differentiated practical nature (Hammuori, 2020). Indeed, recent evidence supports the idea that physical fitness has a positive impact on mental health and quality of life (Iserbyt et al., 2020; Prysiazhniuk et al., 2021). Therefore, to ensure student engagement, it is imperative that curriculum content is presented in an attractive way that is challenging and increases the likelihood of improving motor skills (Granero-Gallegos et al., 2014; Green, 2014; Johnson & Turner, 2016; Moreno-Murcia & Hernández, 2019; Pérez-Quero et al., 2023).

It should be noted that in order to achieve the potential goals of physical education classes and to increase the associated benefits, the intensity of practice plays a preeminent role (Biddle & Mutrie, 2007). Therefore, it is important to clarify the factors that determine whether students reach the desired level of intensity. The literature reports that at least 50% of the session should be planned as moderate to vigorous intensity physical activity (Fairclough & Stratton, 2005). However, most of the time the intensity of the classes does not reach the recommended levels (Hollis et al., 2016). In this regard, other research suggests that lessons based on team games seem to induce higher intensities than sessions that include individual games and activities of an analytical nature (Brusseau & Kulinna, 2015; Harvey & García-López, 2017). However, high levels of motor competence have also been associated with the ability to perform tasks at higher intensities (Fairclough & Stratton, 2005; Hastie & Trost, 2002; Spessato et al., 2013).

The evidence seems to indicate that the use of team games combined with the development of motor skills can help to achieve the proposed goals. Furthermore, the physical fitness profile of students is related to their technical and tactical performance, which is a strong indicator of success in team games (Gabbett et al., 2009). Hence, it is important to plan lessons that recognize this relationship (Mancha-Triguero et al., 2021). In this sense, multivariate training programs have been widely recognized as an effective strategy to develop the skills necessary for good performance in the collective modalities addressed in physical education (Biddle & Mutrie, 2007; Walton-Fisette & Sutherland, 2020), such as technical and tactical skills (Fox & Riddoch, 2000; Siegel, 2008; Zolotarjova et al., 2018). They prescribe functional loads that allow the students to overcome their typical muscle activity (Janssen & LeBlanc, 2010; Ferraz et al., 2020; Faigenbaum et al., 2015). Typically, this type of program consists of multiple stations designed to improve strength, balance, endurance, coordination (Spanaki et al., 2016) and cardiovascular function (Borbón-Castro et al., 2019). It has been recommended in combination with neuromuscular training, which includes regular activities for basic movement, specialized activities with exercises designed to improve motor deficits, and physical conditioning exercises (directly affecting resistance, dynamic stability, plyometrics and agility) (Faigenbaum et al., 2013; Myer et al., 2011). Furthermore, Fort-Vanmeerhaeghe et al. (2016) highlight the need to implement an integrative neuromuscular training program to increase injury resistance and improve athletic and motor performance capabilities in young people. According to the authors, this is important because the consequences of a sedentary lifestyle during childhood and adolescence appear to have long-term effects on overall health that extend into adulthood if unhealthy habits are not addressed and prevented during this critical period of life.

This type of program can also have some social and psychological benefits for young people, such as improving self-esteem and reducing depressive symptoms (Borbón-Castro et al., 2019). Furthermore, its implementation has the potential to simultaneously promote the development of both motor skills and creativity (Zachopoulou et al., 2006), which can be particularly helpful in team sports.

Essentially, this specific training program aims to help young people develop a strong foundation, improve their physical movements and mechanics, and build confidence in their physical abilities. It involves a well-rounded approach with a variety of exercises, gradual progression, and adequate rest for optimal recovery (Faigenbaum & Myer, 2010; Myer et al., 2011). This approach seems to provide the necessary tools to experiment, improve and master basic movements (i.e., locomotion, stability and manipulation skills) (Faigenbaum et al., 2015; Ferraz, Branquinho, et al., 2020; Ferraz, Marques, et al., 2020; Fort-Vanmeerhaeghe et al., 2016). A previous study showed improvements in basic motor skills and physical fitness after an 8-week integrated neuromuscular training program, during the first part of the physical education class (i.e., 15 minutes) (Faigenbaum et al., 2011). Similar findings were documented in a recent study (Duncan et al., 2019) that examined the effects of 10 weeks of integrated neuromuscular training in a school setting, while another investigation (Malar & Maniazhagu, 2020) examined the effects of combining integrated neuromuscular training with yoga and various stretching techniques.

In this sense, innovative and high-quality pedagogical interventions in physical education classes can be essential for the development of children's motor skills (Cohen et al., 2015; Fahimi et al., 2013), which are necessary for learning the collective modalities. The collective modalities have always had a prominent place in the school environment, mainly due to the receptivity of the students, because of their ease of application in the school context. However, the pedagogical approaches of physical education cross constant discussions about the best method for learning and developing students' motor skills in relation to the teaching of collective modalities (Ferraz et al., 2023).

Although physical education training has undergone changes in recent years, the reference in terms of methodologies and pedagogical actions used by teachers currently includes, in many cases, the teaching of sport in the traditional approach. The methods used to implement the traditional approach, in which students are enabled to perform technical elements, are very far from what would be expected in terms of transfer to the game situation (da Costa & do Nascimento, 2004). In order for the technical skills to be transferred to a real game situation, the student must experience, from the very beginning of the learning process, a series of sequences that represent the game situations, i.e., it is necessary for the teacher to have the sensitivity to carry out tasks that are as close as possible to the "real" game. By deconstructing the game and creating situations of progression, the student will tend to bring his simplified tasks closer to the real situation, thus giving meaning to the learning. In collective sports, the game situation changes with each attack, so that technical skills are subject to rhythmic variations, intensity and amplitude. The goal of tactical learning is therefore for the student to learn to make decisions to solve problems at each turn, not to limit the success of the actions taken (Griffin et al., 1997). In this sense, and in order to observe and measure students' performance, it is necessary to instrumentalize the evaluation of team sports games in a school context. One of the most commonly used instruments for this purpose is the Game Performance Assessment Instrument (GPAI), which allows for the analysis of action outcomes (i.e., movement product) and the motor execution process variables related to game actions (e.g., technique and tactics) (Mitchell, 2016; Santos, 2016).

As far as is known, no study to date has examined the effects of a multivariate training program consisting of game-based activities and physical fitness exercises to improve physical and tactical performance in team sports (e.g., basketball), during physical education classes, and at different levels of education (primary and secondary education). Therefore, the main objective of this study was to verify the effects of applying a multivariate training program on physical fitness and tactical performance during the teaching of a basketball didactic unit in basic and secondary education. The study hypothesis is that the training program will have a positive effect on physical fitness and tactical performance in both teaching groups.

Methods

Participants

Seventy-five students from a Portuguese school participated in the study. Forty-two students from basic/elementary school education (13,85±2,95) and thirty-three students from secondary/high school (15,13±2,95). All subjects participated in the study voluntarily and their parents or guardians were informed in writing about the study and signed an informed consent form to confirm their child's participation. To participate in the study, students had to be healthy and participate in physical education classes, and there were no exclusion criteria. G*Power 3.1 software (Kang, 2021) was used for this quasi-experimental randomized controlled trial. It was established through an a priori analysis that 75 students would be required for the study (effect size dz: 0,3, error probability α:0,05, power: 0,85). The students and the professor were informed about the genesis and requirements of the study, the risks involved, and the possibility of withdrawing from the research even after volunteering. All procedures followed the guidelines of the Declaration of Helsinki for research involving human subjects. The experimental approach was approved and followed by the local ethical committee (Project Number D2605).

Procedures

During the teaching of the basketball didactic unit (i.e., 6-weeks interventions), the students were randomly divided into two groups, a control group that will not perform the training program and an experimental group that will perform a training program consisting of strength, high-intensity explosive exercises and game-based activities. The two groups will be assessed at two different moments: before the application of the training program (pre-training test) and after the application of the training program (post-training test) in terms of changes in physical fitness and tactical performance. The experimental group began the multivariate training program class by class, while the control group began the warm-up at the same time for approximately 15 minutes.

Changes in the level of physical fitness were measured using the FitEscola test battery (i.e., sit-ups, push-ups, horizontal impulse, shuttle test, 40m sprint and agility). Changes in tactical performance were measured using the GPAI instrument after collecting videos of game situations.

Training Program

The training program was developed based on some adaptations of previous studies (Branquinho et al., 2020; Ferraz et al., 2012). The training program was carried out over 6 weeks (Table 1) and consisted of four stations, detailed below, and 3 vs. 3 SSGs played in the midfield without the intervention of the coach and taking into account the knowledge acquired during the teaching of the didactic unit.

Station 1 - consists of two exercises: the 4x10m maximum speed and 10 push-ups. For the maximum speed exercise, a 10-meter corridor was set up. The students were asked to complete the exercise at their maximum speed in the four lanes, and to move their feet beyond the signaling cones when changing direction (factors directly related to the FITESCOLA test). For the push-up exercise, the students were asked to straighten their torso and bend their arms at 90º.

Station 2 - consists of three exercises: running with changes of direction, horizontal push (into the cones) and the squat jump. For the change of direction running exercise, eight flags were placed at equal intervals, and they had to be circled from the outside, at the maximum possible speed. For the horizontal push, two rows of arcs were placed (preferably different colors for each row), with one row of arcs at a greater distance than the other, depending on the level of difficulty to be applied. It is ideal to increase the distance as the session progresses, forcing the students to jump further. As for the squat jump, amplitude is required in both the squat and the vertical jump, and should be as dynamic as possible.

Station 3 – consists of two exercises: sprint and Russian twist. The sprint exercise is about 10 meters, so students should do it at maximum speed, with a start and finish flag. Students should start the exercise by trying to accelerate at the beginning of the race and maintain maximum speed until they pass the finish signal, not slowing down before then. The Russian twist exercise must be performed with the lower limbs raised (flexed), in a dynamic manner, with the abdomen turning sideways.

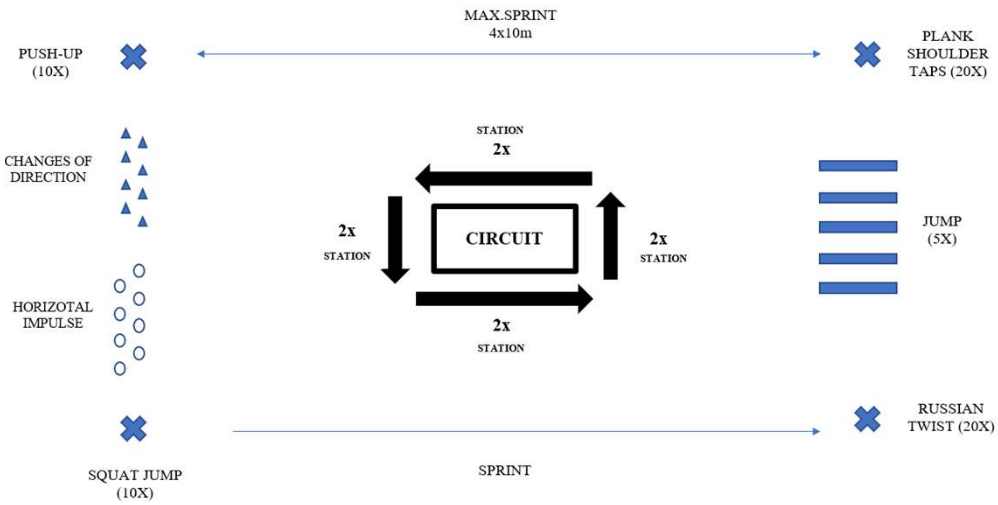
Station 4 – consists of two exercises: Jump and Plank Shoulder Taps. The Jump exercise must be performed with feet together, without interruption, for the duration of the five hurdles. The height of the hurdles should also be adjusted (increased) throughout the session. The Plank Shoulder Taps exercise must be performed in a plank position with the arms alternately touching the opposite shoulder with the hand, without breaking the starting position.

Students were asked to distribute themselves randomly (i.e., two to three students per station) to avoid queuing and to ensure that they were always exercising. The initial distribution was maintained throughout the application of the training program in Table 1.

Table 1. Multivariate Training Program (four stations)

	S	R	PUSH-UP	Change of Direction	Horizontal Impulse	SQUAT JUMP	Sprint	RUSSIAN TWIST	JUMP	Plank Shoulder Taps	Max. Sprint 4X10m
Week 1	S1	2	4 x 10	4 x 8	4 x 4	4 x 10	4 x 1	4 x 20	4 x 5	4 x 20	4 x 1
Week 2	S2	2	4 x 10	4 x 8	4 x 4	4 x 10	4 x 1	4 x 20	4 x 5	4 x 20	4 x 1
	S3	2	4 x 10	4 x 8	4 x 4	4 x 10	4 x 1	4 x 20	4 x 5	4 x 20	4 x 1
Week 3	S4	2	4 x 10	4 x 8	4 x 4	4 x 10	4 x 1	4 x 20	4 x 5	4 x 20	4 x 1
	S5	3	6 x 10	6 x 8	6 x 4	6 x 10	6 x 1	6 x 20	6 x 5	6 x 20	6 x 1
Week 4	S6	3	6 x 10	6 x 8	6 x 4	6 x 10	6 x 1	6 x 20	6 x 5	6 x 20	6 x 1
	S7	3	6 x 10	6 x 8	6 x 4	6 x 10	6 x 1	6 x 20	6 x 5	6 x 20	6 x 1
Week 5	S8	3	6 x 10	6 x 8	6 x 4	6 x 10	6 x 1	6 x 20	6 x 5	6 x 20	6 x 1
	S9	4	8 x 10	8 x 8	8 x 4	8 x 10	8 x 1	8 x 20	8 x 5	8 x 20	8 x 1
Week 6	S10	4	8 x 10	8 x 8	8 x 4	8 x 10	8 x 1	8 x 20	8 x 5	8 x 20	8 x 1
	S11	4	8 x 10	8 x 8	8 x 4	8 x 10	8 x 1	8 x 20	8 x 5	8 x 20	8 x 1

R= Repetition; S= Session



Instruments

<u>Physical fitness</u>

The FITescola test battery was used to assess physical fitness. The tests used are described in detail below.

Sit-ups

The sit-up test consists of performing as many sit-ups as possible at a given cadence (Henriques-Neto et al., 2020). The purpose of this test is to assess the resistance of the abdominal muscles. This action was repeated at a predetermined cadence of 20 sit-ups per minute. The number of times the participants performed this action correctly was recorded.

Push-ups

The push-up test consists of performing the maximum number of push-ups (arm flexion and forearm extension) at a predetermined cadence (Henriques-Neto et al., 2020). This test aims to assess the endurance strength of the upper limbs. This action was repeated at a predetermined cadence of 20 push-ups per minute. The number of times the participant performed the action correctly was recorded.

Horizontal Impulse

The horizontal impulse test consists of reaching the maximum distance in a long jump with feet together (Henriques-Neto et al., 2020). The purpose of this test is to assess the explosive strength of the lower limbs. A horizontal line is drawn at the starting point, with reference lines every 10 cm. Starting from a standing position, the subject must bend the knees, pull the arms behind him and jump in length as far as possible. Two jumps must be made. The best of the two measurements is recorded in cm.

Shuttle Test

The shuttle test consists of completing the maximum number of routes performed over a distance of 20 m, at a predetermined cadence, using an audio device (Mayorga-Vega et al., 2015). The student must remain in the test for as long as possible and must stop if he/she fails to reach the line before the sound signal on two occasions, not necessarily consecutive. The first foul is counted towards the score.

40m Sprint

The test consists of running a 40 m race in the shortest possible time according to a previously described protocol (Wang et al., 2016). The purpose of this test is to measure the student's acceleration capacity and speed. There must be two attempts per student. The recorded value is the best result of the two trials in hundredths of a second.

Agility 4 x 10m

The agility test (4x10 m) consists of completing a predetermined route, combining maximum speed of execution with coordination translated into the movement of grasping, carrying and placing a sponge in a predetermined place (Vicente-Rodríguez et al., 2011). The purpose of the test is to evaluate the student's agility, characterizing the ability to accelerate, the coordination of the movements required and the speed with which they are performed. Two tests must be performed and the registered value is the best result of the two evaluations, expressed in hundredths.

Tactical performance

GPAI

The GPAI was used to assess students' tactical performance in accordance with previously reported recommendations. (Oslin et al., 1998). Each player's game performance in a 20-minute 3 *vs.* 3 match was coded by two experts using footage that was taken with a standard video camera. The experts were selected based on the following criteria: i) having at least 10 years of professional experience in the modality; ii) current experience as a high-performance basketball coach; iii) at least a Master's degree with scientific research in the modality. The GPAI record sheet was used by the experts during the assessment. In order to validate the observations, coders were required to achieve a coefficient of interobserver agreement greater than 80% using the Kendall's W coefficient of agreement (Oslin et al., 1998). Coders recorded and calculated measures of appropriate and inappropriate actions in four components of the game, taking into account the Decision Making Index (DMI), the Skill Execution Index (SEI), the Support Actions Index (SI), and the Adaptability Index (AI), based on an adaptation of a previously defined and validated protocol (Oslin et al., 1998) (Table. 2). These four game components were selected as the most important for assessing general and non-specific game skills in young people.

Table 2. Definition of appropriate and inappropriate actions for applying the GPAI in the following indexes: Decision Making Index (DMI), Skill Execution Index (SEI), Support Actions (SI) and Adaptability Index (AI).

Components of game	Assumption	AA	IA
Decision-Making	When receiving the ball, he adjusts to the basket in a basic offensive stance.	Fulfils the assumption	Does not meet the assumption
	He shoots when he is within range of the basket and the defender is not pressuring him.		
	He passes when he has an unmarked teammate in a more offensive position.		
	If he has none of the above options, he dribbles away from the defender.		
Skill Execution	Throwing: Throwing arm extension, wrist flexion.		
	Passing: Passing to a teammate; the ball reaches the teammate in good condition.		
	Dribbling: Not looking at the ball; not "carrying" the ball.		
Support Actions	He attempts to create passing lines.		
	He does not come within 3 meters of the person with the ball.		
Saving/marking	When he loses the ball, he takes a basic offensive stance and looks for his immediate opponent.		
	He places himself between his opponent and the basket.		

Abbreviation: AA – Appropriate action; IA – Inappropriate action

Statistical analysis

Descriptive statistics were presented as the mean ± one standard deviation (SD) with a 95% confidence interval (CI). The Kolmogorov-Smirnov and Levene tests were used to determine the normality and homogeneity of the data distribution. The independent samples t-test was used to compare appropriate and inappropriate actions within each group and between groups before and after the intervention. Effect sizes (ES) were calculated based on Cohen's d and classified as follows: 0.2-0.6 (trivial); 0.6-1.2 (small); 1.2 (large); and greater than 2.0 (very large) (Hopkins, 2019; Hopkins et al., 2009). Statistical significance was set at $p<0.05$. Statistical analyses were performed using SPSS for Windows version 26.0 (SPSS Inc., Chicago, IL, USA).

Results

Inter-group comparison (HS, High School vs. BS, Basic School)

Table 3 shows the comparison between groups (HS vs BS) in the pre- and post-assessment tests for the GPAI indexes. All indexes present significant differences between methods with small effects (t = -6.54 to -4.82, Δ = -27.57 to -0.16, $p < 0.05$ to $p < 0.001$, d = 0.78 to 1.05).

Table 3 – Inter-group comparison (HS vs BS) in the pre- and post-assessment for the GPAI indexes.

Variable	$Pre_{Overall}$	$Post_{Overall}$	*t*	*Δ*	*p*	*d*	*QS*
GI	45.52 ± 23.52	73.09 ± 28.59	-6.54	-27.57	< 0.001	1.05	Small
DMI	0.72 ± 0.24	0.90 ± 0.14	-5.67	-0.18	< 0.001	0.91	Small
SEI	0.49 ± 0.31	0.75 ± 0.24	-5.79	-0.26	< 0.001	0.93	Small
SI	0.69 ± 0.23	0.84 ± 0.17	-4.82	-0.16	< 0.001	0.78	Small
AI	0.57 ± 0.24	0.73 ± 0.14	-5.35	-0.17	< 0.001	0.86	Small
GP	0.63 ± 0.22	0.83 ± 0.15	-6.42	-0.20	< 0.001	1.04	Small

Abbreviation: Δ – mean differences; d – Cohen; DMI – Decisions Made Index; GP – Game performance; p – p value; QS – qualitative effect size; SEI – Skill Execution Index; SI – Support Index; GI – Game involvement; *t* – t test.

Table 4 shows the comparison between groups (HS vs BS) in the pre- and post-assessment tests for physical fitness. Significant differences with trivial effects were found between the pre- and post-assessments for the speed test (t = 2.27, Δ = 0.30, p = 0.025, d = 0.37) and the agility test (t = 3.09, Δ = 0.62, p = 0.002, d = 0.51).

Table 4 – Inter-group comparison (HS vs BS) in the pre- and post-assessments for physical fitness.

Variable	**Pre$_{Overall}$**	**Post$_{Overall}$**	***t***	***Δ***	***p***	***d***	***QS***
Horizontal jump	151.76 ± 36.40	161.14 ± 34.03	-1.62	-9.38	0.108	0.27	Trivial
Velocity (40m)	7.16 ± 0.77	6.87 ± 0.82	2.27	0.30	0.025	0.37	Trivial
Agility (4x10)	13.10 ± 1.24	12.47 ± 1.21	3.09	0.62	0.002	0.51	Trivial
Abdominal Strength	43.73 ± 21.84	48.38 ± 24.47	-1.28	-4.65	0.204	0.21	Trivial
Shuttle Run (20m)	36.37 ± 20.15	38.77 ± 20.50	-0.72	-2.41	0.473	0.12	Trivial
Push ups	12.62 ± 8.03	14.37 ± 8.26	-1.30	-1.74	0.195	0.21	Trivial

Abbreviation: Δ – mean differences; d – Cohen; p – p value; QS – qualitative effect size; *t* – t test.

3.1. Inter-group comparison for pre- and post-assessment moments in elementary school students

Table 5 shows the comparison between groups for the pre- (Pre $_{CG}$ vs. Pre $_{IG}$) and post- (Post $_{CG}$ vs. Post $_{IG}$) assessments for the elementary school students. The pre-tests showed no significant differences for the overall GPAI indexes. Otherwise, significant differences with small effect sizes were found in the post-tests for the DMI (t = -3.13, Δ = -0.07, p = 0.003, d = 0.97) and SI (t = -2.38, Δ = -0.12, p = 0.022, d = 0.74).

Table 5 – Inter-group comparison for the pre-assessment moment (Pre CG vs Pre IG) for the GPAI indexes in elementary school students.

Variable	Pre $_{CG}$	Pre $_{IG}$	*t*	*Δ*	*p*	*d*	*QS*	Post $_{CG}$	Post $_{IG}$	*t*	*Δ*	*p*	*d*	*QS*
GI	44.24 ± 25.98	41.95 ± 20.16	0.319	2.29	0.752	0.10	Trivial	58.95 ± 31.26	78.86 ± 32.81	-2.01	-19.91	0.051	0.62	Small
DMI	0.74 ± 0.21	0.73 ± 0.29	0.148	0.01	0.883	0.05	Trivial	0.93 ± 0.09	0.99 ± 0.02	-3.13	-0.07	0.003	0.97	Small
SEI	0.43 ± 0.31	0.52 ± 0.38	-0.850	-0.09	0.400	0.26	Trivial	0.70 ± 0.29	0.77± 0.27	-0.82	-0.07	0.416	0.25	Trivial
SI	0.67 ± 0.22	0.79 ± 0.17	-1.994	-0.12	0.053	0.62	Small	0.79 ± 0.22	0.91 ± 0.09	-2.38	-0.12	0.022	0.74	Small
AI	0.55 ± 0.23	0.54 ± 0.24	0.086	0.01	0.932	0.03	Trivial	0.69 ± 0.15	0.71 ± 0.14	-0.58	-0.03	0.563	0.18	Trivial
GP	0.61 ± 0.23	0.68 ± 0.25	-0.894	-0.07	0.377	0.28	Trivial	0.80 ± 0.18	0.89 ± 0.11	-1.88	-0.09	0.068	0.58	Trivial

Abbreviation: Δ – mean differences; d – Cohen; DMI – Decisions Made Index; GP – Game performance; p – p value; QS – qualitative effect size; SEI – Skill Execution Index; SI – Support Index; GI – Game involvement; *t* – t test.

Regarding the effects of the training program on physical fitness, no differences were found between the CG and the IG in the pre-test comparisons (Table 6). In the pre-test evaluation, significant differences with small effects were found for horizontal jump (t = -3.26, Δ = -26.76, p = 0.002, d = 1.01), agility (t = 3.35, Δ = 1.29, p = 0.002, d = 1.04) and shuttle run (t = 2.27, Δ = 12.86, p = 0.029, d = 0.70). Post-tests showed significant differences for horizontal jump (t = -3.39, Δ = -26.43, p = 0.002, d = 1.05) and agility (t = 2.31, Δ = 0.86, p = 0.026, d = 0.71).

Table 6 – Inter-group comparison for the pre-assessment moment (Post CG vs Post IG) for physical fitness in elementary school students.

Variable	**Pre** $_{CG}$	**Pre** $_{IG}$	***t***	***Δ***	***p***	***d***	***QS***	**Post** $_{CG}$	**Post** $_{IG}$	***t***	***Δ***	***p***	***d***	***QS***
Horizontal jump	137.10 ± 26.21	163.86 ± 26.92	-3.26	-26.76	0.002	1.01	Small	134.81 ± 22.91	161.14 ± 27.40	-3.39	-26.43	0.002	1.05	Small
Velocity (40m)	7.43 ± 0.68	7.05 ± 0.67	1.84	0.38	0.074	0.57	Trivial	7.14 ± 0.85	6.71 ± 0.85	1.64	0.43	0.110	0.51	Trivial
Agility (4x10)	13.86 ± 1.24	12.57 ± 1.25	3.35	1.29	0.002	1.04	Small	12.76 ± 1.41	11.91 ± 0.94	2.31	0.86	0.026	0.71	Small
Abdominal Strength	47.81 ± 23.66	44.57 ± 26.01	0.42	3.24	0.675	0.13	Trivial	58.29 ± 21.31	53.76 ± 25.71	0.62	4.52	0.538	0.19	Trivial
Shuttle Run (20m)	40.24 ± 20.86	27.38 ± 15.46	2.27	12.86	0.029	0.70	Trivial	32.95 ± 15.14	41.67 ± 24.14	-1.40	-8.71	0.169	0.43	Trivial
Push ups	10.52 ± 6.71	14.05 ± 8.16	-1.53	-3.52	0.134	0.47	Trivial	13.33 ± 17.49	17.14 ± 7.45	-1.65	-3.81	0.106	0.51	Trivial

Abbreviation: Δ – mean differences; d – Cohen; p – p value; QS – qualitative effect size; *t* – t test.

3.2. Inter-group comparison for the pre- and post-assessment moments in high school students

Table 7 shows the comparison between groups for the pre- (Pre $_{CG}$ vs. Pre $_{IG}$) and post- (Post $_{CG}$ vs. Post $_{IG}$) assessments for the GPAI indexes. Significant differences with small to large effects were found in the pre-test assessment for DMI ($t = -7.33$, $\Delta = -0.36$, $p < 0.001$, $d = 2.49$), SI ($t = -3.00$, $\Delta = -0.24$, $p = 0.005$, $d = 1.02$), AI ($t = -4.08$, $\Delta = -0.28$, $p < 0.001$, $d = 1.38$) and GP ($t = -3.22$, $\Delta = -0.20$, $p = 0.003$, $d = 1.09$). In the post-tests, significant differences with small to very large effects were found for the overall indexes ($t = -8.63$ to 2.83, $\Delta = -0.26$ to 18.52, $p < 0.05$ to $p < 0.001$, d = 0.96 to 2.93).

Table 7 – Inter-group comparison for the pre-assessment moment (Pre CG vs Pre IG) for the GPAI indexes in high school students.

Variable	Pre $_{CG}$	Pre $_{IG}$	*t*	*Δ*	*p*	*d*	*QS*	Post $_{CG}$	Post $_{IG}$	*t*	*Δ*	*p*	*d*	*QS*
GI	49.79 ± 26.84	46.81 ± 21.23	0.36	2.98	0.722	0.12	Trivial	86.58 ± 19.85	68.06 ± 18.62	2.83	18.52	0.008	0.96	Small
DMI	0.53 ± 0.18	0.89 ± 0.09	-7.33	-0.36	< 0.001	2.49	Very large	0.71 ± 0.11	0.96 ± 0.04	-8.63	-0.26	< .0001	2.93	Very large
SEI	0.51 ± 0.18	0.52 ± 0.34	-0.11	-0.01	0.917	0.04	Trivial	0.66 ± 0.15	0.90 ± 0.12	-5.07	-0.23	< 0.001	1.72	Very large
SI	0.53 ± 0.23	0.76 ± 0.24	-3.00	-0.24	0.005	1.02	Small	0.74 ± 0.15	0.95 ± 0.06	-5.12	-0.21	< 0.001	1.74	Very large
AI	0.47 ± 0.22	0.75 ± 0.18	-4.08	-0.28	< 0.001	1.38	Large	0.70 ± 0.09	0.87 ± 0.08	-5.53	-0.16	< 0.001	1.88	Very large
GP	0.52 ± 0.18	0.73 ± 0.20	-3.22	-0.20	0.003	1.09	Small	0.70 ± 0.11	0.94 ± 0.05	-7.57	-0.23	< 0.001	2.57	Very large

Abbreviation: Δ – mean differences; d – Cohen; DMI – Decisions Made Index; GP – Game performance; p – p value; QS – qualitative effect size; SEI – Skill Execution Index; SI – Support Index; GI – Game involvement; *t* – t test.

Regarding the effects of the training program on physical fitness, no differences were found between the CG and the IG for the pre- and post-test comparisons (Table 8).

Table 8 – Inter-group comparison for the pre-assessment moment (Post CG vs Post IG) for physical fitness in basic school students.

Variable	**Pre $_{CG}$**	**Pre $_{IG}$**	***t***	***Δ***	***p***	***d***	***QS***	**Post $_{CG}$**	**Post $_{IG}$**	***t***	***Δ***	***p***	***d***	***QS***
Horizontal jump	157.24 ± 50.51	149.13 ± 37.31	0.51	8.10	0.614	0.18	Trivial	174.24 ± 34.95	183.00 ± 32.58	-0.73	-8.77	0.471	0.26	Trivial
Velocity (40m)	7.06 ± 1.03	7.07 ± 0.70	-0.03	-0.01	0.980	0.01	Trivial	6.65 ± 0.86	6.93 ± 0.59	-1.08	-0.29	0.289	-0.38	Trivial
Agility (4x10)	12.71 ± 0.92	13.20 ± 1.08	-1.40	-0.49	0.173	0.50	Trivial	12.41 ± 0.94	12.93 ± 1.28	-1.33	-0.52	0.195	0.47	Trivial
Abdominal Strength	44.94 ± 16.53	35.47 ± 17.55	1.57	9.48	0.126	0.56	Trivial	38.24 ± 15.88	38.47 ± 18.18	-0.04	-0.23	0.970	0.01	Trivial
Shuttle Run (20m)	43.53 ± 23.62	35.40 ± 17.61	1.09	8.13	0.284	0.39	Trivial	42.71 ± 20.42	38.40 ± 21.71	0.58	4.31	0.568	0.21	Trivial
Push ups	14.59 ± 8.11	11.33 ± 9.26	1.06	3.26	0.297	0.38	Trivial	12.00 ± 9.05	14.60 ± 9.09	-0.81	-2.60	0.425	0.29	Trivial

Abbreviation: Δ – mean differences; d – Cohen; p – p value; QS – qualitative effect size; *t* – t test.

Intra-group comparison (CG – control group vs IG – intervention group) in elementary school students

Considering the effects of the training program on tactical performance, an intra-group comparison was made between the pre- and post-assessments for the GPAI indexes (Table 9). Significant differences with trivial to large effect sizes were found between pre- and post-tests for the CG ($t = -3.71$ to -1.66; $\Delta = -14.71$ to -0.14, $p < 0.05$ $p < 0.001$, $d = 0.51$ to 1.15) and the IG ($t = -4.39$ to -2.48; $\Delta = -36.91$ to -0.12, $p < 0.05$ $p < 0.001$, $d = 0.77$ to 1.36), except for GI and SI in CG. Considering the effects of the training program on physical fitness, an intra-group comparison was made between the pre- and post-assessment tests (Table 10). In the CG, significant differences with trivial effect sizes were found between the pre- and post-tests for agility ($t = 2.68$, $\Delta = 0.29$, $p = 0.011$, $d = 0.83$). In the IG, significant differences with trivial effects were reported for shuttle run ($t = -2.28$, $\Delta = -14.29$, $p = 0.028$, $d = 0.71$).

Table 9 – Intra-group comparison (CG & IG) in the pre- and post-assessments for the GPAI indexes.

	Control Group (CG)							Intervention Group (IG)						
Variable	**Pre**	**Post**	**t**	**Δ**	**p**	**d**	**QS**	**Pre**	**Post**	**t**	**Δ**	**p**	**d**	**QS**
GI	44.24 ± 25.98	58.95 ± 31.26	-1.66	-14.71	0.105	0.51	Trivial	41.95 ± 20.16	78.86 ± 32.81	-4.39	-36.91	< 0.001	1.36	Large
DMI	0.74 ± 0.21	0.93 ± 0.09	-3.71	-0.19	< 0.001	1.15	Small	0.73 ± 0.29	0.99 ± 0.02	-4.11	-0.27	< 0.001	1.27	Large
SEI	0.43 ± 0.31	0.70 ± 0.29	-2.94	-0.27	0.005	0.91	Small	0.52 ± 0.38	0.77 ± 0.27	-2.48	-0.25	0.017	0.77	Small
SI	0.67 ± 0.22	0.79 ± 0.22	-1.75	-0.12	0.088	0.54	Small	0.79 ± 0.17	0.91 ± 0.09	-2.88	-0.12	0.006	0.89	Small
AI	0.55 ± 0.23	0.69 ± 0.15	-2.34	-0.14	0.025	0.72	Trivial	0.54 ± 0.24	0.71 ± 0.14	-2.84	-0.17	0.007	0.88	Small
GP	0.61 ± 0.23	0.80 ± 0.18	-3.01	-0.19	0.005	0.93	Small	0.68 ± 0.25	0.89 ± 0.11	-3.61	-0.21	<0.001	1.11	Small

Abbreviation: DMI – Decisions Made Index; SEI – Skill Execution Index; SI – Support Index; GI – Game involvement; GP – Game performance; d – Cohen; Δ – mean differences; p – p value.

Table 10 – Intra-group comparison (CG & IG) in the pre- and post-assessments for physical tests.

	Control Group (CG)							Intervention Group (IG)						
Variable	**Pre**	**Post**	**t**	**Δ**	**p**	**d**	**QS**	**Pre**	**Post**	**t**	**Δ**	**p**	**d**	**QS**
Horizontal jump	137.10 ± 26.21	134.81 ± 22.91	0.30	-0.71	0.765	0.09	Trivial	163.86 ± 26.92	161.24 ± 27.40	0.31	2.62	0.756	0.10	Trivial
Velocity (40m)	7.43 ± 0.68	7.14 ± 0.85	1.20	2.29	0.236	0.37	Trivial	7.05 ± 0.67	6.71 ± 0.85	1.48	0.33	0.164	0.44	Trivial
Agility (4x10)	13.86 ± 1.24	12.76 ± 1.41	2.68	0.29	0.011	0.83	Trivial	12.57 ± 1.25	11.91 ± 0.94	1.95	0.67	0.058	0.60	Trivial
Abdominal strength	47.81 ± 23.66	58.29 ± 21.31	-1.51	1.10	0.139	0.47	Trivial	44.57 ± 26.01	53.76 ± 25.71	-1.15	-9.19	0.256	0.36	Trivial
Shuttle run (20m)	40.24 ± 20.86	32.95 ± 15.14	1.30	-10.48	0.203	0.40	Trivial	27.38 ± 15.46	41.68 ± 24.14	-2.28	-14.29	0.028	0.71	Trivial
Push ups	10.52 ± 6.71	13.33 ± 7.49	-1.28	7.29	0.208	0.40	Trivial	14.05 ± 8.16	17.14 ± 7.45	-1.28	2.62	0.207	0.40	Trivial

Abbreviation: Δ – mean differences; d – Cohen; p – p value; QS – qualitative effect size; *t* – t test.

Intra-group comparison (CG – control group vs IG – intervention group) in high school

Considering the effects of the training program on tactical performance, an intra-group comparison was made between the pre- and post-assessments for the GPAI indexes (Table 11). Significant differences with small to large effect sizes were found between the pre- and post-tests in both groups, specifically: CG (t = -4.80 to -2.77; Δ = -36.79 to -0.15, $p < 0.05$ t o $p < 0.001$, d = 0.90 to 1.56) and IG (t = -4.15 to -2.39; Δ = -21.25 to -0.07, $p < 0.05$ to $p < 0.001$, d = 0.99 to 1.47).

Considering the effects of the training program on physical fitness, an intra-group comparison was made between the pre- and post-assessment tests (Table 12). In the GC, no statistical significance was found between the pre and post physical fitness. In the IG, significant differences were found for the horizontal jump (t = -2.65, Δ = -33.87, p = 0.013, d = 0.97).

Table 11 – Intra-group comparison (CG & IG) in the pre- and post-assessments for the GPAI indexes.

	Control Group (CG)							Intervention Group (IG)						
Variable	**Pre**	**Post**	**T**	**Δ**	**p**	**d**	**QS**	**Pre**	**Post**	**t**	**Δ**	**p**	**d**	**QS**
GI	49.79 ± 26.84	86.58 ± 19.85	-4.80	-36.79	< 0.001	1.56	Large	46.81 ± 21.23	68.06 ± 18.62	-3.01	-21.25	0.005	1.06	Small
DMI	0.53 ± 0.18	0.71 ± 0.12	-3.57	-0.18	0.001	1.16	Small	0.90 ± 0.09	0.96 ± 0.04	-2.79	-0.07	0.009	0.99	Small
SEI	0.51 ± 0.18	0.66 ± 0.15	-2.77	-0.15	0.009	0.90	Small	0.52 ± 0.34	0.90 ± 0.12	-4.12	-0.37	< 0.001	1.46	Large
SI	0.52 ± 0.18	0.74 ± 0.15	-3.45	-0.22	0.001	1.12	Small	0.76 ± 0.24	0.95 ± 0.06	-3.02	-0.19	0.005	1.07	Small
AI	0.47 ± 0.22	0.70 ± 0.09	-4.33	-0.23	< 0.001	1.41	Large	0.75 ± 0.18	0.87 ± 0.08	-2.39	-0.12	0.023	0.85	Small
GP	0.52 ± 0.18	0.70 ± 0.11	-3.72	-0.18	< 0.001	1.21	Large	0.73 ± 0.20	0.94 ± 0.05	-4.15	-0.21	< 0.001	1.47	Large

Abbreviation: DMI – Decisions Made Index; SEI – Skill Execution Index; SI – Support Index; GI – Game involvement; GP – Game performance; d – Cohen; Δ – mean differences; p – p value.

Table 12 – Intra-group comparison (CG & IG) in the pre- and post-assessments for physical tests.

	Control Group (CG)							Intervention Group (IG)						
Variable	**Pre**	**Post**	**t**	**Δ**	**p**	**d**	**QS**	**Pre**	**Post**	**t**	**Δ**	**p**	**d**	**QS**
Horizontal jump	157.24 ± 50.51	174.24 ± 34.95	-1.14	-17.00	0.262	0.39	Trivial	149.13 ± 37.31	183.00 ± 32.56	- 2.65	- 33.87	0.013	0.97	Small
Speed (40m)	7.06 ± 1.03	6.65 ± 0.86	1.27	0.41	0.215	0.43	Trivial	7.07 ± 0.70	6.93 ± 0.59	0.56	0.13	0.579	0.21	Trivial
Agility (4x10)	12.71 ± 0.92	12.41 ± 0.94	0.92	0.29	0.363	0.32	Small	13.20 ± 1.08	12.93 ± 1.28	0.62	0.27	0.543	0.23	Trivial
Abdominal Strength	44.94 ± 16.53	38.24 ± 15.88	1.21	6.71	0.237	0.41	Small	35.47 ± 17.55	38.47 ± 18.18	- 0.46	-3.00	0.649	0.17	Trivial
Shuttle run (20m)	43.53 ± 23.62	42.71 ± 20.42	0.11	0.82	0.914	0.04	Trivial	35.40 ± 17.61	38.40 ± 21.71	- 0.42	-3.00	0.681	0.15	Trivial
Push ups	14.59 ± 8.11	12.00 ± 9.05	0.88	2.59	0.386	0.30	Trivial	11.33 ± 9.26	14.60 ± 9.09	- 0.98	3.10	0.338	0.40	Trivial

Abbreviation: Δ – mean differences; d – Cohen; p – p value; QS – qualitative effect size; *t* – t test.

Discussion

The aim of the study was to investigate the effects of a 6-week multivariate training program on physical fitness and tactical performance during a basketball didactic unit in basic and high schools. The results of the study showed that there was a significant difference between the pre- and post-test for all GPAI indices in both groups, indicating an improvement in tactical performance. The implementation of a multivariate program in basic and high schools also has a positive effect, especially on variables related to game performance. There were significant differences between the pre- and post-test scores for decision-making (DMI) and support actions (SI) for primary school students. The high school students showed a significant difference between all GPAI scores on the post-test. Regarding physical fitness, the multivariate training program had some positive effects on physical fitness, especially on the speed and agility components. However, there were no other significant differences in physical fitness variables in basic and high school students. In a school environment, a well-structured multivariate training program can effectively improve students' tactical skills while increasing their physical fitness levels.

Overall, differences were found in all GPAI variables for elementary and high school students. These results indicate that the teaching of the didactic unit had a positive effect on Game Involvement (GI) Decision-Making (DMI), Skill Execution (SEI), Support Actions (SI), Adaptability (AI), and overall Game Performance (GP). The teaching-learning process was also positive in the areas of motor skill execution and game understanding. Silva et al. (2022) concluded that the use of a multivariate training program can provide benefits in several areas of student development, such as physical fitness, creativity and motor skills. A tactical approach can be useful to improve students' decision-making, skill execution, game involvement (Robles et al., 2019; Özcan et al., 2018; Pizarro et al., 2017; Darnis & Lafont, 2015; Darnis-Paraboschi et al., 2005; Blakemore & Robbins, 2012; Slade et al., 2015; Gréhaigne & Godbout, 1998), adaptability (Sousa, 2007), support actions and overall game performance (Harvey et al., 2010; Darnis & Lafont, 2015; Ward, 2006; Memmert & Harvey, 2008). According to these studies, teaching a didactic unit with a multivariate approach focusing on tactical components can be very helpful.
Some significant differences were observed in the variables of speed (40 m) and agility (4x10), suggesting that the training program had some positive effects on the speed and agility skills of the participants. However, the training program did not have a statistically significant effect on variables such as horizontal jump, abdominal strength,

shuttle run (20m), and push-ups. Different components of physical fitness may respond differently to training stimuli, and some participants may already have higher baseline values. In addition, the maturity, duration and intensity of the participants' exercise programs may have influenced the observed differences in physical fitness variables. Some authors (Marcus et al., 2006) acknowledge that the effectiveness of a particular exercise program may vary widely from person to person. Many individual factors such as training program characteristics, environmental conditions, regular physical activity, fitness level, physiological and genetic differences, and social and psychological factors contribute to the differences. (Marcus et al., 2006). Specifically, the study found differences in all GPAI variables in elementary and high school students. However, for physical fitness, the training program showed significant differences only for elementary school students.

Specific differences were observed in the Decisions Made Index (DMI) and the Support Index (SI) in the elementary school context. The observed increases in DMI and SI scores suggest that the instructional intervention had an impact on students' decision-making and support skills, enabling them to make more effective decisions during the game, such as creating more passing lines to help teammates.

In terms of physical fitness, a previous study also showed that soccer players with higher levels of physical fitness demonstrated a greater number of skills, such as dribbling and shooting, during an 8-a-side soccer game. The authors also observed a positive relationship between physical performance and player engagement throughout the game (Portillo et al., 2022). In this study, the intervention had a positive effect on student performance and engagement during the game. Multivariate training programs offer the opportunity to improve physical fitness, motor skills, and creativity. According to the results obtained, the multivariate training program tested seems to be an excellent tool and a pedagogical alternative for the integrated development of tactical indicators such as comprehension, interpretation and technical/tactical performance. A study conducted by Silva et al. (2022) suggests that this type of training program is a valuable tool that can be used effectively for the simultaneous development of basic skills (Silva et al., 2022). They contribute to the development of various aspects, including technical, tactical, physical, and physiological factors (Fernández-Espínola et al., 2020). These training exercises provide players with a multidimensional experience that includes technical and tactical skills, as well as physiological and physical demands. In addition, participation in small-sided games allows players to focus on specific tactical elements while improving their overall understanding of the game and physical performance (Ometto et al., 2018).

In this study, differences were observed between the Control and Intervention Groups in high school students on variables such as Game Involvement (GI), Skill Execution Index (SEI), Support Index (SI), Adaptability Index (AI), and Game Performance (GP). These differences were characterized by effect sizes ranging from trivial and small for SEI, SI and GP to very large for all variables, except for GI. In the post-test assessment of Game Involvement (GI), Decision-Making (DMI), Support Actions (SI), Adaptability (AI), and overall Game Performance (GP), both elementary and high school students showed significant differences between the Control and Intervention Groups. However, the effect size was larger for high school students, suggesting that the training program had a greater impact on improving their game involvement, decision-making and overall game performance compared to elementary school students. In terms of skill execution (SEI), high school students showed more significant differences between the Control and Intervention Groups in the post-test assessment compared to elementary school students.

Taking into account the physical fitness variables, it is clear that the observed results may be influenced by individual variability resulting from different maturation processes and the interrelated development of motor skills across different tasks and exercises in different lessons, in an integrated manner and in relation to the different learning tasks. Individual differences in skill level and learning capacity between participants may have influenced the extent of progress in certain tactical aspects, resulting in this variability. In addition, the duration and intensity of the training program may have had different effects on different GPAI variables. (Guijarro-Romero et al, 2018; Bracco et al., 2019). Furthermore, the positive effects of other learning tasks in the classroom, not just the training program, should also be considered. However, the multivariate training program tested seems to be an excellent tool and a pedagogical alternative for the integrated development of tactical indicators such as understanding, interpretation and technical/tactical execution of the game. This type of program, used at the beginning of the physical education class as an alternative to the traditional warm-up, seems to allow a holistic and well-rounded educational experience for the students, maximizing the useful class time and contributing to their overall development according to the objectives of the didactic unit (Weaving et al., 2017). There is also evidence suggesting that the use of this type of training during adolescence is highly beneficial, as it allows the body to be trained during a period of accelerated musculoskeletal growth, at a time when balance and coordination are impaired as a result of this growth (Zolotarjova et al., 2018; Janssen & LeBlanc, 2010). Additionally, physical tests in basketball physical education provide essential quantitative data on an athlete's physical fitness, encompassing aspects like speed, agility, endurance, vertical leap, and strength.

Also confirming the potential of the multivariate program in terms of game performance, the students showed a significant improvement in their ability to make effective decisions during the game. The GPAI were based on critical game components such as decision-making, spatial awareness, teamwork, goals and strategic execution. Progress in decision-making skills reinforces the impact of the training program, which is also reflected in the positive results on the SEI. The increased SEI scores within the IG appear to be improving their skills. Moreover, the increase in SI scores, even taking into account the reduced 3 vs. 3 format, suggests that the IG has improved in important aspects such as collective organization and the ability to create passing lines and help their teammates. The progress observed in the GP index was also supported by an increase in the overall skills of the GI, which enabled them to perform better during matches. Combining GPAI dimensions with physical tests offers a comprehensive assessment approach by qualitative insights into game performance with quantitative data on physical capabilities. This combined approach enables a well-rounded evaluation, aiding in tailored training programs, targeted skill development, and enhanced overall performance in basketball.

This is a positive indicator of the positive association for match performance when considering the implementation of the training program. There may not be significant differences in all the physical fitness variables, but the functional significance for match improvement may come from the implementation of this multivariate approach. This study is not free of limitations, as it was not possible to control the potential impact that students' extracurricular activities may have on outcomes, and future studies should take this variable into account. The study results were not adjusted for baseline values, such as physical fitness levels, and no comparisons between genders or participant maturation status were done. Future studies on the Game Performance Assessment Instrument (GPAI) should focus on refining its metrics to accurately capture game scenarios and player roles, enhancing its validity and reliability. Validating GPAI through correlations with actual game outcomes will establish its predictive value and practical relevance. Integration of cutting-edge technologies like AI and advanced analytics could automate data collection and analysis, making the GPAI more efficient and providing real-time insights. Additionally, exploring how GPAI-guided training programs impact individual and team performance will contribute to its broader adoption in sports coaching and talent development.

Conclusion

In conclusion, the study demonstrated that the implementation of a 6-week multivariate training program had positive effects on both physical fitness and tactical basketball performance in basic and high school students. The program led to significant improvements in tactical performance, particularly in Decision-Making, Skill Execution, Adaptability, Support Actions, and overall Game Performance. It also had a positive effect on physical fitness, particularly the speed and agility components. However, the program did not show statistically significant effects on all physical fitness variables such as horizontal jump, abdominal strength, shuttle run, and push-ups. Individual factors such as baseline fitness levels and the duration and intensity of the program may have influenced these results. Overall, the results suggest that a well-structured multivariate training program can effectively improve the tactical skills and physical fitness of students in a school setting.

Chapter 4. Correlational Study

Correlation between tactical performance and physical fitness in basketball during physical education classes using a multivariate training program

Abstract

Multivariate training programmes are widely recognised as an effective strategy for developing the skills necessary for good performance in the collective modalities addressed in physical education. The aim of this study was to verify the correlation between tactical performance and physical fitness levels in young secondary school students during the teaching of the didactic unit of basketball, using a multivariate training programme. A group of forty-seven students from a Portuguese school volunteered to participate in the study. A correlational study was used to verify association between tactical performance and physical fitness during the teaching of the Basketball Didactic Unit based on TGFU (i.e., 6 weeks) in two different moments. All subjects were randomly divided into two groups (control and experimental) and assessed at two different moments: before the teaching of the didactic unit (pre-test) and at the end of the teaching of the didactic unit (post-test). Tactical performance in basketball was assessed using the Game Performance Assessment Instrument (GPAI), while physical fitness was assessed using some physical tests from the FitEscola battery. Overall, the multivariate training programme did not differentiate the magnitudes of the correlations between the variables analysed. However, it is confirmed that the multivariate training programme seems to emerge as a positive and differentiating pedagogical strategy that should be integrated into physical education classes.

Keywords: multivariate training program, physical education, pedagogy, didactic unit, physical fitness, tactical performance

Introduction

Today, physical education (PE) plays an extremely important role in promoting the health of the world's population. A sedentary lifestyle is a global problem that can contribute to the development of numerous physical and psychological pathologies (Branquinho et al., 2022; Raudsepp & Kais, 2019). Therefore, participation and positive experiences during childhood through PE, sports clubs or non-organized physical activities are crucial for developing healthy habits that can persist into adulthood and combat this scourge (Chen et al., 2018; Li & Moosbrugger, 2021). PE can also contribute to the development of the student' personality, social involvement, and various skills (i.e., teamwork, self-motivation, communication skills, responsibility, leadership, patience, courage, creativity, critical spirit and moral thinking, self-confidence, self-knowledge, self-discipline) (Ho et al., 2017).

The primary goals of PE are to improve the strength and overall well-being of the students as well as to provide the acquisition of relevant knowledge, physical activity experience, athletic competence and interpersonal social skills. These courses have a significant impact on students' engagement in physical activity and lifelong habits, especially after graduation (Alcalá & Garijo, 2017; Huang, 2017; Kao & Luo, 2020; Luo, 2019; Moreno et al., 2010). In addition, as explained by Metzler & Colquitt (2021), numerous factors, including instructional objectives, curriculum organization, and the pedagogical framework chosen, have a significant impact on students' acquisition of knowledge in the area of PE.

According to Scarpa & Nart (2012), the level of enjoyment students derive from physical activity plays a critical role in whether they begin or continue such activity. Team-based sports offer students the opportunity to learn in a motivating way. Evidence suggests that team-based physical education (i.e., handball, volleyball, football, and basketball) is one of the most beneficial strategies for increasing physical activity levels in the classroom (Brusseau & Kulinna, 2015; Harvey & García-López, 2017), largely due to students' motivation for the task (Ferraz et al., 2021; Tendinha et al., 2021). These games are based on fundamental principles such as positive interdependence, individual skills, social skills related to face-to-face interaction, and group reflection (Johnson & Johnson, 1994), where each member of the group is expected to contribute and strive for the goal. Working with diverse team members is considered an essential skill in today's society (Lee et al., 2017). These benefits include increased motivation to learn (Ning & Hornby, 2014), improved motor skills (Johnson & Johnson, 2002), improved learning outcomes (Adu & Galloway, 2015), development of creativity (Gossett & Fischer, 2005), critical thinking skills (Lin & Jou, 2013), refinement of social skills (Arisoy & Tarim, 2013), and promotion of problem-solving skills (Gorucu, 2016).

In addition, recent research has reported that physical activity can stimulate mental abilities, such as effectiveness and efficiency of decision-making processes, ease of problem solving, innovative thinking and memory retention capacity (Metzler & Colquitt, 2021; Mitsea et al., 2022; Tomporowski et al., 2015). This trend has been reported in previous research, which concluded that children generally respond more quickly and accurately to a variety of cognitive tasks after participating in a physical education class (Ellemberg & St-Louis-Deschênes, 2010; Hillman et al., 2009; Pesce et al., 2009).

For a competent learning process, the literature regularly presents new methodological teaching approaches, such as the Teaching Games for Understanding (TGFU), introduced by Bunker and Thorpe in 1982 (Bunker & Thorpe, 1982). This methodology provides an instructional model for teaching team games in the realm of PE. The game plays a central role, with lessons beginning and ending with a mini-game, and technical skills practiced in between (Thorpe, 1990). This is modified according to the objectives of the lesson and the age and ability of the students, while effectively maintaining student engagement (Kirk & MacPhail, 2002). The implementation of TGFU has been shown to effectively promote students' cognitive and psychomotor development (Allison & Thorpe, 1997; Gray & Sproule, 2011; Turner & Martinek, 1999), as well as their emotional growth (Chatzopoulos et al., 2006; S. Chen & Light, 2006; Jones et al., 2010; Mandigo et al., 2008). They also emphasised that the programme's structured teaching leads to higher levels of student motivation, enjoyment, and learning.

In terms of curriculum, the teaching of team sports (e.g., basketball) aims to enable students to perform a combination of actions that allow the development of specific skills (i.e., physical, tactical, and technical) (Góis et al., 2020). Skills can be essentially perceptual (i.e., tactical understanding) or motor (i.e., physical fitness), or a combination of both, while technique is characterised by the effective and efficient execution of specific movements required by the modality (e.g., running, throwing) (Gudmundsson & Horton, 2017). It is important to note that any physical or technical action always has an underlying tactical intent (Griffin et al., 1997), which emphasises the importance of the tactical component in learning and reinforces the need to consider it in the teaching process.

To this end, multivariate training programmes are widely recognised as an effective strategy for developing the skills necessary for good performance in the collective modalities addressed in physical education (Biddle & Mutrie, 2007; Silva et al., 2022). These programmes are designed to improve technical and tactical skills in team games that are an integral part of the PE curriculum (Capel, 2013; Sproule et al., 2011). Success in team games, such as basketball, is closely related to a student's level of physical fitness and proficiency in technical and tactical aspects (Gabbett et al., 2009). Therefore, the teaching of team games should be designed to recognise this relationship (Mancha-Triguero et al., 2021)

In addition, an individual's level of physical fitness (i.e., speed, strength, agility, coordination) appears to significantly influence the effectiveness of technical and tactical actions in volleyball (Boichuk et al., 2020), Frisbee (Portillo et al., 2022) and handball (Cetin & Ozdol, 2012; Śliż et al., 2022). In contrast, a study that examined a different modality (i.e., football) concluded that physical fitness did not affect tactical understanding and technical skills (Borges et al., 2017). To date, there appears to be no consensus regarding the effect of physical fitness level on tactical behaviour during participation in team games. In addition, as far as is known, no research has been conducted on the potential relationship between physical activity level and tactical performance in basketball, particularly in the context of physical education, where the learning context is promoted. This is due to the fact that the typology of exercises most commonly used in teaching the modality generally involve problems with infinite solutions, making it difficult for students to find the best option (i.e., tactical behaviour), and their physical fitness can be beneficial to the learning process.

Therefore, the aim of this study was to verify the correlation between tactical performance and physical fitness levels in young secondary school students during the teaching of the didactic unit of basketball, using a multivariate training programme.

Methods

Participants

A group of forty-seven students from a Portuguese school volunteered to participate in the study. Due to their age, all guardians were formally informed of the study, both verbally and in writing, and signed an informed consent form authorising the voluntary participation of their children. Inclusion criteria for the study were: 1) being healthy; 2) having no injuries; 3) participating regularly in physical education classes. There were no exclusion criteria. To participate in the study, students had to be healthy and participate in physical education classes, and there were no exclusion criteria. To calculate the sample, the G*Power 3.1 software (Kang, 2021) was used. An a priori analysis was performed and it was determined that 47 subjects would be needed for the study (effect size dz: 0,40, error probability α: 0,05, power: 0,90). The students and the teacher were informed of the known health risks before the study began and that they could withdraw from the study at any time, even after it began. All procedures were conducted in accordance with the recommendations of the Declaration of Helsinki for research involving human subjects.

Procedures

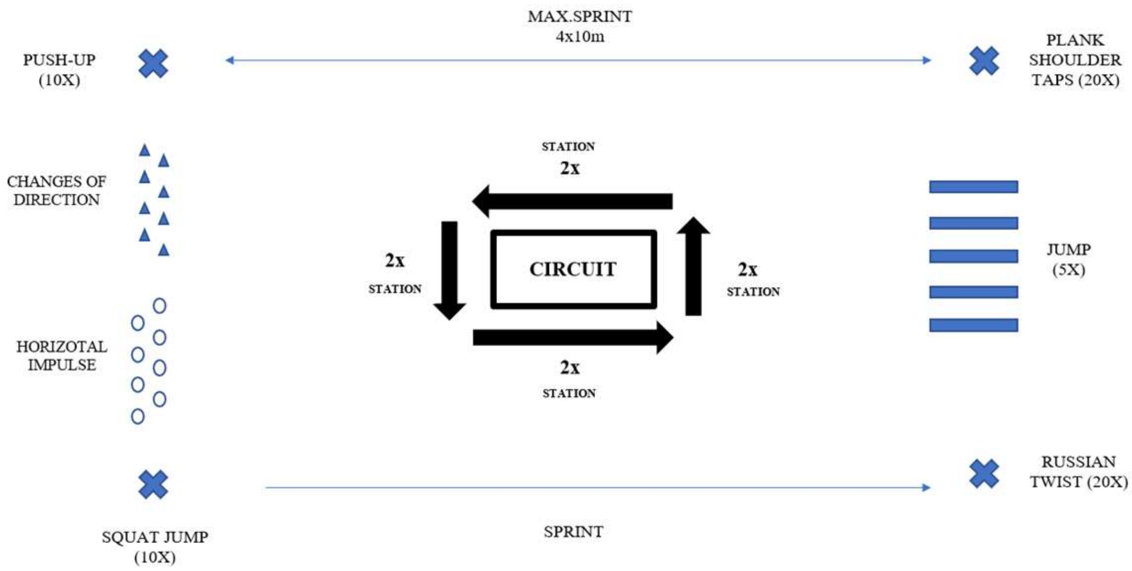
This research used a correlational design to verify the existence of correlations between tactical performance and physical fitness during the teaching of the Basketball Didactic Unit based on TGFU (i.e., 6 weeks) in two different moments. All subjects were randomly divided into two groups (control and experimental) and assessed at two different moments: before the teaching of the didactic unit (pre-test) and at the end of the teaching of the didactic unit (post-test). Tactical performance in basketball was assessed using the Game Performance Assessment Instrument (GPAI), while physical fitness was assessed using some tests from the FitEscola battery (i.e., sit-ups, push-ups, horizontal impulse, shuttle test, 40m sprint and agility). All students had the same educational opportunities, but the intervention group also used a multivariate training programme at the beginning of the physical education class instead of the traditional warm-up. This research used a correlational design to verify the existence of correlations between tactical performance and physical fitness during the teaching of the Basketball Didactic Unit based on the

TGFU (ie, 6 weeks) at two different times. All subjects were randomly divided into two groups (control and experimental) and evaluated at two different times: before teaching the didactic unit (pre-test) and at the end of teaching the didactic unit (post-test). Tactical performance in basketball was assessed using the Game Performance Assessment Instrument (GPAI), while physical fitness was assessed using some tests from the FitEscola battery (i.e., sit-ups, push-ups, horizontal jump, shuttle test, 40m sprint and agility). All students had the same educational opportunities, but the intervention group also used a multivariate training program and small-sided basketball games (SSGs) at the beginning of physical education class instead of the traditional warm-up. The multivariate training program was designed based on adaptations to previous protocols (Branquinho et al., 2020; Ferraz et al., 2012). This was applied for 6 weeks (Table 1) and incorporated 4 stations (Figure 1) that contained the following exercises: Station 1 - maximum speed and push-ups; Station 2 - running with changes of direction, horizontal impulse and the squat jump; Station 3 - sprint and Russian twist; Station 4 - jump and plank shoulder taps. In addition, the students also performed a 3 *vs*. 3 SSGs in midfield, without teacher intervention and considering the learning acquired from the didactic unit.

Table 1. Multivariate training program (four stations)

	S	R	PUSH-UP	Change of Direction	Horizontal Impulse	SQUAT JUMP	Sprint	RUSSIAN TWIST	JUMP	Plank Shoulder Taps	Max. Sprint 4X10m
Week 1	S1	2	4 x 10	4 x 8	4 x 4	4 x 10	4 x 1	4 x 20	4 x 5	4 x 20	4 x 1
Week 2	S2	2	4 x 10	4 x 8	4 x 4	4 x 10	4 x 1	4 x 20	4 x 5	4 x 20	4 x 1
	S3	2	4 x 10	4 x 8	4 x 4	4 x 10	4 x 1	4 x 20	4 x 5	4 x 20	4 x 1
Week 3	S4	2	4 x 10	4 x 8	4 x 4	4 x 10	4 x 1	4 x 20	4 x 5	4 x 20	4 x 1
	S5	3	6 x 10	6 x 8	6 x 4	6 x 10	6 x 1	6 x 20	6 x 5	6 x 20	6 x 1
Week 4	S6	3	6 x 10	6 x 8	6 x 4	6 x 10	6 x 1	6 x 20	6 x 5	6 x 20	6 x 1
	S7	3	6 x 10	6 x 8	6 x 4	6 x 10	6 x 1	6 x 20	6 x 5	6 x 20	6 x 1
Week 5	S8	3	6 x 10	6 x 8	6 x 4	6 x 10	6 x 1	6 x 20	6 x 5	6 x 20	6 x 1
	S9	4	8 x 10	8 x 8	8 x 4	8 x 10	8 x 1	8 x 20	8 x 5	8 x 20	8 x 1
Week 6	S10	4	8 x 10	8 x 8	8 x 4	8 x 10	8 x 1	8 x 20	8 x 5	8 x 20	8 x 1
	S11	4	8 x 10	8 x 8	8 x 4	8 x 10	8 x 1	8 x 20	8 x 5	8 x 20	8 x 1

R= Repetition; S= Session



Instruments

Tactical performance

The GPAI (Oslin et al., 1998) was used to assess the students' tactical performance in the two moments analysed (i.e., pre-test and post-test). Students were instructed to perform 3 vs. 3 formats, which were filmed with a common video camera and later analysed by two experts. The experts were selected based on the following criteria: i) at least 10 years of professional experience in the modality; ii) current experience as a high performance basketball coach; iii) at least a Master's degree with scientific research in the modality. The GPAI record sheet was used by all experts during the assessment. To validate the observations made, coders were required to achieve interobserver agreement greater than 80% using Kendall's W coefficient of agreement (Oslin et al., 1998). The experts coded and calculated measures of appropriate and inappropriate actions in four game components: decision-making, skill execution, support actions, saving/marking based on an adaptation of a previously defined and validated protocol (Oslin et al., 1998) (Table 2). These four game components were selected as being the most important for assessing general and non-specific game skills in young people.

Table 13. Definition of appropriate and inappropriate actions for applying the GPAI

Components of game	Assumption	AA	IA
Decision-Making	When receiving the ball, he adjusts to the basket in a basic offensive stance.	Fulfils the assumption	Does not meet the assumption
	He shoots when he is within range of the basket and the defender is not pressuring him.		
	He passes when he has an unmarked teammate in a more offensive position.		
	If he has none of the above options, he dribbles away from the defender.		
Skill Execution	Throwing: Throwing arm extension, wrist flexion.		
	Passing: Passing to a teammate; the ball reaches the teammate in good condition.		
	Dribbling: Not looking at the ball; not "carrying" the ball.		
Support Actions	He attempts to create passing lines.		
	He does not come within 3 meters of the person with the ball.		
Saving/marking	When he loses the ball, he takes a basic offensive stance and looks for his immediate opponent.		
	He places himself between his opponent and the basket.		

Abbreviation: AA – Appropriate action; IA – Inappropriate action

Physical fitness

The FITescola test battery was used to assess physical fitness. The tests used are described in detail below.

Sit-ups

The sit-up test consists of performing the maximum number of sit-ups at a predetermined cadence (Henriques-Neto et al., 2020). The purpose of this test is to evaluate the strength of resistance of the abdominal muscles. This action was repeated at a predetermined cadence of 20 sit-ups per minute. The number of times the participants performed this action correctly was recorded.

Push-ups

The push-up test consists of performing the maximum number of push-ups (arm flexion and forearm extension) at a predetermined cadence (Henriques-Neto et al., 2020). This test aims to evaluate the endurance strength of the upper limbs. This action was repeated at a predetermined cadence of 20 push-ups per minute. The number of times the participants performed this action correctly was recorded.

Horizontal Impulse

The horizontal impulse test consists of reaching the maximum distance in a long jump with feet together (Henriques-Neto et al., 2020). The purpose of this test is to evaluate the explosive strength of the lower limbs. A horizontal line is drawn at the starting point, with reference lines every 10 cm. Starting from a standing position, the subject must bend the knees, pull the arms behind him and jump in length as far as possible. Two jumps must be performed. The best result of the two measurements in cm is recorded.

Shuttle Test

The shuttle test consists of performing the maximum number of routes performed over a distance of 20 m at a predetermined cadence through an audio device (Mayorga-Vega et al., 2015). The student must remain in the test as long as possible, stopping when he or she fails to reach the line before the sound signal on two occasions, not necessarily consecutive. The first foul is counted towards the score.

40m Sprint

The test consists of running a 40-meter race in the shortest possible time according to a previously described protocol (Wang et al., 2016). The purpose of this test is to measure the student’s acceleration capacity and speed. Two attempts per student are required. The registered value is the best result of the two evaluations in hundredths.

Agility 4 x 10m

The agility test (4x10 m) consists of completing a predetermined route, combining the maximum speed of execution with the coordination translated into the movement of grasping, carrying and placing a sponge in a predetermined place (Vicente-Rodríguez et al., 2011). In order to evaluate the student's agility, the test aims to characterize the acceleration capacity, the coordination of the required movements and their speed of execution. Two tests must be performed and the value recorded is the best result of the two evaluations, expressed in hundredths.

Statistical analysis

Descriptive statistics are presented as mean ± one standard deviation (SD) with a 95% confidence interval (CI). Kolmogorov-Smirnov and Levene tests were used to determine the normality and homogeneity of data distribution. The Pearson correlation coefficient was calculated to analyse the relationship between the variables analysed within each group and between groups. Effect sizes (ES) were calculated based on Cohen's d and were classified as follows: 0.2-0.6 (trivial); 0.6-1.2 (small); 1.2 (large); and greater than 2.0 (very large) (Hopkins, 2019; Hopkins et al., 2009). Statistical significance was set at $p < 0.05$. Statistical analyses were performed using SPSS for Windows version 26.0 (SPSS Inc., Chicago, IL, USA).

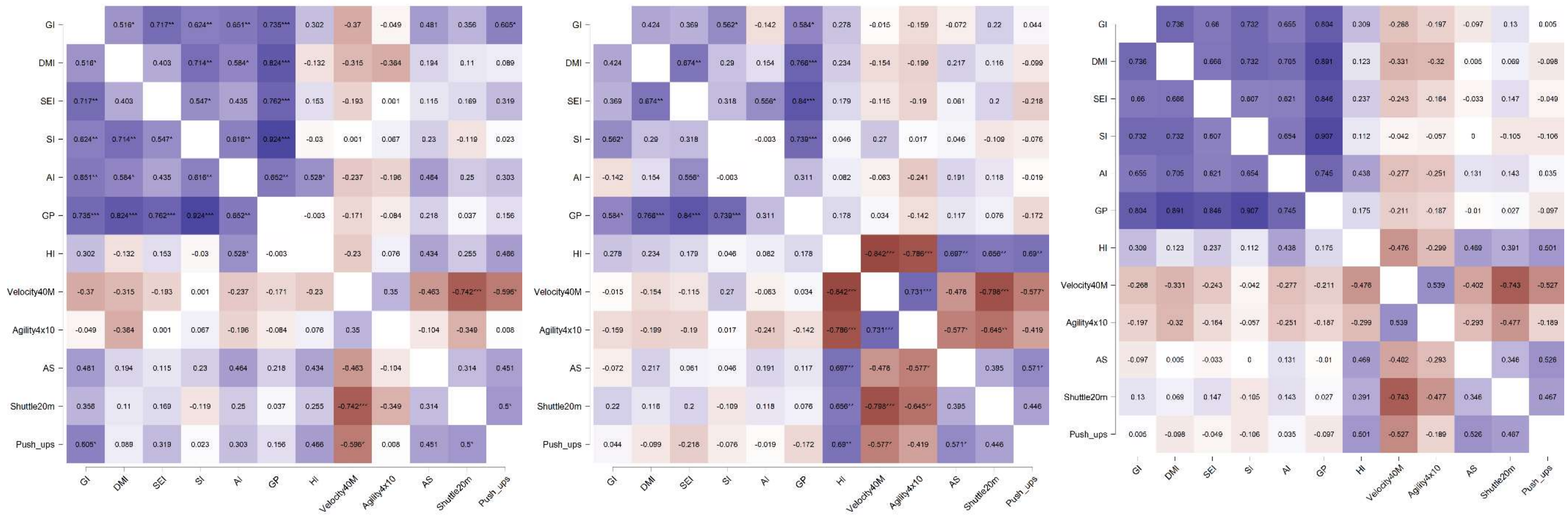
Results

Pearson parametric correlations between the GPAI indexes and the physical fitness measures in the control group (CG).

Figure 2 shows the Pearson parametric correlations between the GPAI indexes and the physical fitness measures in the CG for the pre-intervention moment (Figure a), the post-intervention moment (Figure b) and both intervention moments (Figure c). The Pearson correlation matrix showed trivial to very high correlations for the pre-intervention moment (r = -0.74 to 0.92; $p < 0.05$ to $p < 0.001$), the post-intervention moment (r = -0.84 to 0.84; $p < 0.05$ to $p < 0.001$) and both intervention moments (r = -0.55 to 0.89; $p < 0.05$ to $p < 0.001$).

Pearson parametric correlations between the GPAI indexes and the physical fitness in the intervention group (IG)

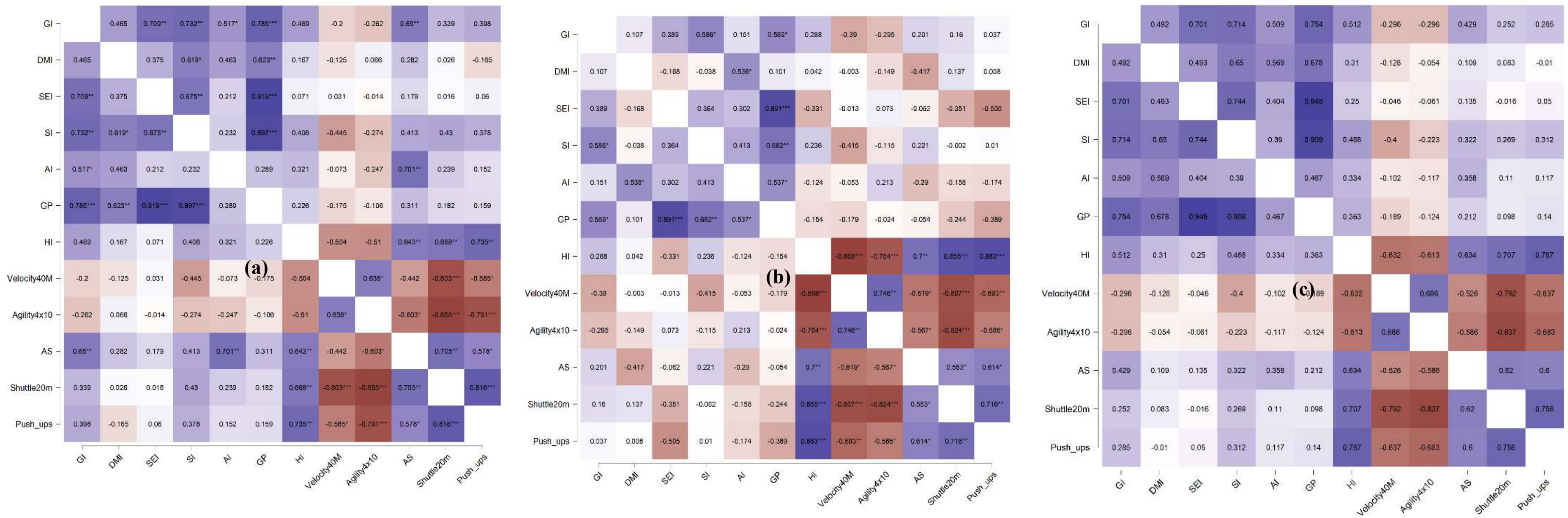
Figure 3 shows the Pearson parametric correlations between the GPAI indexes and the physical fitness measures in the IG for the pre-intervention moment (Figure a), the post-intervention moment (Figure b) and both intervention moments (Figure c). The Pearson correlation matrix showed trivial to very high correlations for the pre-intervention moment (r = -0.86 to 0.92; $p < 0.05$ to $p < 0.001$), the post-intervention moment (r = -0.86 to 0.89; $p < 0.05$ to $p < 0.001$) and both intervention moments (r = -0.55 to 0.89; $p < 0.05$ to $p < 0.001$).



(c)

(a) **(b)**

Figure 2 – Pearson parametric correlations between the GPAI indexes and the physical fitness measures in the control group (CG) according to: (a) pre-intervention moment, (b) post-intervention moments; (c) overall population (Pre- vs post-intervention moments). Correlation is significant at: *** $p < 0.001$; ** $p < 0.01$, * $p < 0.05$. The correlation magnitude was classified as: trivial if $r \leq 0.1$, small if $r = 0.1–0.3$, moderate if $r = 0.3–0.5$, large if $r = 0.5–0.7$, and very large if $r = 0.7–0.9$ and almost perfect if $r \geq 0.9$. Abbreviations: AI – Adjustment index; AS – Abdominal Strength; DMI – Decision making index; GI – Game Involvement; GP – Game performance; HI – Horizontal impulse; SEI – Skill execution index; SI – Support index.



(a) (b) (c)

Figure 3 – Pearson parametric correlations between the GPAI indexes and the physical fitness measures in the intervention group (IG) according to: (a) pre-intervention moment, (b) post-intervention moments; (c) overall population (Pre- vs post-intervention moments). Correlation is significant at: *** $p < 0.001$; ** $p < 0.01$, * $p < 0.05$. The correlation magnitude was classified as: trivial if $r \leq 0.1$, small if $r = 0.1–0.3$, moderate if $r = 0.3–0.5$, large if $r = 0.5–0.7$, and very large if $r = 0.7–0.9$ and almost perfect if $r \geq 0.9$. Abbreviations: AI – Adjustment index; AS – Abdominal Strength; DMI – Decision making index; GI – Game Involvement; GP – Game performance; HI – Horizontal impulse; SEI – Skill execution index; SI – Support index.

Discussion

The aim of this study was to verify the correlation between tactical performance and physical fitness levels in young secondary school students during a basketball didactic unit, using a multivariate training programme. Overall, there did not appear to be any significant differences between the groups in terms of the implementation or absence of the multivariate training programme. However, tactical components and physical fitness were positively associated with optimising game performance. The results show positive correlations between improved decision-making, support actions, and overall match performance in both groups. A balanced pedagogical approach that considers both aspects could lead to improved performance.

Overall, and for both groups, there appear to be no differences in a differentiated analysis, regardless of whether the multivariate training programme was used or not. According to the results obtained, the application of the multivariate training programme during the didactic unit based on the TGfU does not seem to increase the degree of association between the variables of physical fitness and tactical performance. Therefore, the multivariate training programme did not differentiate the magnitudes of the correlations between the variables analysed. However, it is confirmed that the multivariate training programme seems to emerge as a positive and differentiating pedagogical strategy that should be integrated into physical education classes (Silva et al., 2022).

The results observed in both groups (overall graph) show an interesting relationship between speed, agility, and all tactical performance variables. A strong correlation between speed and agility suggests a link between these physical attributes. Increasing one tends to increase the other. This finding highlights the complementary nature of speed and agility in athletic performance. According to Coburn & Malek (2012) and Köklü et al. (2015), these phenomena can be explained by the fact that both abilities require the use of explosive power and fast twitch muscle fibres. However, there is a curious strong negative correlation between tactical performance and speed/agility. This relationship may imply a trade-off between physical fitness and tactical performance, where a focus on improving tactical performance may sacrifice speed and agility and vice versa. These findings confirm that although speed and agility are two important skills for game performance in basketball (Gudmundsson & Horton, 2016), players with higher speed and agility are less able to respond to the tactical needs of the game due to greater irregularity in their collective behaviour, which tends to lead to greater collective disorganisation (Ferraz et al., 2021). Ferraz et al (2018), in a study of small-sided games in football, showed that higher game speeds may have affected the stability of players' interpersonal distances. It seems, therefore, that fast games require a faster ability to identify this information, which can influence the players' positional behaviour. Therefore, in the context of teaching a didactic unit of physical education in a school context and trying to improve performance in the game, these physical components can be used with some caution.

The analysis also revealed an interesting relationship between push-ups and abdominal strength (AS). Improved push-up performance was associated with an increase in abdominal muscle strength, suggesting a possible interaction between fitness measures and horizontal force generation. However, these physical fitness variables do not have a significant relationship with tactical variables. Previous research has also shown no clear correlation between fitness levels and performance in small-sided games (Sabarit et al., 2020). However, it can be inferred that the below-average performance observed in the technical and tactical aspects of the game has implications for physical performance, particularly in terms of how players allocate their physical effort in relation to the rhythm and intensity of the game (Smith et al., 2015, 2016). It seems that skill and decision-making deficits can affect how players allocate their energy and effort during the game. The results also showed that push-ups and SEI were strongly associated in the IG after the implementation of the multivariate programme training. These results also highlight the importance of upper limb strength in achieving the goal of the game, especially in this age group (pre-pubertal and pubertal). In this context, the implementation of a multivariate training programme that emphasises upper limb strength training could be very useful (Silva et al., 2022).

In both groups (pre- and post-tests) it was observed that overall game performance (GP) had a strong positive correlation with decision-making (DMI) and actions of support (SI). This suggests that students who demonstrate improved decision-making skills and provide effective support during the game are more likely to achieve higher overall game performance, which is consistent with the findings of Gabriele & Maxwell (1995) and Griffin et al. (1995). As noted by Arias-Estero & Castejón (2014) and Oslin et al. (1998), it can be said that the support index makes a significant contribution to GP, as well as skill execution, adaptability, and game engagement. This study also provides strong evidence to support the hypothesis that improvements in tactical performance variables, particularly SEI, SI, and DMI, lead to significant improvements in overall game performance.

Also, considering that the players in the pre-test have a lower level of physical fitness, it can be deduced that the students are likely to have a higher level of physical fatigue when playing. Physical fatigue affects the players' ability to perform certain movements aimed at blocking passing lines close to the opponent and maintaining defensive stability in lateral areas. Instead, players prioritise actions that are further away from the ball, focusing on reducing the opponent's width or depth and limiting the effective playing space. This behaviour suggests a shift towards increasing marking in sectors further away from the ball, possibly to prioritise key aspects of the game such as goal protection. Similar tendencies have been observed in studies of individuals performing mentally demanding tasks, where they prioritise essential actions over less important ones (da Costa et al., 2009; Sampaio et al., 2014; van der Linden, 2011).

There was also a positive correlation between game involvement (GI) and the number of push-ups performed. This positive correlation suggests that physical fitness, particularly upper body strength as indicated by push-up performance, may contribute to increased engagement and active participation in the game. According to Faigenbaum et al. (2016), core strength training should be a fundamental component of conditioning programmes at every stage of long-term athlete development. It can help young athletes withstand the rigours of prolonged training and competition. This finding is consistent with the notion that higher levels of physical fitness may have a positive impact on engagement in the game and the ability to execute tactical manoeuvres effectively.

According to the results, the horizontal jump is negatively associated with both speed and agility. Notably, an inverse relationship was observed between push-up performance and agility, demonstrating that as agility decreases, push-up performance tends to increase and vice versa. This suggests that when attempting to improve tactical performance, students should favour weight-based activities such as push-ups over agility-related exercises. The results suggest that improving decision-making abilities, support skills, and upper body strength can have a positive impact on game performance and engagement. From a pedagogical perspective, the ability to make precise decisions in complex game situations under pressure and time constraints is a crucial component of game performance (Höner et al., 2020), and the relationship between the components of physical performance must always be well manipulated.

Another interesting analysis is the post-tests conducted on the control group, which revealed that overall game performance (GP) increased in conjunction with skill execution (SEI), decision-making (DMI), and support actions (SI), showing strong positive correlations. Individuals who excel in SEI, DMI and SI are more likely to achieve superior overall in-game performance, as evidenced by the robust and flawless correlation observed between these metrics. In addition, post-tests in the IG also showed significant improvements in overall game performance (GP), which was strongly associated with increases in skill execution (SEI) and support actions (SI).

Improvements in skill execution (SEI), support actions (SI), and overall game performance (GP) are strongly related. This phenomenon can be explained by previous studies that have shown a correlation between players with higher levels of inhibitory control and their superior performance in game-related tactical situations (Albuquerque et al., 2019). The ability to accurately understand game scenarios requires players to be able to inhibit impulsive reactions and adapt their actions according to the demands of the game (Huijgen et al., 2015). This could include tasks such as anticipating passing opportunities, identifying numerical advantages in attack, coordinating defensive transitions, and understanding movements into unoccupied areas (Carnevale et al., 2022). Furthermore, decision-making has been identified as an important skill, and numerous cross-sectional studies have examined decision-making performance, consistently demonstrating that it is a differentiating factor between skilled and less skilled players in team sports (Lorains et al., 2013; Woods et al., 2016).

Conclusion

In summary, this study investigated the relationship between tactical performance and physical fitness levels in young secondary school students during a basketball teaching programme. The results indicated that the implementation of a multivariate training programme did not significantly affect the correlation between physical fitness and tactical ability.

However, it is confirmed that the multivariate training programme seems to emerge as a positive and differentiating pedagogical strategy that should be integrated into physical education classes. Also, it was evident that both tactical components and physical fitness play an important role in optimising match performance. The study also highlighted the importance of multivariate training programmes that integrate tactical skill development and physical fitness enhancement. The results underlined the link between physical fitness and tactical performance, highlighting the need for comprehensive training to optimise game performance. Decision-making skills were identified as crucial, and cooperative actions to support teammates were found to influence effective decision-making and overall game performance. Teachers should consider the results of this study for a differentiated pedagogical implementation to improve students' physical fitness and game performance. In addition, this study suggests that the physical fitness programmes to be implemented need to be properly designed in order to improve the tactical performance, but more research is needed in this area.

Chapter 5. Overall Conclusions

Overall, the first study demonstrated that the implementation of a 6-week multivariate training program had positive effects on both physical fitness, particularly in the speed and agility components, and tactical basketball performance variables, such as Decision-Making, Skill Execution, Adaptability, Support Actions, and overall Game Performance, in elementary and high school students. Moreover, it was shown that these improvements occurred at the elementary and high school levels. In the second article, it was found that the implementation of a multivariate training program did not significantly affect the correlation between physical fitness and tactical ability. However, it has been shown that both tactical and physical fitness components play an important role in improving game performance. In conclusion, it is critical to emphasize the importance of holistic multivariate training programs that include both tactical and physical components to improve the game performance of students and athletes. Based on the results obtained, it can be concluded that the application of training programs with multivariate skills (physical, tactical) should be considered as a valid pedagogical tool and an alternative teaching method to replace the traditional warm-up or to use this type of programs for this purpose in physical education classes, either in elementary or high school. As a training program of short duration and because it can be implemented without the need for large investments by schools, this methodology can and should be considered by physical education teachers.

In particular, the results of the first study showed a remarkable contrast between the pre- and post-tests on all GPAI indexes for both groups, indicating an improvement in tactical performance. The implementation of a multivariate program in elementary and high schools also showed positive effects, especially on variables related to game performance. This study found some differences between the Control and Intervention Groups among elementary and high school students on variables such as Game Involvement (GI), Decision-Making (DMI), Skill Execution Index (SEI), Support Index (SI), Adaptability Index (AI), and Game Performance (GP). For the high school students, the highest dissimilarities were classified by effect sizes ranging from trivial and small in the pre-test for SEI, SI, and GP, to very large in the post-test for all variables, except GI. Therefore, it can be argued that the program probably had a greater impact on high school students than on elementary school students. Concerning physical fitness, the multivariate training program showed some positive effects on physical fitness, especially in terms of speed and agility. However, no other significant differences in physical fitness variables were observed in primary and secondary school students. Nevertheless, it is evident that the observed results may have been influenced by individual differences, such as different maturation processes and motor skill development in a variety of tasks and exercises, integrated with different lessons, and in relation to different learning objectives.

The results presented in the second study showed an interesting negative correlation between speed and agility and tactical performance variables, which may suggest a trade-off between physical fitness and tactical performance, where prioritizing improvements in tactical performance could potentially result in compromising speed and agility, and vice versa. Furthermore, a negative correlation was observed between these physical fitness components and horizontal jumps and push-ups. The results suggest that improving decision-making abilities, support skills, and upper body strength can have a positive impact on game performance and engagement. Apparently, there is a positive correlation between speed and agility, meaning that improving one usually leads to improvements in the other. These phenomena can be explained by the fact that both skills require explosive power and fast-twitch muscle fibers. There is also an interesting relationship between push-ups and abdominal strength (AS). Improved push-up performance showed a positive correlation between push-ups and abdominal strength. However, these physical fitness variables do not show a significant association with tactical variables. The results also demonstrated a strong correlation between push-ups and game involvement (GI) and skill execution index (SEI), underscoring the importance of upper limb strength in achieving game goals. Another interesting analysis revealed that a strong positive correlation was observed between overall game performance (GP) and decision-making (DMI), skill execution (SEI), and support actions (SI), indicating that students with better DMI, SEI, and SI were more likely to achieve superior overall game performance.

Chapter 6. Practical applications and suggestions for future investigations

Based on the results, the integration of multivariate training programs using a physical fitness circuit and small-sided games (game-based activities) can lead to improvements in physical and tactical performance variables. This approach allows students to increase their physical fitness while improving their participation, decision-making, skill execution, adaptability, support actions, and overall game performance. Based on these findings, it has been determined that physical education teachers must maintain the ability to plan effective lessons that promote physical fitness, technical skills, tactical understanding, and social skills in an integrated manner. Teachers could also begin each class with a dynamic warm-up that includes SSGs and drills to develop physical fitness components such as speed, agility, and coordination. Although there seems to be no significant degree of association between the two analyzed components, the pedagogical usefulness of the multivariate training program is confirmed, establishing itself as a valid and alternative pedagogical tool to be used in the initial part of the class, replacing the traditional warm-up. Small-sided games can also be incorporated into the warm-up routine to improve decision-making, skill performance, support actions, and adaptability by providing realistic scenarios that require quick decision-making, precise skill execution, and flexible responses to the changing dynamics of the game. Therefore, this approach allows students to take a more active role in the game, engage with the ball more often, improve their technical, tactical, physical, and social skills, and develop a deeper appreciation for physical activity. Finally, it is important to emphasize that teachers should consider the individual characteristics of each student, such as age, maturation process, personal preferences, and motor skills and abilities.

Objectively, the main practical applications are:

I – Integrating Multivariate Training Programs with Small-Sided Games:
In addition to the physical fitness benefits, students will be able to improve their participation, decision-making, skill execution, adaptability, support actions, and overall game performance, leading to improvements in tactical variables.

II – Warm-up Planning:
The warm-up must be effectively planned to promote physical fitness, technical abilities, tactical understanding, and social skills. Physical education teachers should be able to plan and organize classes to effectively promote these improvements through the implementation of multivariate training programs.

III – Benefiting from Dynamic Warm-ups and Small-Sided Games in the Classroom:
Teachers can begin a class by incorporating drills designed to develop physical fitness components such as speed, agility, and coordination, along with dynamic warm-ups and small-sided games. Small-sided games can also be added into the warm-up routine to improve useful class time, decision-making, skill performance, support actions, and adaptability because they involve realistic scenarios that require quick decision-making, precise skill execution, and flexible responses to the changing dynamics of the game.

IV – Considering the Individuality of Each Student:
All individual factors that may influence the results of the classes must be considered. These factors include gender, cultural background, personality traits, interests and preferences, prior knowledge or experience, individual goals, fitness level, skill level, attention span and ability to concentrate, physical limitations, or disabilities, learning styles, motivation levels, emotional well-being, and peer dynamics. Neglecting any of these factors can interfere with the desired outcomes.

V – Encouraging Commitment and Passion for Physical Activity and Sports:
Following this path can lead to greater student engagement and enjoyment. Students who take a more active role in a game and touch the ball more often can improve their technical, tactical, physical, and social skills and develop a deeper appreciation for physical activity.

Suggestions for future research

There is a need for future research to investigate the long-term effects of multivariate training programs on physical fitness and tactical performance. The studies reviewed had a relatively short intervention period, lasting a total of 6 weeks. By conducting studies with longer intervention periods, researchers can evaluate the lasting effects of improved physical fitness and tactical performance, and examine whether the observed improvements are maintained or whether there is a potential decline in these outcomes. An alternative approach for future research is to examine the impact of individual differences on the effectiveness of exercise programs. Factors such as age, gender, skill ability, and maturity can influence an individual's response to a training program. By examining these individual differences, researchers can gain a deeper understanding of whether certain segments of students benefit more from aspects of the educational program or whether modifications are needed to meet the needs of each group. Moreover, future studies may further explore the specific components of physical fitness that contribute to tactical performance in basketball. Although research highlights the positive effects of multivariate training programs on speed and agility, other physical characteristics may also play an important role in tactical performance. Researchers can examine the effects of strength, endurance, coordination, and related factors on tactical variables to better understand the relationship between physical fitness and tactical performance. Additionally, an imperative focus for future research would be to refine the formulation and delivery of training programs to achieve optimal results. Researchers can also study the optimal duration, frequency, and intensity of exercise to maximize program effectiveness. Furthermore, the effectiveness of the training program can be improved by identifying specific training exercises and drills that have the greatest impact on physical strength and tactical performance. Future studies could also explore the transferability of these findings to other sports beyond the focus on basketball. Analyzing the relationship between physical fitness and tactical performance in different sports can provide insight into the generalizability of these findings and support the development of training programs tailored to different sports.

Objectively:

I – Investigate the Long-Term Effects of Multivariate Training Programs:

Investigate the long-term effects of extended intervention periods on physical fitness and tactical performance to determine if the observed improvements are maintained or if there is a potential decline in these outcomes over time.

II – Assess the Influence of Individual Differences on the Effectiveness of the Training Program:

Assess how factors such as age, gender, skill level, and maturity affect an individual's response to the program. Determine if certain segments of students benefit more from certain aspects of the program, and if modifications are needed to accommodate different needs.

III – Explore the Role of Different Physical Fitness Components in Tactical Performance:

Explore the role of strength, endurance, coordination, and other physical attributes on tactical performance in basketball and improve the understanding of the relationship between physical fitness and tactical variables.

IV – Refine the Formulation and Execution of Training Programs:

Optimize the duration, frequency, and intensity of training to maximize program effectiveness. This includes identifying specific training exercises and drills that have the greatest impact on physical strength and tactical performance.

V – Examine Transferability to Other Sports:

Analyze the relationship between physical fitness and tactical performance in various sports. Assess the generalizability of research findings to different sport modalities and support the development of tailored training programs.

Chapter 7. References

Chapter 1. General Introduction

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