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A STUDY ON THE PHYSICAL AND COGNITIVE BENEFITS OF BADMINTON IN SECONDARY EDUCATION

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Abstract Badminton, as a highly accessible and dynamic sport, can respond to multiple educational needs, contributing significantly to the formation of motor skills and to the development of intellectual and socio-emotional competences. The aim of the paper is to analyze the influence of practicing badminton on physical parameters, such as speed, coordination and endurance, as well as cognitive skills, such as concentration, strategic thinking, emotional and mental balance. The hypothesis of the paper hypothesizes that the implementation of a badminton-based program in physical education lessons for 6th and 7th grade students will have a significant impact on improving physical and cognitive performance, while contributing to the development of social skills. Objectives of the paper: to evaluate the impact of the badminton program on the physical and cognitive skills of students; to evaluate the students' perception of the impact of the badminton program on their physical and cognitive skills; to analyze the differences between the experimental and control groups. Integrating this sport into the educational program can support the formation of a healthy lifestyle, promoting regular physical activity and reducing the risks associated with a sedentary lifestyle.

Introduction Sports, and badminton in particular, is one of the areas where there is a growing interest in the use of modern strategies, due to the beneficial effects on the speed of learning and the efficiency in investing the time and effort required [15]. The use of computational techniques for sports performance evaluation has become a common practice, being integrated into the selection and training process of athletes. This includes the use of specialized programs for exercise planning and recovery [9,13]. Regular physical activity, including badminton, has multiple benefits for the overall health of the individual at any age and stage of life [4]. Badminton is a dynamic, speed and skill sport that requires jumping, rapid changes of direction and

rapid arm movements from various postural positions [11]. It is also a sport with growing popularity, and its application in educational programs for students with mild intellectual disabilities has demonstrated significant improvements in their health and well-being [5]. A program developed based on practice and science for young people aged 9-11 years has positively influenced their physical fitness [6]. Studies have emphasized that badminton is a demanding sport that requires athletes to channel their attention to the game by focusing on a moving object in a large playing area. In this context, the ability to maintain concentration, coordinate eye movements and demonstrate agility are essential for success in the sport [16]. In addition, virtual reality (VR)-based teaching methods have shown a significant improvement in learning efficiency in badminton, facilitating the understanding of essential elements, mastery of skills, postural adjustment, as well as the development of teamwork and motivation [8]. Although the use of VR has brought benefits to the educational process, teachers have faced dilemmas related to 'movement', 'play' and 'learning', which have influenced how to implement this method. Theoretical and empirical studies emphasize the importance of the physical education and sport teacher's professional mindset in improving the instructional-educational process, having a direct impact on communication and student achievement [1]. In addition, the use of technology to improve the playing technique in badminton, even in the pandemic period, has been an effective method for developing students' motor skills [17]. Thus, sport continues to be a fundamental element in the development of the human being, contributing both to the improvement of physical performance and to the development of cognitive and social qualities [3,12].

Material-method

The study was conducted on a sample of 60 secondary school students from the 6th and 7th grades of the "Alexandru Ioan Cuza" School in Fălticeni. Participants were equally divided into two groups: experimental and control. The experimental group benefited from a program structured in 5 modules, designed to stimulate physical and cognitive development through badminton practice, using methods and means specific to this sport. The program aimed to improve physical (speed, coordination, endurance) and cognitive (concentration, strategic thinking, emotional and mental balance) skills through a progressive approach tailored to the needs of the students. The control group followed the usual physical education lessons, according to the standard school curriculum, without the integration of badminton specific activities. The implementation of the program took place over a period of 35 weeks, covering the 5 proposed modules. Each module had clearly defined objectives, aimed at ensuring the gradual progress of the students in the development of technical-tactical skills and psychomotor skills. In order to evaluate the effectiveness of the program, periodic measurements were carried out on both groups, using standardized

methods and statistical indicators for comparative analysis. Inclusion criteria for the students: age and grade, medical advice for participation in physical education classes, willingness to participate in classes, no significant previous badminton playing experience, informed consent agreement for participation in the badminton program. In this study, a number of research methods were used: the scientific documentation method consisted of reviewing relevant literature, previous studies and theoretical resources in order to identify and understand current concepts, strategies and trends in physical education and cognitive development through sport. The observation method was used to analyze students' behavior during physical education lessons, focusing on how they interact with the proposed exercises, the degree of involvement, physical and psychological responses and individual progress in relation to the set objectives. The pedagogical experiment method was the main method of the research, involving the implementation of a program structured in 5 modules for the experimental group. The control group, on the other hand, continued to participate in the standard lessons. Questionnaire survey method, in order to obtain additional information, a questionnaire was administered to the students in order to collect opinions and perceptions about the proposed program. The mathematical-statistical method was used to process and interpret the data obtained from the tests and evaluations. The testing method was used to assess the physical (speed, coordination, balance) and cognitive (attention, concentration, strategic planning ability) performance of the students, both before and after the implementation of the program. The tabular-graphical method was used for a clear and easy to interpret presentation of the collected data, the results were summarized in the form of tables and graphs. These representations provided an overview of the students' evolution and the differences between groups, highlighting the impact of practicing badminton. The aim of the paper is to analyze the influence of badminton on physical parameters such as speed, coordination and endurance, as well as cognitive skills such as concentration, decision making and teamwork on secondary school students.

The hypothesis of the paper hypothesizes that the implementation of a badminton-based program in physical education lessons for students in 6th and 7th grades will have a significant impact on improving physical and cognitive performance, while contributing to the development of social skills Objectives of the paper: to evaluate the impact of the badminton program on students' physical and cognitive skills; to evaluate students' perception of the impact of the badminton program on their physical and cognitive skills; to analyze the differences between the experimental and control groups.

Table 1 Model program structured on 5 modules for secondary school students

Module	General objectives	Main means	Comments

Module 1: Introduction to badminton	Familiarization with the rules of the game, basic equipment and techniques.	Equipment presentation (rocket, butterfly). Exercises to control the butterfly (throwing, catching). Learning basic positions and simple strokes.	Ability to control the butterfly correctly. Correctness of positions and simple strokes.
Module 2: Physical development and coordination	Increase reaction speed, coordination and balance in movement.	Exercises moving around the field with quick changes of direction. Short distance sprints followed by kicking. Coordination games (e.g. throwing a butterfly into a target area).	Increased reactive and execution speed. Improved balance and coordination in movement.
Module 3: Refining advanced techniques	Develop the ability to execute more accurate and complex shots.	Long and short badminton shots in different areas of the court, at varying distances from the opponent's court - quick exchange games between students. Improving defense and attack positions.	Increased accuracy in long and short shots. Ability to execute fast and efficient movements on the court.
Module 4: Cognitive development through strategy	Improve tactical thinking and the ability to anticipate your opponent's game.	Tactical games (identifying your opponent's weaknesses). Lessons to quickly change the style of play depending on the opponent. Analysis of video matches to observe the tactics used.	Ability to analyze and adapt strategy in the game. Increased tactical reaction speed in the game.
Module 5: Physical and cognitive integration in competitions	Apply techniques and strategies in real matches and develop mental toughness.	Simulated matches between students with subsequent performance analysis. Mental toughness exercises: maintaining concentration throughout the game. Group games to strengthen team spirit.	Improved competitive performance. Ability to stay focused and motivated during a badminton match.

Results

The introduction of badminton program in physical education lessons had a significant impact on the development of students' physical and cognitive skills, and the analysis of results, presented by means of charts, showed clear improvements in speed, coordination, concentration and strategic thinking compared to the control group. The aim of data processing is to assess the current level of physical fitness of the athletes and to estimate their potential for future performance [10].

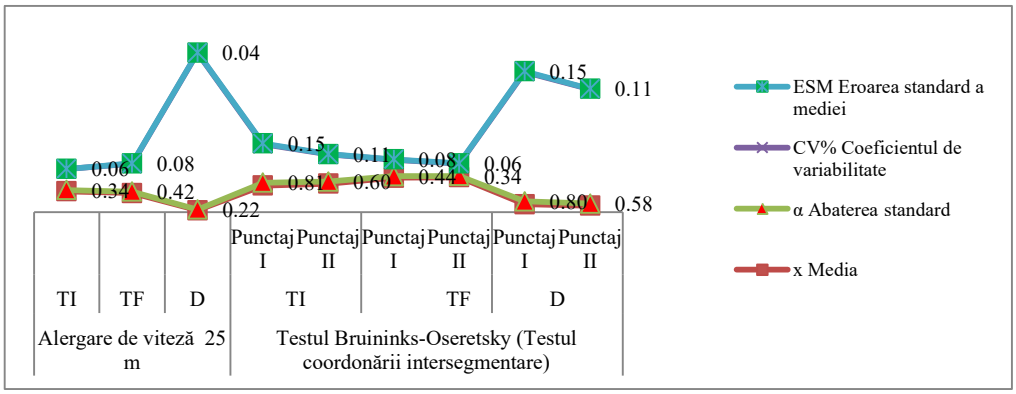

Fig. 1 Experimental group - Calculation of statistical indicators for the "25 m sprint run" and "Bruininks-Oseretsky" tests

As shown in Figure 1, in the 25 m sprint test, the mean time decreased from 5.88 s (TI) to 5.37 s (TF), indicating a significant improvement in speed (−0.51 s). The standard deviation increased from 0.34 to 0.42, and the coefficient of variation from 5.93% to 7.90%, demonstrating greater variability in performance among students, while the standard error of the mean remained low (TI: 0.06; TF: 0.08), confirming the representativeness of the means. In the Bruininks–Oseretsky Intersegmental Coordination Test, the I score increased from 7.50 (TI) to 8.03 (TF) (+0.53 points), with a decrease in the standard deviation (0.81 to 0.60) and the coefficient of variation (10.93% to 7.65%), indicating improved coordination and greater homogeneity. The standard error decreased from 0.15 to 0.11. For Score II, the mean increased slightly from 9.73 (TI) to 9.87 (TF) (+0.14 points), with a reduced standard deviation (0.44 to 0.34) and a reduced coefficient of variation (4.62% to 3.50%), while the standard error decreased from 0.08 to 0.06, reflecting stable and consistent results.

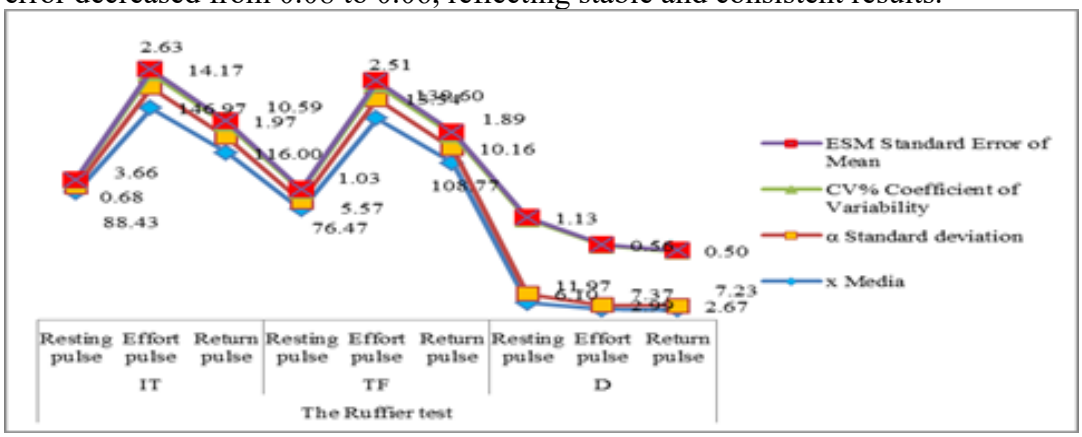

Fig. 2 Experimental group - calculation of statistical indicators in the Ruffier test

In Figure 2, for resting heart rate, the mean decreased from 88.43 bpm (TI) to 76.47 bpm (TF), with a difference of 11.97 bpm, indicating a significant improvement in resting cardiovascular fitness. The standard deviation increased from 3.66 to 5.57,

and the coefficient of variation from 4.21% to 7.40%, suggesting greater interindividual variability. The standard error of the mean increased slightly (0.68 - 1.03). For exercise heart rate, the mean decreased from 146.97 bpm (TI) to 139.60 bpm (TF), with a difference of 7.37 bpm, indicating improved cardiovascular adaptation to exercise. The standard deviation decreased (14.17 - 13.54 bpm), the coefficient of variation remained almost constant (9.81% - 9.86%), and the standard error of the mean decreased slightly (2.63 - 2.51). Regarding recovery heart rate, the mean decreased from 116.00 bpm (TI) to 108.77 bpm (TF), with a difference of 7.23 bpm, indicating faster post-exercise cardiovascular recovery. The standard deviation decreased (10.59 - 10.16), the coefficient of variation remained relatively stable (9.28% - 9.50%), and the standard error of the mean decreased (1.97 - 1.89). Overall, the differences between TI and TF highlight significant improvements in cardiovascular capacity at rest, during exercise, and in the recovery phase.

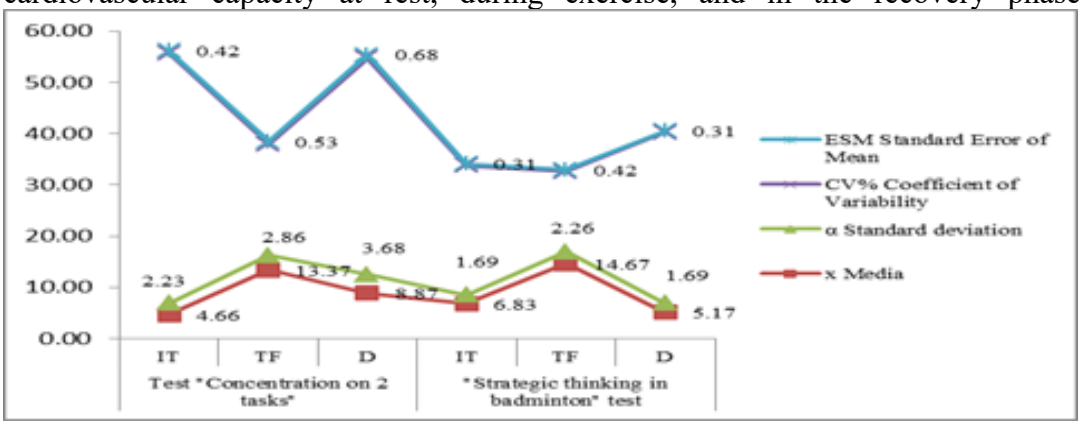

Fig.3 Experimental group - statistical calculation for the tests "Focus on 2 tasks" and "Strategic thinking in badminton"

In Figure 3, the dual-task concentration test shows a significant increase in the mean from 4.66 (TI) to 13.37 (TF) (+8.87). The standard deviation increased (2.23 - 2.86), while the coefficient of variation decreased markedly from 48.81% to 21.74%, indicating improved performance homogeneity. The standard error of the mean increased slightly (0.42 - 0.53). For the strategic thinking in badminton test, the mean increased from 6.83 (TI) to 14.67 (TF) (+5.17). The standard deviation increased (1.69 - 2.26), while the coefficient of variation decreased from 25.23% to 15.64%, indicating greater group uniformity. The standard error of the mean increased slightly (0.31 - 0.42).

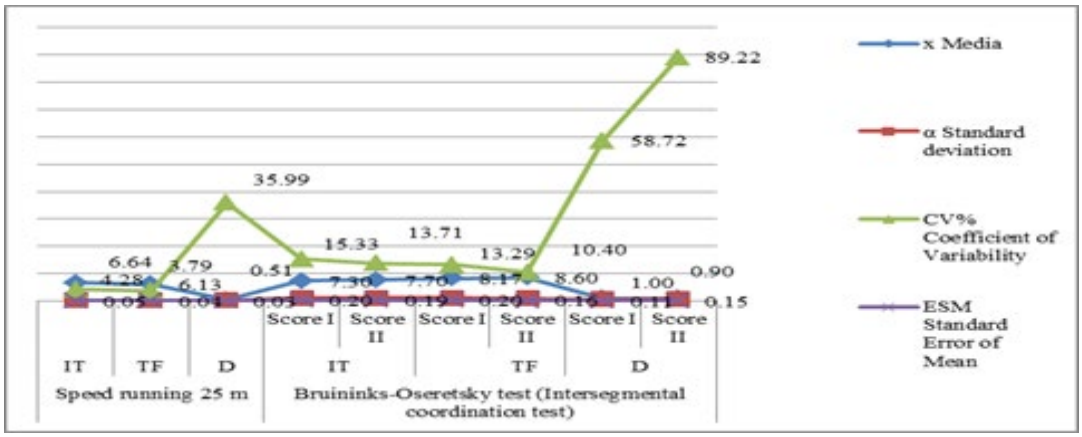

Fig. 4 Control group - Calculation of statistical indicators for the "25 m sprint" and "Bruininks-Oseretsky" tests

In Figure 4, for the 25 m sprint test, the mean decreased from 6.64 s (TI) to 6.13 s (TF) (−0.51 s), indicating improved running speed. The standard deviation decreased (0.28 - 0.23), the coefficient of variation decreased (4.28% - 3.79%), and the standard error of the mean decreased (0.05 - 0.04), demonstrating more consistent group performance and better representativeness of the mean. For the Bruininks–Oseretsky intersegmental coordination test, the I-Score increased from 7.30 (TI) to 8.17 (TF) (+1.00). The standard deviation decreased slightly (1.10 - 1.07), the coefficient of variation decreased (15.33% - 13.29%), and the standard error of the mean decreased (0.20 - 0.16), indicating improved coordination and greater homogeneity. The II score increased from 7.70 (TI) to 8.60 (TF) (+0.90). The standard deviation decreased (1.04 - 0.88), the coefficient of variation decreased (13.71% - 10.40%), and the standard error of the mean decreased (0.19 - 0.16), reflecting considerable progress and more uniform results. The mean differences highlight the variability between students: Difference in score I: 1.00, SD 0.58, CV 58.72%; Difference in score II: 0.90, SD 0.79, CV 89.22%, indicating that individual progress varied considerably within the group.

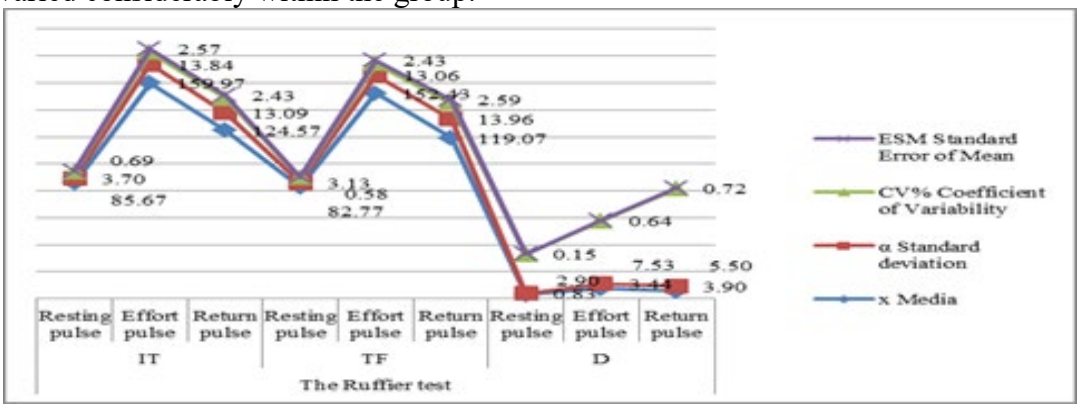

Fig. 5 Control group - calculation of statistical indicators in the Ruffier test

In Figure 5, at resting pulse, there is a decrease in the mean value from 85.67 RT to 82.77 TF, with a difference of 2.90, which signals an improvement in the physical fitness of the students. The standard deviation decreased from 3.70 to 3.13, indicating a reduction in the variability between results. The coefficient of variability decreased from 4.39% to 3.84%, suggesting greater homogeneity in the group, and the standard error of the mean decreased from 0.69 to 0.58, confirming a better accuracy of the final mean. Regarding the exercise pulse, the mean value decreased from 159.97 TI to 152.43 TF, with a difference of 7.53, a sign that the students' body adapted better to exercise. The standard deviation decreased slightly from 13.84 to 13.06, suggesting a greater stability of results between pupils. The coefficient of variability decreased from 8.80% to 8.71%, indicating a slight improvement in group homogeneity, and the standard error of the mean decreased from 2.57 to 2.43, emphasizing a better representativeness of the mean. In the return pulse, the mean decreased from 124.57 TI to 119.07 TF, with a difference of 5.50, suggesting a faster recovery after exercise. The standard deviation increased slightly from 13.09 to 13.96, which indicates a small increase in variability between students. The coefficient of variability increased from 10.68% TI to 11.93% TF, reflecting a slight increase in the dispersion of results, and the standard error of the mean increased from 2.43 to 2.59, but this variation remains insignificant.

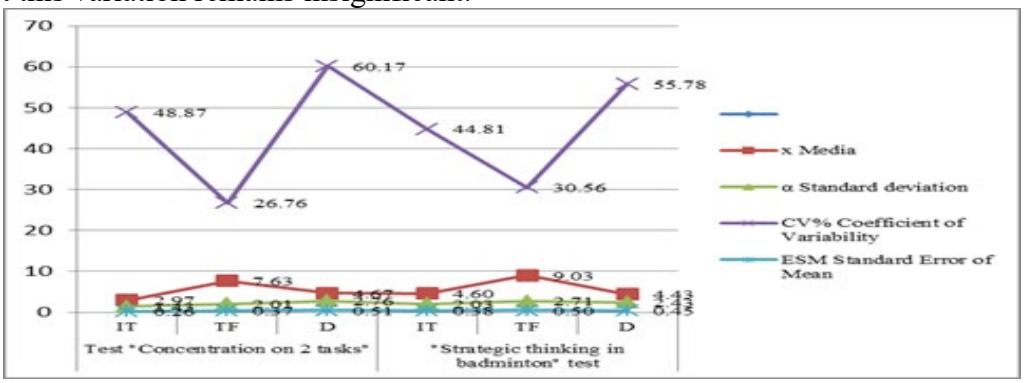

Fig. 6 Control group - statistical calculation for the tests Focus on 2 tasks and Strategic thinking in badminton

In Figure 6, on the Test "Focusing on 2 tasks", the mean increased from 2.97 TI to 7.63 TF, with a difference of 4.67, indicating a significant progress in students' ability to focus on multiple tasks simultaneously. The standard deviation increased from 1.43 TI to 2.01 TF, with a difference of 2.76, suggesting a greater variation in student performance. The coefficient of variability decreased significantly from 48.87% TI to 26.76% TF, showing an improvement in the consistency of group performance, and the standard error of the mean increased slightly from 0.26 TI to 0.37 TF, indicating better accuracy of the results obtained.

On the "Strategic Thinking in Badminton" Test, the mean increased from 4.60 TI to 9.03 TF, with a difference of 4.43, signaling considerable progress in developing

students' ability to think strategically within the game. The standard deviation increased from 2.03 TI to 2.71 TF, with a difference of 2.43, indicating variation between pupils, but less than in the previous test. The coefficient of variability decreased from 44.81% TI to 30.56% TF, reflecting more uniformity in the results at the end of the test, and the standard error of the mean increased slightly from 0.38 TI to 0.50 TF, suggesting a good representation of the data within the group.

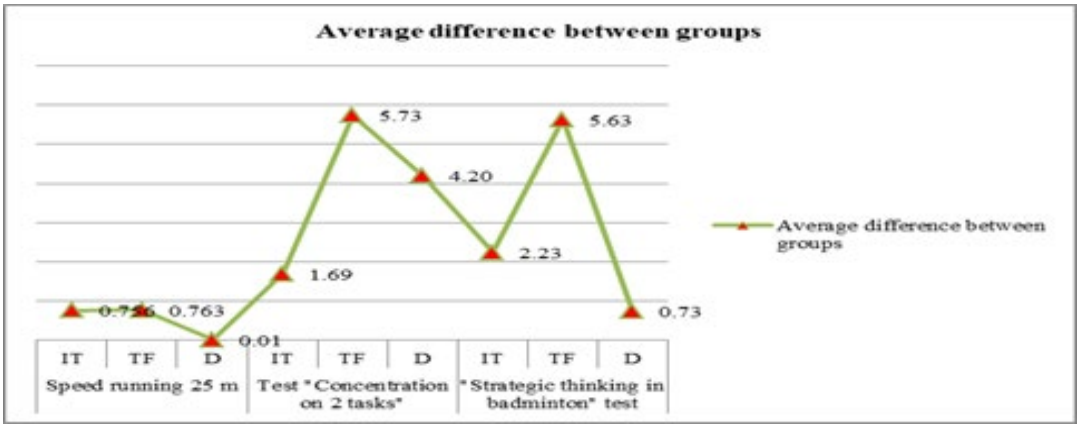

Fig. 7 Mean difference between experimental and control groups

In Figure 7, in the 25 m sprint run test, the small difference between the group means in TI and TF is 0.01 suggesting similar performance, with slightly greater improvements observed in the experimental group. In the 'Concentration on 2 tasks' test, the experimental group showed a significant increase in the ability to concentrate, with the difference between the groups decreasing to only 2.23 in TF. As for the "Strategic Thinking in Badminton" test, the mean difference between groups in TF is 0.73 which reflects a notable progress of the experimental group in developing strategic thinking.

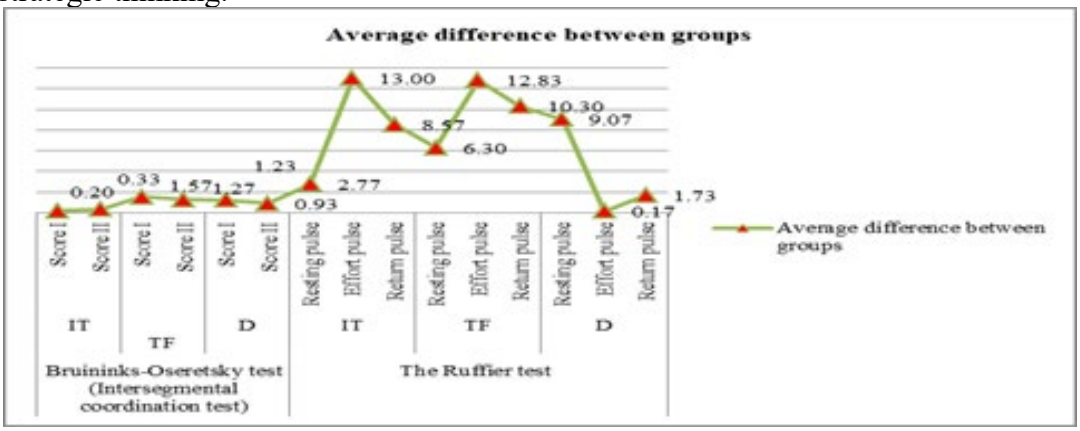

Fig. 8 Mean difference between experimental and control groups

In Figure 8, in the Bruininks-Oseretsky Test (Test of Intersegmental Coordination), the experimental group showed greater improvements in coordination,

with a significant difference of 1.57 in the final TF scores. In the Ruffier Test, the significant difference in the return pulse is 13.00 which emphasizes a significant improvement in cardiovascular capacity in the experimental group. A percentage analysis of the results and the answers provided by the 60 students participating in the experiment shows that the badminton program had a significant impact on certain physical and cognitive skills. The most notable improvements were observed in physical endurance and the ability to make quick decisions.

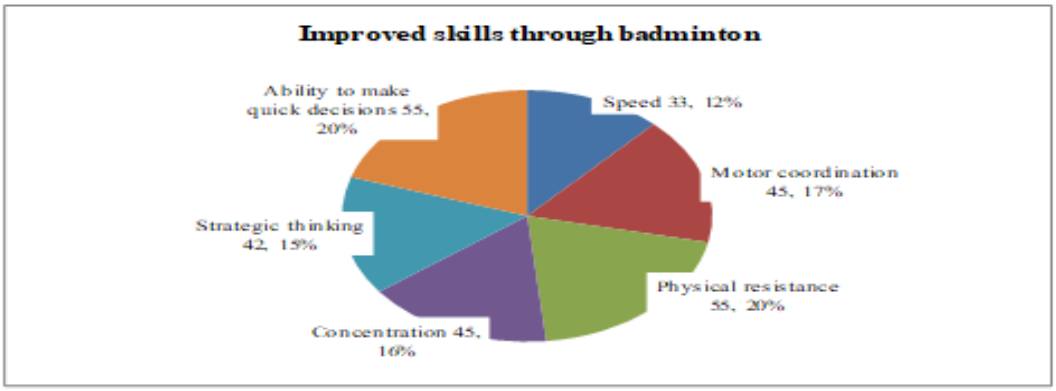

Fig. 9 Assessment of students' perception of the impact of the badminton program on their physical and cognitive abilities

In Figure 9 shows that physical endurance and the ability to make quick decisions were the two skills that improved the most due to badminton, with a 20% improvement in both cases. This suggests that students perceived a significant development in their physical endurance and ability to react quickly during games, which are essential aspects for badminton performance. In terms of motor coordination and concentration, these skills had a moderate impact, with 16% and 17% respectively. These results indicate that, although the badminton program helped to improve students' coordination and concentration, progress in these areas was not particularly marked, but still significant. Finally, strategic thinking and speed had the lowest percentages of 15% and 12% respectively, suggesting that although badminton involves strategic aspects and requires speed of reaction, students did not perceive significant improvements in these areas in the proposed program.

Discussion: The study by Ruihao [14] demonstrated a strong correlation between students' involvement in badminton and the improvement of their physical fitness, highlighting the benefits of badminton in developing aerobic endurance and muscular strength due to fast movements and changes of direction. At the same time, research by Blomqvist et al [2] showed that strategy-oriented instruction significantly improved students' technical knowledge and skills compared to the traditional method, emphasizing the impact of strategic instruction on students' understanding of the game and performance.

Conclusions

The analysis of the collected data shows that the implementation of the means program in the game of badminton had a significant impact on the development of students' physical skills such as speed, coordination and endurance. At the same time, notable improvements were observed in cognitive skills such as concentration, strategic thinking and mental balance, confirming the hypothesis of the paper. Students participating in the badminton program reported increased confidence in their physical and mental abilities, highlighting improvements in concentration and the ability to make quick decisions. The results highlight the impact of the badminton program, with significant improvements in the experimental group: a difference of 13.00 in the Ruffier Test (cardiovascular capacity), of 1.57 in the Bruininks-Oseretsky Test (intersegmental coordination) and a reduction to 2.23 in the "Concentration on 2 tasks" test. The improvement in strategic thinking, difference of 0.73 and speed difference of 0.01 highlight the benefits of the program on physical and cognitive parameters, supporting the integration of badminton in the educational process. The results from the evaluation of students' perceptions of the impact of the badminton program on their physical and cognitive abilities demonstrate that the badminton program had the greatest impact on physical endurance and the ability to make quick decisions, with significant improvements of 20% in both cases. Motor coordination and concentration improved moderately, by 16% and 17%, and strategic thinking and speed had smaller increases of 15% and 12%. These data reflect the effectiveness of the program in developing skills essential for progression in badminton, although speed and strategy, require additional means for better results.

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