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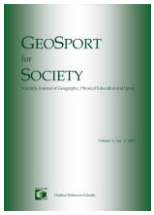

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THE INFLUENCE OF LOGICAL THINKING ON THE ABILITY TO MANIPULATE RHYTHMIC GYMNASTICS APPARATUS IN ELITE ATHLETES

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Abstract: Rhythmic gymnastics, a distinguished discipline within the Olympic sports family, exemplifies a sophisticated blend of athleticism and artistic expression, categorizing it as a technical-combinatory sport where precise motor control is paramount. This study investigates the relationship between academic performance in subjects requiring logical and mathematical reasoning and the proficiency of gymnasts in handling rhythmic gymnastics apparatus. Through the analysis of statistical data and mathematical assessments, the research aims to determine the impact of mathematical skills on executing complex and high-risk elements in rhythmic gymnastics routines. The findings reveal a significant correlation between mathematical test scores and gymnasts' performance, indicating that cognitive abilities in logical and mathematical reasoning substantially enhance the athletes' capability to perform intricate maneuvers with precision and control. This suggests that success in rhythmic gymnastics is not solely dependent on physical attributes but is also significantly influenced by cognitive skills. These results underscore the importance of integrating cognitive training into athletic preparation to achieve excellence in rhythmic gymnastics.

Keywords: rhythmic gymnastics, logical thinking, athletic performance, mathematical skills

Introduction

Rhythmic gymnastics is a comprehensive sport and an artistic domain in motion that intricately combines elements of ballet, acrobatics, and dance with the manipulation of specific apparatus such as rope, hoop, ball, clubs, and ribbon. This sport elevates these elements to the level of art through harmonious execution. As a sport, rhythmic gymnastics falls into the category of technical-combinatory sports (Papp et al., 2019; Erdely et al., 2020; Giurgiu et al., 2024). These sports are characterized by motor performances based on automated elements that continuously evolve through new combinations and associations of movements (Sierra-Palmeiro et al., 2019; Furtado et al., 2020; Grosu and Grosu, 2021). The dominant factor in terms of motor skills is motor control. Competitions, which serve as the ultimate form of assessing athletic performance, rely on elegant, precise, and expressive executions and are evaluated through a judging system with a significant subjective component (Macovei si Buțu, 2018; Sabau, 2022).

The first forms of rhythmic gymnastics exercises emerged within official artistic gymnastics competitions. The sport originated in the Union of Soviet Socialist Republics (USSR), where, in 1936, during an artistic gymnastics' competition, the technical program required athletes to participate with one exercise without apparatus and one with a portable apparatus, incorporating elements of dance and pantomime. In 1948, the USSR held the first official Artistic Gymnastics competition, the initial designation for what is now known as rhythmic gymnastics (Manos, 2008).

Rhythmic gymnastics has undergone a spectacular evolution, rapidly transforming into a form of expression and rhythm that is well-suited for female education and subsequently becoming an Olympic discipline.

A study conducted by researchers at the University of Illinois found that regular participation in sports can influence brain structure in children. They discovered that a smaller volume of gray matter is associated with superior cognitive abilities. Children who were more physically active had a smaller amount of gray matter in their brains and performed better in mathematics, although not in writing and reading. Thus, stimulating children's physical activities can contribute to the optimal development of brain structures involved in mathematical abilities (Hillman et al., 2011; Bidzan-Bluma and Lipowska, 2018).

Logic, as the science that establishes the conditions for correct thinking, is an essential aspect of human knowledge. The Greek term "logos," from which logic derives, suggests multiple meanings such as word, idea, reason, and order. From childhood to adulthood, logic is a skill used in various contexts, including daily life. Mathematics, particularly geometry, contributes significantly to the development of logical thinking. This ability is essential for professionals in various fields such as forensic science, mathematics, and medicine. Logic is vital for every individual, enabling coherent and efficient thinking (Apostolopoulou, 2016).

Logic is a species of exact knowledge, with its object being the abstract form of human thought. For instance, in the game of dominoes, logical thinking aids in finding optimal solutions for arranging the pieces. Similarly, in sports like tennis or basketball, we logically associate movements and strategies to achieve favorable

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outcomes, such as making a basket or tracking the opponent's actions. Constructing a mechanism also requires structured and logical thinking to arrange the parts so that they function properly. Furthermore, the logic of propositions and grammar rules helps us understand and interpret texts, and in the process of correcting an error, we use logic to identify the mistake and provide counterarguments (Mihăiță et al., 2022).

Although the connection is not always apparent, we unconsciously apply mathematical thinking in almost all daily activities. In sports, discipline and resource management represent just a visible aspect of the influence of mathematics on performance, with many effects becoming unconscious actions through repetition. Over time, the importance of mathematics in sports has been repeatedly demonstrated (Randall, 1990; Aycan et al., 2020). Mathematical knowledge aids in developing cognitive skills and specialized problem-solving thinking, relying on pattern recognition and solution-finding. In some situations, mathematical thinking can distinguish between those for whom problem-solving is a natural, unconscious task and those who require conscious effort to analyze aspects of the game or sport practiced. For example, in sports, fractions are used to divide team games into periods and sets, allowing children to learn and experience fraction concepts in real-time. Geometry plays a crucial role in sports by using angles and shapes to determine the direction and trajectory of movements. Additionally, elementary arithmetic and algebra knowledge enable graphical representation of athletes' results and analysis of their performance based on time and other relevant factors (Rulence-Pâques et al., 2005; Önal et al., 2017).

Our ability to solve mathematical problems has long been considered a clear expression of our intelligence. The time required to detect mathematical patterns in a series, solve a mental calculation, or respond to ordinary geometry exercises is measured. Today, this capacity remains vital in assessing human cognitive abilities, but our conception of intelligence has become broader (Bahar, 2015; Grosu et al., 2016).

Based on our experience as both former athletes and coaches, we have observed that gymnasts with outstanding academic results in practical and logical disciplines master actions involving the loss of contact with the apparatus more quickly and easily. Thus, the hypothesis emerged that mathematics and logical thinking are important qualities for a gymnast to achieve remarkable performances. We decided to investigate this hypothesis to validate it and develop appropriate tests for future gymnast selections. We aim to implement these tests in the selection process for children to improve the talent identification system in performance sports, similar to other countries. We believe this initiative is important for the development of sports and for maximizing each child's potential in this field.

Materials and methods

The subjects of this study were gymnasts from various sports clubs across the country, all affiliated with the Romanian Rhythmic Gymnastics Federation. A total of 50 gymnasts, aged between 9 and 12 years old, who competed in the Junior III and Junior II categories, were tested. The tests were administered during the pre-

competition period, specifically during training sessions, to minimize the influence of the emotional factor.

We selected subjects aged between 9 and 12 years old because this is the age range in which gymnasts predominantly compete with specific apparatus, and the frequency of actions involving loss of contact with the apparatus increases as they gain competitive experience and progress in competition categories. Additionally, at this age, they are capable of answering questions related to mathematics.

The methods used in the study included the bibliographic study method, the conversation method, the observation method, the graphical method, the statistical-mathematical method, and the arithmetic mean.

Mathematical tests

These tests focus on logical deduction, practical mathematical thinking, and spatial orientation. They were designed to highlight the analytical abilities specific to the left hemisphere of the brain, which is responsible for logical, mathematical, and analytical thinking.

A set of three mathematical tests was utilized in this study. The first two tests comprised sets of 3×3 matrices, each with the last element missing. The gymnasts were required to indicate the image from a selection provided below the matrix that logically completed the place marked with a question mark. The third test consisted of 12 mathematical logic problems presented in a grid format. The gymnasts had to choose the correct answer based on logical deduction or mathematical calculation.

The format of the problems is as follows: a 3×3 matrix with the last element missing, where the gymnast must determine the logical or mathematical element that completes the sequence. This structure aims to assess the gymnasts' ability to recognize patterns, perform logical reasoning, and apply mathematical principles (Figure 1).

These tests were meticulously designed to measure the cognitive functions related to logical deduction, practical mathematical thinking, and spatial orientation, which are essential for successful performance in rhythmic gymnastics. The results of these tests provide insight into the gymnasts' analytical abilities and their potential for mastering complex movements involving the loss of contact with apparatus.

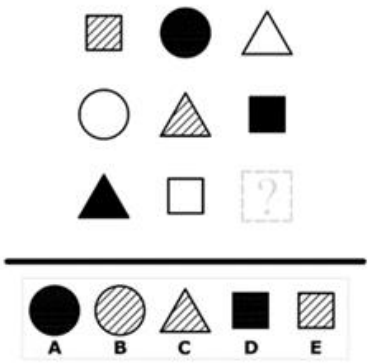

Figure 1. Matrix image used for the tests

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The test consisted of indicating the image, from those below the line (labeled from A to E), which logically completes the space marked with the question mark. The correct answer was marked on the TEST form with an X. Thus, if it is considered that in the example above the correct answer corresponds to the image labeled with C, then on the test form the box corresponding to option C is marked with an X.

Practical tests

For the practical test, each gymnast selected one apparatus of her choice and performed a specific risky element, defined as an action involving loss of contact with the apparatus. The selected element required the gymnast to execute a throw, perform two rotations underneath the apparatus, and then successfully catch it.The gymnasts were instructed to perform this risky throw ten times. Only the successful attempts, defined as those where the gymnast successfully caught the apparatus after completing the two rotations, were recorded. This approach allowed for a precise assessment of the gymnast's ability to perform complex maneuvers involving coordination, timing, and spatial awareness under controlled conditions. This practical test aimed to quantify the proficiency and consistency of gymnasts in executing high-risk elements, which are critical components in rhythmic gymnastics performances. The results provided valuable data on each gymnast's skill level and the effectiveness of their training in mastering such advanced techniques.

Results and discussions

After administering the tests, the results were consolidated into a summary table, and a hypothetical average of the results was calculated. Following the completion of the three mathematics tests, an average score was derived to reflect the expected performance in the practical tests. The 50 gymnasts displayed a wide range of results across the three tests. Out of a possible total of 36 points, only one gymnast achieved the maximum score, while the lowest recorded score was 8 points. These scores were used to calculate a hypothetical average intended to predict the outcomes in the practical test.

The diversity in test scores among the gymnasts highlighted the varying levels of cognitive and analytical skills within the group. The calculated average provided a benchmark to evaluate whether the theoretical skills assessed by the mathematics tests correlated with the practical performance in rhythmic gymnastics, particularly in executing risky elements involving loss of contact with the apparatus. This approach allowed for a comprehensive analysis of the relationship between cognitive abilities and practical performance, offering insights into the effectiveness of incorporating logical and mathematical training into the athletic development of gymnasts.

Mathematics tests had a slightly increased weight in the evaluation of the gymnasts, accounting for 51% due to the utilization of three theoretical tests and only one practical test. Although the practical test accounts for a lower weight of 49%, it is equally relevant as it depicts the precise action of losing contact with the object, which is the aim of the study. Between the two tests, a slight difference is recorded, a

difference that, however, confirms the theory that mathematics should be part of practice in rhythmic gymnastics.

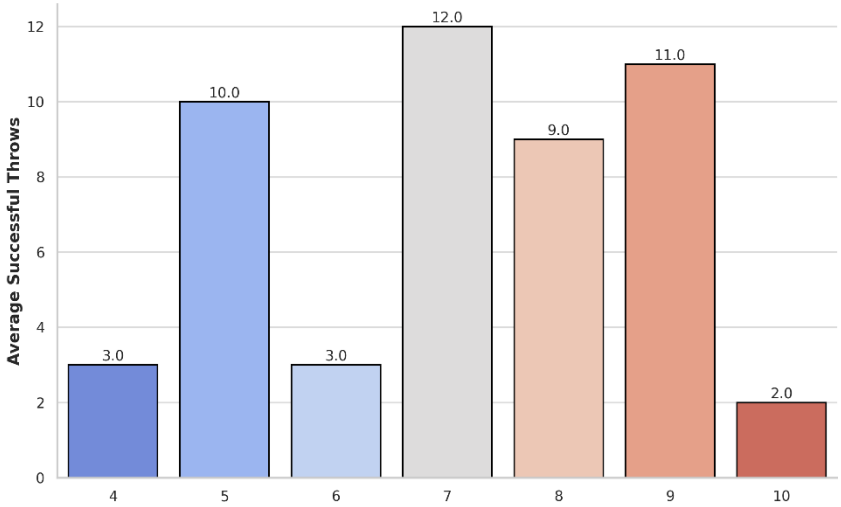

Figure 2. Average throws of the subjects

Figure 2 illustrates the performance distribution of gymnasts in successfully catching the thrown object during the risky element test. Specifically, three gymnasts managed to correctly catch the thrown object four times, resulting in a very poor rating. A larger group of gymnasts, consisting of ten individuals, achieved a slightly better performance by catching the object five times during the risky action. Only three gymnasts succeeded in catching the object six times, which surpasses half of the maximum possible number of successful catches. The graph indicates that the majority of gymnasts achieved higher ratings, with twelve gymnasts catching the object seven times, nine gymnasts catching it eight times, and eleven gymnasts catching it nine times. These results reflect a good performance, indicating that most gymnasts were able to execute the risky element with a high degree of consistency and skill.

Notably, only two gymnasts achieved a perfect score by successfully catching the object ten times out of a possible ten attempts. This exceptional performance demonstrates their superior coordination, timing, and ability to manage the complexity of the risky element under the given test conditions. Overall, the data depicted in Figure 3 highlights the varied levels of proficiency among the gymnasts in performing high-risk elements, emphasizing the importance of further training to enhance consistency and skill in such critical aspects of rhythmic gymnastics.

In Figure 3, the precise results obtained by each gymnast in the administered tests are depicted. The data reveal that the peak of the performance plateau was reached within the score range of 24.5 to 30. This indicates that the majority of subjects achieved favorable outcomes in the conducted assessments. The concentration of scores within this range suggests that the tests were effectively designed and appropriate for evaluating the cognitive and practical skills of children

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aged 9 to 12 years old. These results underscore the suitability of the test parameters in accurately measuring the intended competencies within this age group. Consequently, the implemented tests have proven to be reliable tools for assessing the logical, mathematical, and spatial orientation abilities necessary for rhythmic gymnastics. This conclusion is supported by the observed distribution of scores, which demonstrates that a significant proportion of the participants performed well, thereby validating the efficacy of the tests.

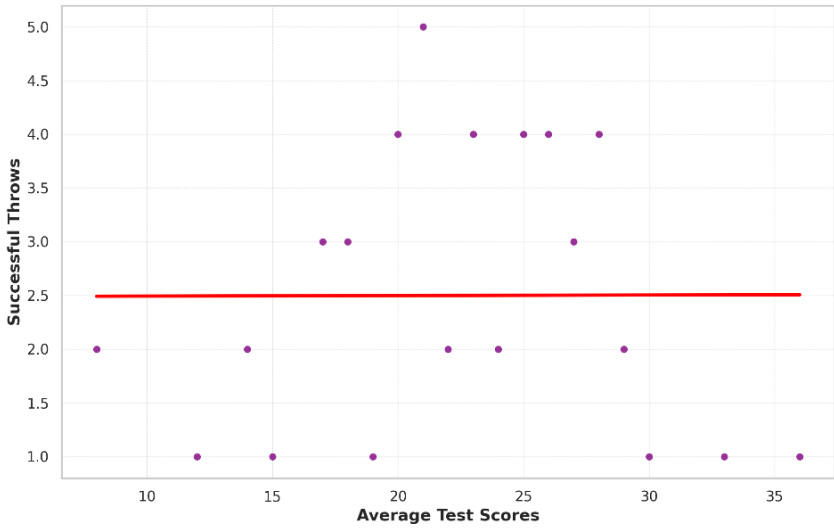

Figure 3. Average scores of mathematics tests

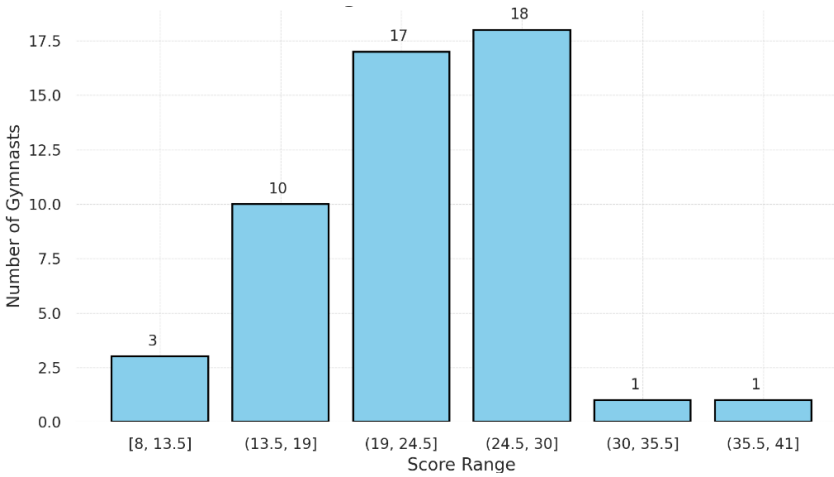

Figure 4. Average qualifying test scores

As shown in figure 4, the gymnasts were classified into 5 categories of scores. Between 8 and 13.5 points, 3 gymnasts received a poor rating. Out of a total of 36 possible points, between 13.5 and 19 points, 10 gymnasts achieved a satisfactory rating. A good rating was awarded to 17 athletes who scored between 19 and 24.5

points. In the same tests, 18 gymnasts achieved excellent results, ranging between 24.5 and 30 points. One gymnast fell between 30 and 35.5 points, and one answered all 36 questions correctly, achieving an outstanding rating.

Thus, the graph reflects a diverse distribution of gymnasts' performances, with the majority achieving ratings from satisfactory to very good. Only a few gymnasts had poor or excellent results, highlighting differences in levels of preparation and performance.

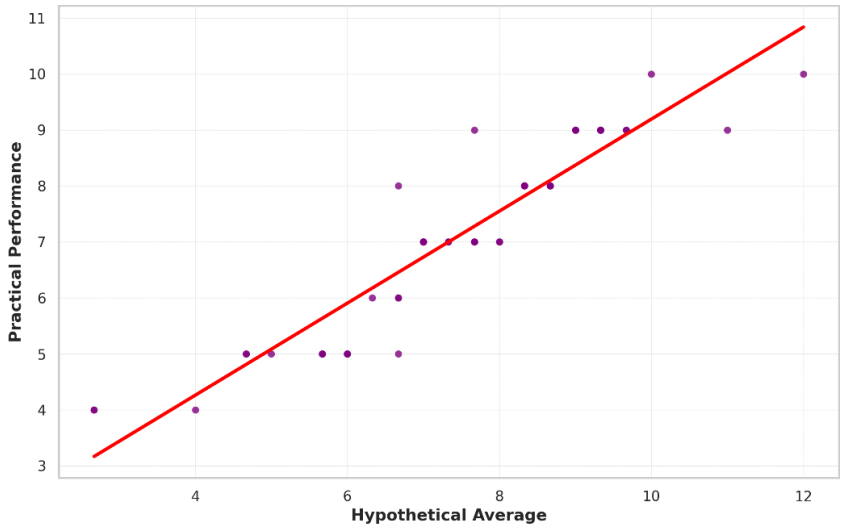

Figure 5. Correlation Between Hypothetical Average Scores and Practical Performance in Gymnasts

In Figure 5, a hypothetical average was calculated based on the results obtained in the mathematics tests. This hypothetical average predicts the number of successful catches the gymnasts should achieve in the practical tests. The x-axis represents the hypothetical average scores, while the y-axis represents the actual number of successful catches by the subjects.The scatter plot provides a comprehensive view of the correlation between theoretical knowledge and practical execution. The purple points indicate the performance of each gymnast, with the red regression line highlighting the overall trend.

The data reveals both gymnasts who effectively translated their theoretical knowledge into practice, achieving the predicted number of successful catches, and those who deviated from the hypothetical results. This variation underscores the influence of other factors, such as physical coordination, mental focus, and training consistency, on practical performance.This analysis is critical for understanding the extent to which cognitive abilities, as measured by the mathematics tests, can predict practical performance in rhythmic gymnastics. The positive correlation observed suggests that higher hypothetical averages tend to be associated with better practical performance. However, the deviations also indicate that while theoretical knowledge is important, it is not the sole determinant of practical success.

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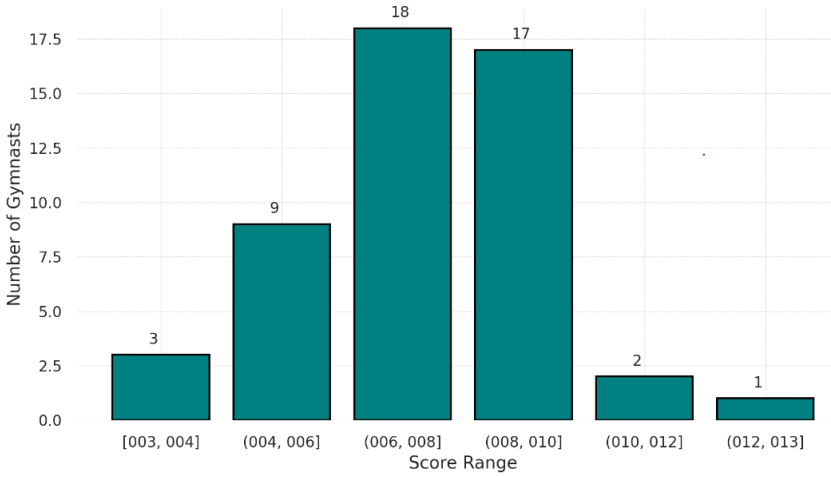

Figure 6. Hypothetical Average - Practical Average

The gymnasts are grouped into 6 reference groups, each assigned an interval of values and a rating. The first 3 gymnasts recorded the weakest values, with an average ranging from 2.67 to 4.47. Satisfactory values were obtained by the next 9 gymnasts, ranging between averages of 4.47 and 6.27. Better results were achieved by the largest number of subjects, 18, who managed to fall between averages of 6.27 and 8.07. Good results were also demonstrated by the 17 gymnasts falling between averages of 8.07 and 9.87. Only 2 gymnasts achieved very good results, ranging between values of 9.87 and 11.67. The best results were obtained by the gymnast who achieved a maximum score in both tests, receiving an outstanding rating (Figure 6).

Conclusion

The findings of this study confirm the initial hypothesis that mathematics and logical thinking significantly influence the ability to manipulate objects in performance gymnasts. The two tests administered clearly demonstrated the correlation between theoretical knowledge and practical execution, highlighting the interaction between cognitive and motor skills. The results suggest that analytical thinking, associated with the left hemisphere of the brain, is crucial for achieving success in sports performance. The data reveal that gymnasts who scored higher in mathematical and logical tests tended to perform better in practical tasks involving object manipulation. This correlation underscores the importance of cognitive skills in enhancing physical performance, particularly in complex sports like rhythmic gymnastics.

The implementation of these tests in future selection processes for performance gymnasts is recommended. By incorporating these assessments, it will be possible to identify children with exceptional cognitive abilities who are likely to excel in the sport. Moreover, understanding the thinking processes of gymnasts can inform the development of more effective training programs. By tailoring external stimuli during training to enhance cognitive and motor integration, coaches can optimize the performance outcomes of their athletes.These tests have proven to be

valuable tools for not only selecting potential high achievers but also for gaining insights into the cognitive strategies employed by gymnasts. Future research could further explore the specific cognitive mechanisms that contribute to successful performance in rhythmic gymnastics, leading to even more refined training methodologies.

In conclusion, the integration of cognitive and physical assessments provides a comprehensive approach to developing and nurturing talent in rhythmic gymnastics. The findings of this study support the continued use of mathematical and logical tests in the selection and training of performance gymnasts, contributing to the overall advancement of the sport.

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