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Cognitive Flexibility and Inhibitory Control of Behavior of Artistic Junior Gymnasts

[*Flexibilidad cognitiva y control inhibitorio de la conducta: comportamiento en atletas de gimnasia artística escolar*]

[*Flexibilidade cognitiva e controle comportamental inibitório: comportamento em atletas de ginástica escolar*]

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ABSTRACT

Introduction: Artistic Gymnastics training and competition require several demands from athletes, which go beyond the psychological, as they will move through the neuropsychological and psychophysiological for optimum performance on the equipment, based on the previous learning of technical elements.

Aim: To evaluate the executive functions of cognitive flexibility and inhibitory control of behavior in junior artistic gymnastics athletes in the province of Granma, Cuba.

Materials and methods: A transversal and descriptive study was done through a quantitative research design, which took place between February and June 2022, with a population made of 15 athletes of the junior artistic gymnastics selection of the province, using the Wisconsin Sorting Cards Test (WSCT) and the cognitive flexibility and inhibitory control of behavior, respectively. Data processing was done through SPSS, 21.0, along with statistical-descriptive tests, like frequency distribution, rank-like test for dispersion, and standard deviation.

Results: The evaluation of executive functions of cognitive flexibility and inhibitory control of behavior in junior artistic gymnastics athletes in the province of Granma, Cuba allowed the authors to learn their athletes' behavior in the studied population, which showed critical executive functioning as to cognitive flexibility, particularly associated with the occurrence of incorrect responses given, and perseveration errors during the evaluation.

Conclusions: The results permitted the identification of distinctive development signs of these functions in the studied population, which caused difficulties in athlete preparedness during their development.

Keywords: Cognitive flexibility, inhibitory control of behavior, junior artistic gymnastics.

RESUMEN

Introducción: Los entrenamientos y competiciones en la Gimnasia Artística demandan del atleta una serie de exigencias, que van más allá de lo psicológico, pues transitarán por lo neuropsicológico y lo psicofisiológico para una óptima performance sobre el aparato, a partir del aprendizaje de elementos técnicos previos. **Objetivo**: evaluar las funciones ejecutivas flexibilidad cognitiva y control inhibitorio de la conducta en atletas de gimnasia artística escolar en Granma.

Materiales y métodos: Para ello, se empleó un estudio de corte transversal y descriptivo, a través de un diseño de investigación cuantitativa, su ejecución tuvo lugar de febrero a junio del 2022, y la población se compone de los 15 atletas de la selección escolar de gimnasia artística en la provincia Granma. Se utilizaron pruebas las cognitivas Wisconsin Sorting Cards Test (WSCT) o Sorteo de cartas de Wisconsin y el Test de

Stroop, para evaluar la flexibilidad cognitiva y el control inhibitorio de la conducta respectivamente. En el procesamiento de la información de datos, se empleó el paquete computacional SPSS en su versión 21.0, pruebas estadísticas descriptivas como la distribución de frecuencia, media, prueba de dispersión como rango y desviación estándar.

Resultados: La evaluación de las funciones ejecutivas flexibilidad cognitiva y control inhibitorio de la conducta en atletas de gimnasia artística escolar en Granma permitió conocer el comportamiento de las mismas en la población estudiada, que mostró mayores dificultades de funcionamiento ejecutivo en cuanto a la flexibilidad cognitiva, específicamente en cuanto a su incidencia en respuestas incorrectas emitidas y errores por perseveración durante la evaluación.

Conclusiones: Los resultados constatados permitieron identificar signos distintivos del desarrollo de estas funciones en la población estudiada que implicaron dificultades para el proceso de preparación de los atletas y que forman parte de su desarrollo.

Palabras clave: Flexibilidad cognitiva, control inhibitorio de la conducta, gimnasia artística escolar.

RESUMO

Introdução: Treinamento e competições em Ginástica Artística requerem do atleta uma série de exigências, que vão além do psicológico, pois passarão pelo neuropsicológico e psicofisiológico para um ótimo desempenho no aparelho, a partir do aprendizado de elementos técnicos anteriores.

Objetivo: Avaliar as funções executivas, a flexibilidade cognitiva e o controle inibitório do comportamento dos atletas de ginástica artística escolar em Granma. **Materiais e métodos**: Para este fim, foi utilizado um estudo transversal e descritivo, através de um desenho de pesquisa quantitativa, sua execução ocorreu de fevereiro a junho de 2022, e a população era composta pelos 15 atletas da equipe de ginástica artística escolar da província de Granma. O teste cognitivo Wisconsin Sorting Cards Test (WSCT) e o Stroop Test foram utilizados para avaliar a flexibilidade cognitiva e o controle comportamental inibitório, respectivamente. No processamento das

informações de dados, foi utilizado o pacote de computador SPSS 21.0, testes estatísticos descritivos como distribuição de freqüência, média, teste de dispersão como intervalo e desvio padrão.

Resultados: A avaliação das funções executivas de flexibilidade cognitiva e controle inibitório do comportamento em atletas de ginástica artística escolar em Granma nos permitiu conhecer o comportamento destas funções na população estudada, o que mostrou maiores dificuldades no funcionamento executivo em termos de flexibilidade cognitiva, especificamente em termos de sua incidência em respostas incorretas dadas e erros devido à perseverança durante a avaliação.

Conclusões: Os resultados nos permitiram identificar sinais distintivos do desenvolvimento destas funções na população estudada que implicaram dificuldades para o processo de preparação dos atletas e que fazem parte de seu desenvolvimento.

Palavras-chave: Flexibilidade cognitiva, controle de comportamento inibitório, ginástica artística escolar.

INTRODUCTION

Artistic gymnastics (AG) is defined as the gymnastic specialty practiced with various pieces of equipment or without them, on a well-defined surface; it is a sport that demands expert judgment (referees) that qualifies every athlete's performance. Both male and female AG have their scoring codes created by the International Gymnastics Federation (IGF), whose official rules govern the inclusion in every meeting, marking the guidelines that will guide the coaches while training their athletes. Besides teaching the competitors every detail of the sport to participate in equal conditions, uniformly and honestly, it is the guideline to evaluate the exercises and the contents published in the Comprehensive Manual for Artistic Gymnastics Athletes, and constitute the norms to evaluate athlete performance and goal accomplishment.

The singularity of this sports discipline lies in the deployment of coordinating and artistic expression capacities, both in the training process and in competition. It is one of the disciplines involving competitive art, whose execution is merely based on the achievement of previously set up goals, and by meeting the demands of clean execution of movements, in addition to the predominance of psychomotor actions characterized by elegance, virtuosity, and creativity, as factors with a high significance expected for success.

Hence, training and competition require several demands from athletes, which go beyond the psychological side, as they will move through the neuropsychological and psychophysiological aspects for optimum performance on the equipment, based on the previous learning of technical elements. Among the most outstanding are,

- Reaction and movement speed development and eye-hand coordination, a broad reach of peripheral vision, and accuracy in space-time estimations.
- Muscle-motor, eye-hand, and bi-manual coordination.
- The development of attention, focus, volume, intensity, stability, distribution, and commutation.
- The intellectual capacity with proper levels of abstract reasoning and operational thinking, and the suitable mechanisms for information processing.
- The development of specialized perceptions, such as pommel horse, vault, bars, platform, etc., proper psychomotricity, spatial structuring, visoperception, and rhythm.
- The high development of vestibular sensations to perceive spatial information on body balance fluctuations when performing complex technical movements, kinesthetic sensitivity.
- The high development of motivational and volitive processes to assimilate large load volumes under monotonous and hazardous conditions.
- Inhibition of behavioral automatisms, impulse control, cognitive or mental flexibility, work memory, and planning that contribute to self-regulation mechanisms, and ensure the control and motor, attentional, and emotional stability in competition and training sessions.

The former requirements relate to the study of what is known as executive functions (EF), with a relatively novel concept within the area of neurophysiology. Authors like Miyake *et al.* (2000), Tirapu *et al.* (2018), Hoyo (2020), Gutiérrez & Montoya (2022) consider them as the higher-order cognitive control process to achieve a specific objective, whose main capacity is the ability to organize behavior, language, and reasoning, as cognitive problem-solving skills, both internally and externally.

In that direction, Lezak, Howieson, Bigler & Tranel (2012); Fillippetti & López (2013); Tirapu, Cordero, Luna & Hernaez (2017) assumed the term *executive functions* in relation to the capacities that permit a person to function independently, with a given purpose, self-sufficient conducts, and satisfactorily, which comprise four aspects. Volition: The formulation of objectives (planning and decision-making); suggestive actions (target-oriented plans); efficient performance (monitoring). Each aspect comprises behavior-associated activities.

As can be seen, the aspects acknowledged in these studies on executive functions, in the area of sports, particularly artistic gymnastics, with a psychological and neuropsychological perspective, will allow for the evaluation of athlete performance parameters, which are significant at early ages, not only due to their involvement in the overall inhibitory control of behavior, but also because of the cognitive flexibility processes to maintain or change the focus of attention and the processes linked to the work memory, planning, and the decision of implementing several plans over others when executing the routines in this sport.

In that sense, this research assumes the findings of Tirapu, Muñoz & Pelegrín (2002) and Tirapu *et al.* (2018), as they revealed the contribution of neuropsychology and other sciences for sports evaluation and research, demonstrating the efficacy of this instrument to approach cognitive processes, and their treatment in cases of injuries or affections due to different causes, and in the stimulation of these processes in healthy individuals, despite the shortcomings observed in some of its categories and important aspects.

In relation to the previous, evaluation must not be restricted to the psychological needs of athletes, to intervene in the areas that demand so. As reported by Buceta (1998), it should be applied also to evaluate the characteristics and the effects of training. In this sense, the training contents may be evaluated, along with its volume and intensity, or the evaluation of athlete performance, which will surely provide greater knowledge of the context in which sports practice takes place.

This context applies to psychology, neuropsychology, and other sciences to be evaluated and studied in sports settings. The latter is one of the closest to the study of athlete performance parameters, including the EF, which are significant at early ages, not only due to their involvement in the control of irrelevant automatisms and the overall inhibitory control of behavior, but also because of the cognitive flexibility processes to maintain or change the focus of attention when executing the routines in any modality of this sport.

Their evaluation is an effective tool as part of the athlete's psychological preparedness, though there are still theoretical and methodological problems that justify the need for research in this area associated with closely-related sports aspects. The results in each stage of the process will be used not only to learn the aspects evaluated then, but also to set up suitable intervention actions associated with methodological preparedness.

Therefore, the knowledge needed for the psychological athlete's preparedness and psychological control during the training sessions must be put into practice with a psychological perspective, including other sciences in junior athletes, based on the observation of parameters that demand a multi and interdisciplinary approach, even the contribution of specific disciplines belonging to related sciences, in which knowledge has not played a systematic and specific role, either in high-performance or starter athletes.

Having that perspective in mind, this study assumed the executive functions cognitive flexibility and inhibitory control of behavior; the former regarded in this sport as the possibility for change among the possible responses to orientations or requirements by the coach and others, the noise, public, thinking adjustment, and the current attitude depending on the alternatives or new choices, and the processing of several sources of information at the same time. For instance, following the performances of other athletes, whether in the set or using materials supplied by the technician, while waiting. These routines should be repeated in their minds, always remembering the pieces of equipment or strategy adjustments on the go, through simultaneous multi-sided thinking.

For its part, the inhibitory control of behavior is related to the athlete's capacity of inhibiting self-impulses or external stimuli that might endanger the plan designed or the goal to be accomplished. Accordingly, all efforts must be distributed to save physical and psychological resources, based on self-regulation, self-control, and organization of actions, emotional, motor, and verbal, such as the inhibition or activation of psychological states through warm-ups, stretching, visualization, idea-motor visualization, etc., or resistance to interference caused by the set itself, or the external setting, by controlling impulsivity, either at the attentional level or behavioral level.

Their evaluation is made as part of the athlete's psychological preparedness, to characterize the executive capacities depending on age, and depending on the set criteria in the Cuban standards. It is an advantage when these standards exist; otherwise, it is a significant bias that often hinders their exploration, a consequence of the limited number of related studies. These types of instruments usually have standards in their countries; however, the evaluation of these executive functions as self-regulating and potentiating entities of socially adjusted and efficient behavior has an enormous value in the process of the psychological evaluation of the artistic gymnastics athletes, as they can be observed in all the stages of the process.

In that sense, the high demand for adaptative criteria for successful execution performed before that takes place will continue to be highly demanded until after the performance. They are continuous and inseparable parts of executive functioning as a whole. Though the characterization of several different sub-components is feasible, these might become the starting point for diagnosis, and also pave the way for stimulation, potentiation, and development of executive functioning of children engaged in the practice of any sport at any stage.

Hence, how do cognitive flexibility and inhibitory control of behavior behave in junior artistic gymnastics athletes in Granma province? In that direction, this paper aims to evaluate the executive functions of cognitive flexibility and the inhibitory control of behavior in junior artistic gymnastics athletes in the province of Granma, Cuba.

MATERIALS AND METHODS

The population of this study consisted of 15 artistic gymnastics athletes in the junior category, six female and nine male athletes, as part of an intentional sampling.

The population of the study was enrolled in the Pedro Batista Fonseca EIDE (Sports starter school), in the province of Granma. They were normally responding and healthy subjects, in terms of thinking traits, according to the parameters evaluated by the Cuban Ministry of Public Health, with all the athletes within the artistic gymnastic modality in the province.

The following theoretical methods were used:

- Analytical-synthetic, to demonstrate the epistemological elements that support the topic of research, and also to conduct an analysis of the results of athletes, based on the different indicators of executive functions evaluated.
- Inductive-deductive, to analyze the theoretical rationales associated with this topic, and to figure out the relations between the problem's variables.

- Empirical methods:
- Observation.
- Interview.
- Documentary review.
- Measurements: The Wisconsin Sorting Cards Test to evaluate cognitive flexibility and the inhibitory control of behavior.

Descriptive statistics was used as well to interpret the results of the application of evaluation tests of cognitive flexibility and the inhibitory control of behavior.

RESULTS AND DISCUSSION

A cognitive flexibility diagnostic was performed using the Wisconsin Sorting Cards Test, or WSCT; while the inhibitory control of behavior was tested through the Stroop test, which resulted in specific indicators of performance in every function, and was relevant for the characterization of the behavior of the population studied.

The cognitive flexibility was reported through five specific indicators, according to their percentile values:

- Correct responses (CR).
- Incorrect responses (IR).
- Perseveration errors (PE).
- Omissions (O).
- Category reached (CR).

The qualitative assessment depended on the interpretation of the percentiles given as lower (less than or equal to 5), very low (less than or equal to 25), mid (less than or equal to 50), higher (less than or equal to 75), very high (less than or equal to 95). The adequate records were the mid, higher, and very high percentiles, whereas the low to mid

percentiles showed significant difficulties in cognitive flexibility unrelated to injuries or associated diseases in the pre-frontal side.

The inhibitory control of behavior was reported through three specific indicators, according to their percentile values:

- Correct responses (CR).
- Incorrect responses (IR).
- Omissions (O).

Their qualitative assessment followed the same standards as for cognitive flexibility.

The evaluation enabled the assessment of results related to the performance of indicators of executive functioning, as shown below (Table 1).

Table 1. *- Results of the evaluation of cognitive flexibility of junior gymnasts in Granma*

Athlete	Correct responses	Incorrect responses	Perseveration errors	Category reached	Omissions	Percentile	Evaluation
1	5	5	5	5	75	5	Inadequate
2	5	5	5	5	50	5	Inadequate
3	5	5	5	50	95	5	Inadequate
4	50	25	5	50	95	50	Inadequate
5	50	25	25	50	75	50	Inadequate
6	50	5	25	50	75	50	Adequate
7	50	75	75	75	95	75	Adequate
8	50	5	5	50	95	50	Adequate
9	25	5	75	25	95	25	Inadequate
10	25	5	25	25	50	25	Inadequate
11	5	5	25	5	25	5	Inadequate
12	50	25	50	50	75	50	Adequate
13	50	25	95	50	50	50	Adequate
14	50	25	25	50	25	25	Inadequate
15	5	25	25	25	25	25	Inadequate

Overall, 47 % of junior gymnasts (7) in Granma, showed satisfactory behavior in terms of cognitive flexibility, whereas 53 % (8) of the athletes showed inadequate values for this executive function, with the highest incidence of incorrect responses (93 %), and perseveration errors (73 %) Pérez (2019).

Although at least 50% of athletes reached adequate values in the other indicators (correct responses, category reached, and omissions), the difference from the ones with inadequate percentiles or percentiles below the expected mean for the sex and age was below 20 % (category reached), except for the omissions, with a 40 % difference (Figure 1).

Fig. 1. - *Results of the evaluation of cognitive flexibility of junior gymnasts in Granma*

The fact that more than 50% of the sample was below the expected mean showed the existence of shortcomings in executive functioning, which were relevant for the deployment of behaviors associated with cognitive flexibility, which will be characterized in the population studied by error perseveration and inadequate responses according to the requirements, which were corroborated during the field observation and research, in the sports training sessions (Table 2), coinciding with the reports made by Fillippetti and López (2013), and Becerra (2015) as to their possible behavior in junior athletes, as well as the need for intervention, given the case.

Table 2. *- Results of the evaluation of the inhibitory control of behavior of junior gymnasts in Granma*

Athlete	Correct responses	Incorrect responses	Omissions	Percentile	Evaluation
1	50	50	50	50	Adequate
2	50	95	50	75	Adequate
3	50	25	50	50	Adequate
4	75	25	75	75	Adequate
5	50	50	50	50	Adequate
6	95	75	95	75	Adequate
7	75	75	75	75	Adequate
8	25	25	25	25	Inadequate
9	50	50	50	50	Adequate
10	75	75	75	75	Adequate
11	25	95	25	25	Inadequate
12	50	50	50	50	Adequate
13	95	95	95	95	Adequate
14	5	5	5	5	Inadequate
15	25	25	50	25	Inadequate

The evaluation of the inhibitory control of behavior in the population permitted corroboration that 80 % (12 athletes) showed an adequate performance of this executive function, with all their indicators above 70% within the adequate range. Only 20 % (3 athletes) of the sample was within the inadequate range, with a greater incidence of the correct and incorrect response indicators, with 27 % each (Figure 2).

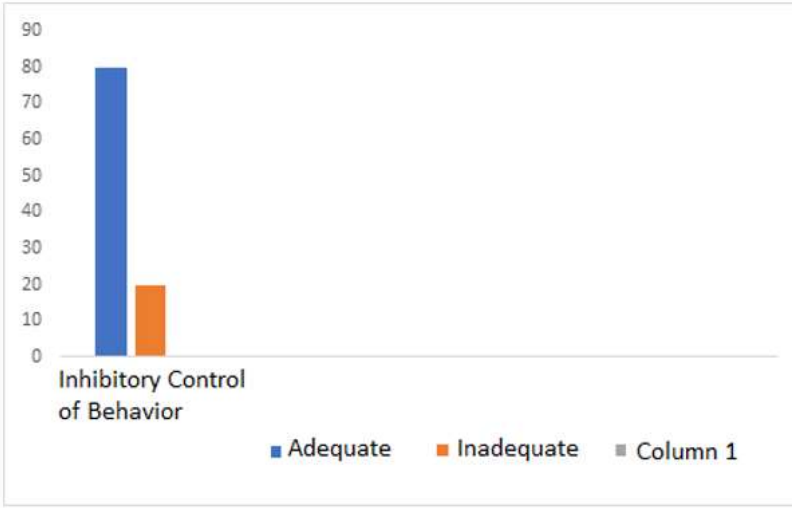

Fig. 2. *- Results of the evaluation of the inhibitory control of behavior of junior gymnasts in Granma*

Overall, better results were observed in the indicators associated with the inhibitory control of behavoir than the cognitive flexibility in the junior artistic gymnasts in Granma.

In the age groups comprising the population studied, the eight-year-old athletes (4), showed lower results (75%) than the mean of cognitive flexibility, with 100% in the mid ranges associated with the inhibitory control of behavior.

The nine-year-old athletes (5) showed adequate performance (80% of cases) in the two domains.

The eleven-year-old athletes (4) showed split results (equal) between the adequate and inadequate ranges in terms of cognitive flexibility, whereas 75% was in the proper range of inhibitory control of behavior.

Lastly, the 2 twelve-year-old athletes in the study showed lower performance than the expected mean in the two domains, with inadequate ranges in the two executive functions. The eight-to-twelve-year-old individuals were closer to cognitive flexibility issues, followed by the eleven-year-old group, while the twelve-year-old group showed a greater incidence of issues related to the inhibitory control of behavior than the rest.

Regarding sex, the six females only showed problems associated with cognitive flexibility (50%), while no difficulties were observed in the inhibitory control of bahavior. The nine male athletes showed inadequate results for cognitive flexibility (56%), and inhibitory control of behavior (44%), with a higher incidence in terms of executive functioning than the female athletes in the two domains.

The previously described results were similar to other findings arguing that executive functions do not follow an even development, but rather, different maturative and progressive trajectories in keeping with age, the specific characteristics of each developmental stage, and the type of executive function, according to Best and Miller (2002) cited by Fernández (2019).

CONCLUSIONS

The evaluation of executive functions of cognitive flexibility and the inhibitory control of behavior in junior artistic gymnastics athletes in the province of Granma, Cuba showed greater executive functioning issues in relation to cognitive flexibility, particularly due to the influence of incorrect responses and perseveration errors during the evaluation, thus entailing difficulties in the athlete's preparedness process as part of their development.

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Authors' contribution:

The authors have participated in the writing of the work and analysis of the documents.