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Original article

Methodology for hammer training and its relationship with neuroscience in pitchers from Cienfuegos

[*Metodología para el entrenamiento del martillo y su relación con la neurociencia en los lanzadores de Cienfuegos*]

[*Metodologia para o treinamento de arremesso de martello e sua relacao com a neurociencia em arremassadores de Cienfuegos*]

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ABSTRACT

Introduction: The research starts from the study of the limitations identified in the analysis of the variability of movement in the hammer throw and its transfer to the throw that is going to be executed, as established by the Comprehensive Program for the Preparation of the Athlete.

Objective: to develop a methodology for hammer throwing and compare it with theoretical elements of sports training in school sports initiation and neuroscience.

Methods: This research is an explanatory study based on a pre-experimental pretest/ posttest design for a single group. The sample consists of six pitchers. Theoretical methods were used for the design and development of the study, including theoretical-logical, analytical-synthetic, inductive-deductive, hypothetical-deductive, and modeling methods. Empirical methods included surveys of coaches, mathematical-statistical methods, and expert opinion for evaluating the proposal before its implementation.

Results: The observation revealed technical deficiencies in the hammer throw, and solutions are being sought. The results of the expert evaluation demonstrate the feasibility and structural functionality of the proposed methodology for its validation.

Conclusion: The results obtained confirm the validity of the hypothesis and lead to conclusions and recommendations for the area of hammer throwing.

Keywords: task duality, hammer throw, neuroscience, movement variety.

RESUMEN

Introducción: la investigación parte del estudio de las limitaciones identificadas en el análisis de la variabilidad del movimiento en el lanzamiento del martillo y su transferencia al lanzamiento que se va a ejecutar, según establece el Programa Integral de Preparación del Deportista.

Objetivo: elaborar una metodología para el lanzamiento del martillo y compararlo con elementos teóricos del entrenamiento deportivo en la iniciación deportiva escolar y la neurociencia.

Métodos: se asume para la investigación un estudio explicativo; se fundamenta en un diseño preexperimental pretest y postest para un solo grupo. La muestra está compuesta por un total de seis lanzadores. Para su diseño y elaboración se emplearon métodos del nivel teórico; entre ellos se encuentran el teórico-lógico, analítico-sintético, inductivo-deductivo, el hipotético-deductivo, la modelación; en el empírico, encuestas a los

entrenadores y el matemático-estadístico, así como el criterio de expertos para la valoración de la propuesta antes de su implementación.

Resultados: la observación evidenció deficiencias técnicas en el lanzamiento del martillo, por lo que se buscan vías para su solución. Los resultados de la evaluación realizada por los expertos evidencian su factibilidad y funcionalidad estructural para la validación de la metodología propuesta.

Conclusión: los resultados obtenidos confirman la validez de la hipótesis planteada y conducen a conclusiones y recomendaciones para el área del lanzamiento del martillo.

Palabras clave: dualidad de tarea, lanzamiento del martillo, neurociencia, variedad del movimiento.

RESUMO

Introdução: Esta pesquisa surge do estudo das limitações identificadas na análise da variabilidade do movimento no lançamento de martelo e sua transferência para o lançamento a ser executado, conforme estabelecido pelo Programa Integral de Preparação do Atleta.

Objetivo: Desenvolver uma metodologia para o lançamento de martelo e compará-la com elementos teóricos do treinamento esportivo na iniciação ao esporte escolar e neurociência.

Métodos: Esta pesquisa adota um estudo explicativo; baseia-se em um delineamento pré-experimental pré-teste-pós-teste para um único grupo. A amostra é composta por um total de 6 lançadores. Métodos teóricos foram utilizados para seu planejamento e desenvolvimento, incluindo teórico-lógico, analítico-sintético, indutivo-dedutivo, hipotético-dedutivo e modelagem; métodos empíricos incluíram questionários aplicados a treinadores; e métodos matemático-estatísticos, bem como a avaliação de especialistas para a validação da proposta antes de sua implementação. Resultados: A observação revelou deficiências técnicas no lançamento de martelo, motivando a busca por soluções. Os resultados da avaliação por especialistas demonstram a viabilidade e a funcionalidade estrutural da metodologia proposta para validação.

Conclusão: Os resultados obtidos confirmam a validade da hipótese e levam a conclusões e recomendações para o lançamento de martelo.

Palavras-chave: dualidade de tarefas, lançamento de martelo, neurociência, variedade de movimentos.

INTRODUCTION

Physical activity and sport require new challenges from the biological sciences and technological innovation, in an integrated and interdisciplinary manner. The improvement of Cuban sports education in schools for young athletes (EIDE) is changing traditional aspects of the comprehensive training of athletes, which, from a neuroscience perspective, could influence the teaching-learning process in throwing training, particularly the hammer throw, using a transdisciplinary approach.

Neuroscience has had an impact on the effectiveness of dual-task training, which consists of a primary and a secondary task. Both tasks can be performed independently or as a single unit and have distinct objectives. In a dual-task intervention, individuals practice both tasks simultaneously. Sports intelligence researchers explain the effects of physical exercise on the brain. The multiple hormonal changes in the body induced by physical exercise, such as the increased secretion of endorphins that promote well-being and regulate stress, lead to a better balance of neurotransmitters and increased brain function (Hernández, 2017). These contributions from these integrated sciences can help improve hammer throw performance by fostering quick and effective decision-making.

Several authors use didactic models, strategies, methodologies, or programs that validate changes in the psychophysiological state of practitioners, which are supposed to occur under the effect of the comprehensive preparation process. Among them are Revuelto (2015), Toledo *et al.* (2020), and Sánchez *et al.* (2024), who guide physical activity in sports with sports intelligence and new technologies through training actions;

however, studies from this perspective are not sufficient to improve the effectiveness of hammer throw technique.

In modern sports, where the effects of air resistance pose a challenge to achieving technical effectiveness, athletes must develop psychophysiological, physical, and technical skills to make increasingly rational decisions. This is why sports intelligence is vital in track and field events. This intelligence is fragmented into tactical and situational aspects, closely linked to the efficient interpretation and use of time and space variables, and connected to emotional management—in other words, emotional intelligence (Hernández, 2017). In this sense, it is a valuable discovery to find methodological approaches for preparing throwers for the situations they may encounter; athletes must be able to find quick and coherent solutions to the given complexity.

Hernández (2018), Ibarra (2019), Alarcón *et al.* (2019), Alfonso (2019), Chávez and Chávez Baca (2020), Mejía and Zaldiva (2020), González *et al.* (2022), Muñoz and Belando (2022) agree that sports training should enhance cognitive motor functions, since the cerebral cortex is responsible for developing attention, memory, the perception-action cycle, decision-making, impulse inhibition, among other functions.

Another aspect to be addressed in the research is movement variability. Toledo *et al.* (2020) and Sánchez *et al.* (2024) consider the analysis of sports movement techniques from the perspective of movement variability to facilitate the monitoring, diagnosis, and control of sports techniques. While several studies have been conducted on the technique of throwing sports implements such as the discus, shot put, and hammer throw, these have not focused their analyses on the variability of the hammer throw, nor have they offered methodological proposals for conducting psychophysiological analysis through neuroscience.

The Comprehensive Program for the Preparation of Throwing Athletes is the methodological document that guides the coaches of the School of Sports Initiation (Eide) "Jorge Agostini Villasana" of Cienfuegos; however, it only gives instructions for

teaching the hammer throw; there is no didactic-methodological material that contributes to the improvement of the execution of the throw of this sports implement.

As can be seen, despite the importance of analyzing the technique based on the variability in movements, no methodology has been found in the bibliographic searches carried out that allows this study to be done from this perspective.

As a result of this analysis, this research aims to establish a methodological proposal through psychophysiological study and neuroscience to diagnose and control the variability of the technical execution of the hammer throw of athletes in the 13-14 year old category of the Eide "Jorge Agostini Villasana" of Cienfuegos.

MATERIALS AND METHODS

The theoretical methods employed included the historical-logical method, used to study the background and evolution of the object of study within the international and national context; the theoretical-logical, analytical-synthetic, inductive-deductive, and modeling methods, which were evident throughout the research process and in the study of the theoretical foundations of biological sciences and neuroscience. These foundations inform the theoretical basis, components, and structure of the hammer throw training teaching-learning process. The hypothetical-deductive method was used to arrive at answers to the given problem situation through the formulation of a hypothesis. The empirical method included document analysis and a survey of track and field coaches, selected intentionally. The selection criteria stipulated that coaches had to have more than five years of experience and some knowledge of biological sciences. The research adopted an explanatory design based on a pre-experimental pretest/ posttest design for a single group.

The research was conducted from September 2025 to December 2025, with a population comprising throwers from the "Jorge Agostini Villasana" School Sports School (EIDE) in Cienfuegos, belonging to the 13-14 age category, distributed as follows: six hammer

throwers, two javelin throwers, and three shot putters. The sample consisted of six hammer throwers from the selected age category, three male and three female, with an average height of 175 cm and a body weight of 65.7 kg; they had three years of athletic experience. The study sample was divided according to the research stages: a preliminary stage in which pre-throws were performed by the selected population as an initial diagnostic to determine the current state of training planning in this sport, and an experimental stage, in which a physical and psychophysiological study was conducted.

On the other hand, to measure the mechanical pattern, the observation designed to determine the current state of technical preparation in the hammer throw was used, the Kinovea biomechanical analysis software , which allows capturing graphic videos, allowing an evaluation of the different biomechanical parameters during the execution of the technical gesture under study and a psychophysiological test when evaluating the neural systems.

Toledo *et al.* (2020) assert that variability is transferred to the field of motor behavior to explain the differences that exist in said behavior between several individuals and even in the motor actions performed by the same person.

The relevant variable is determined by the variability of the movement, whose components are given by the kinematic parameters used in the research for the analysis of the variability were:

- Angular velocity of the hammer.
- Tangential velocity in bipedal support during launch.
- Centripetal velocity in single-leg support during launch.
- Centrifugal speed in single-leg support during launch.
- Execution time of the complete movement.
- Launch scope.
- The indicators are determined by body weight and height in relation to hammer weight and category. In this case, the category for females is 3 kg and for males 4 kg, with a measurement from the hammer head to the handle of 1.19-1.21 cm.

Table 1. *- Operationalization of the variables*

Dependent variable	Dimension	Indicator	Assessment scale
Variability of movement in the hammer throw	It is the movement of support: bipedal (one-foot, free leg), bipedal (double support with feet on the surface, pivot leg) and final effort	1) Technical Test a) Volley (Angular velocity of the hammer (rad/s)) b) Tangential velocity in bipedal support in the launch in 1, 2 and 3 turns. c) Centripetal velocity in single-leg support during launch in 1, 2 and 3 turns. d)Centrifugal velocity in single-leg support during launch in 1, 2 and 3 turns. 2) Body composition	- When the volley phase is correct and the player completes three turns, executing a good two-legged support and culminating in the final effort with a good exit angle. (Eval. B) - When the volley phase is correct and the player manages to turn with two turns, achieving bipedal support and then bipedal support , good bipedal support is achieved , culminating in the final effort in double support, (Eval R) --When the volley phase is correct and a turn is achieved with one rotation, executing a good bipedal support and culminating in the final effort, and the other turns are not achieved (Eval M) - Weight (Kg) - Size (cm): 1.69-1.70 (F), 1.75-1.78 (M) - Hammer weight (3-4 Kg)

Source *: own elaboration.*

The variability of movement. Patterns of mechanical movement

The biological sciences are a set of integrated sciences that deal with the physical, psychological, anatomical, and physiological analysis of biological systems; consequently, with the analysis of movement variability. These are studied through mechanical laws and patterns based on the specific characteristics of the human biological system.

Toledo *et al.* (2020) and Sánchez *et al.* (2024) consider that analyzing the technique of sports movements through the study of movement variability is crucial for monitoring

the diagnosis and control of sports techniques. While several studies have been conducted on the technique of throwing sports implements such as the discus, shot put, and hammer throw, these have not focused their analyses on the variability of the hammer throw, nor have they offered strategies for conducting the analysis from this perspective.

Toledo *et al.* (2020) consider this variability phenomenon to be normal variations that occur in motor execution through multiple repetitions of a movement. Similarly, Sánchez *et al.* (2024) assert that variability extends to the realm of motor behavior to explain the differences in said behavior between various individuals and even in the motor actions performed by the same person. Based on knowledge of the kinetic and neurophysiological parameters that produce and regulate human movement, it has been demonstrated that no two movements are exactly identical, and that interindividual differences exist in the execution of the same motor task.

The author agrees with the criteria of Sánchez *et al.* (2024), since each athlete, considering their individual differences and somatotypes, exhibits variability in movement, and therefore variability in their mechanical patterns. Thus, it becomes necessary to investigate movement variability both within and between individuals; this represents a new approach to the evaluation, diagnosis, and monitoring of sports techniques.

In bibliographic consultations, Schmidt (2005), cited by Sánchez *et al.* (2024), establishes that the variation of a movement pattern at a given moment can be considered as the consequence of errors in the ability to predict the parameters necessary to use a motor program and, with the practice of specific tasks, the prediction of errors can be gradually eliminated and thus optimize the accuracy and efficiency of the motor pattern, applying, for example, the repetition method.

Some research has found that there are other causes of variability besides the traditional ones, such as adjustments, compensations, and coordination. León *et al.* (2016) suggest that human movement occurs in variable external and internal environments and that, because of this variability, it is important to emphasize that the study of movement

variability is closely related to mechanical movement patterns. Therefore, to produce complex movements, it is necessary to develop physical skills that complement athletic movements.

The theoretical framework of Toledo *et al.* (2020) is based on the premise that movement variability in biological systems is self-organized in relation to the environment and biomechanical and morphological constraints in the production of a specific movement. Sports training, particularly hammer throw, is not excluded from these aspects of variability. Sánchez *et al*. (2024) assert that analyzing the movement pattern related to movement variability from a biomechanical perspective is important, as there is a synchronization of centripetal and centrifugal acceleration, the force exerted with rotational velocity, and the athlete's ability to adapt to external conditions, enhance their internal capabilities based on variability, and control the movement.

The authors focus on volleys and turns as essential for the necessary transformation in speed and effectiveness of movement during complex situations, which require attention, coordination, and decision-making. The sports science community is seeking tools in the mechanical patterns related to neuroscience.

Subchapter 1. Neuroscience as a transdisciplinary science

Neuroscience is a transdisciplinary science within the biological sciences that deals with the physical analysis of biological and psychophysiological systems. Its theoretical elements include mechanical patterns based on the specific characteristics of the human biological system, incorporating anatomical, psychological, and physiological knowledge.

Toledo *et al.* (2020), Agalla (2023), and Sánchez *et al.* (2024) consider the analysis of sports movement techniques, based on the study of movement variability, to be crucial for monitoring the diagnosis and control of sports techniques. While several studies have been conducted on the technique of throwing sports implements such as the discus, shot put, and hammer throw, these have not focused their analyses on the variability in

hammer throw and its relationship to neuroscience, nor have they offered methodological proposals from this perspective.

Several authors have conducted such studies, categorizing described variables to determine the effectiveness of the technique and evaluating it using a specific methodology. However, they do not study the neural systems involved in ensuring the effectiveness of the throw. Performance analysis and support programs have examined the influence of the hammer's trajectory on the upper limbs during the final two turns of the throw, specifically in the final effort. Similar to movement variability, the lower limbs also experience some unloading during the final phase, but these studies have not focused on movement variability, particularly the turns. Consequently, this research seeks to conduct a psychophysiological analysis of the athletes under study.

Methodology for training the variability of movement in hammer throwers with dual tasks

Several scientific works apply neurocognitive tests and methods that can measure brain functions such as attention, decision-making, processing speed, and motor control. One example is the NIH Toolbox test with a neurological assessment battery. These are standardized neurocognitive, sensory, and motor tests to evaluate brain function and behavior in people aged 3 to 85 years (González *et al.,* 2022). However, there are few strategies and methodologies for training movement variability with dual tasks.

The preceding analysis is the starting point for the selected proposal. Below is an example of how the dual-task routine can be performed (Muñoz & Belando , 2019).

Phase 1. of diagnosis:

1. Verification of compliance with the functions of the pitchers.
2. Assessment of technical-tactical knowledge.
3. Evaluation of cognitive processes and their relationship with the neuroscience of pitchers.

Modeling Phase 2:

1. General technical-tactical tasks in the laboratory condition and their relationship with the neuroscience of pitchers.
2. Technical-tactical tasks in the condition of sports training.
3. Exercises with double task.

Phase 3 of verification of the practice:

1. Transformation of variability and its relationship with neuroscience in pitchers.
2. Evaluation of exercises with double tasks.

One finding of sports intelligence is dual-tasking. Hernández (2017) considers that for dual-tasking to exist, simultaneous training of individuals to perform two tasks is essential: the primary motor task and the secondary distracting task. Among the results is the Dual- Task Routine for hammer throwers, which aims to improve neuromotor coordination and cognitive functions involved in this type of throw, integrating attention, memory, reaction time, and movement patterns under controlled physical load.

Mejía & Zaldiva (2020) state that dual-tasking involves performing two tasks simultaneously: one motor (such as walking, squatting, or maintaining balance) and the other cognitive (such as counting backward, responding to a stimulus, or recalling information). They also introduce techniques for combined brain activation for performing two independent tasks at the same time. The following outlines the phases of dual-tasking exercises.

This exercise routine has several phases:

Phase 1: cognitive activation (pre-technical).

Exercise 1: attention + basic movement.

The athlete performs technical movements without a hammer (partial turns or entries).

The coach gives verbal or visual stimuli (colors, numbers, keywords).

The athlete must name the stimulus or perform an associated action. For example, “red” = pause, “blue” = continue.

Before each launch:

The athlete answers a simple question or receives an unexpected instruction (rhythm, focus, breathing) .

After executing the launch.

Objective: to simulate the real cognitive stress of competition.

Evaluation indicators.

Technical consistency of the launch.

Reaction time and stimuli.

Cognitive errors.

Quality of body control under fatigue.

Phase 2: memory + technical sequence.

Before each attempt, the coach of a short sequence (e.g., ACB).

Each letter corresponds to a technical phase of the launch.

The athlete must remember and execute the sequence correctly.

Objective: to strengthen working memory and motor planning.

Phase 3: reaction + dynamic movement.

Duration: 8-10 minutes.

Exercise 3: reaction under rotation.

During controlled turns or foot drills :

Audible signal = change speed or stop.

The signals are given randomly.

Objective: to improve quick decision-making while the body is rotating.

Phase 4: cognitive simulation of competition.

Duration: 5-10 minutes.

Exercise 4: Launch with cognitive load.

Objective: to activate the central nervous system before technical work (Table 2).

Table 2. *- Components and structure of the methodology for training the variability of hammer throwers with dual tasks*

General components	Specific components
General objective	Specific objective of the methodology
Rationale	Theoretical-conceptual conception
Elements involved in the structure	Instrumental Component Method: Observation Test: Neuroscience. Battery for neurological assessment. Kinovea measurement , statistics Neurocognitive processes and brain functions such as attention, decision-making, processing speed and motor control with volleys: with one volley and one turn, with two volleys and two turns, with two volleys and three turns up to ten.
Methodology as a process	**Stage** 1. Diagnostic and preparatory stage, Phase 2. Modeling with the dual task: Phase 1: Cognitive activation (pre-technical) **Stage** 2: Memory + technical sequence Exercise 3: Reaction under rotation **Stage** 3. Verification of the practice and the results

Source: *own elaboration.*

RESULTS AND DISCUSSION

The theoretical and practical elements of neuroscience directly impact sports training, particularly in hammer throwing. Neuroscience deals with the analysis of the human biological system, including anatomical, psychological, and physiological knowledge. In this way, it was observed that the thrower was able to find quick and effective solutions to the given complexity. The methodology used had an impact on coaches as a tool to

improve concentration, coordination, and decision-making. Furthermore, an improvement in the mechanical movement pattern was observed. The autonomy to correct technical errors in turns and twists was evident. The methodological approach presented benefits the physical, psychological, and physiological aspects of hammer throwers in the 13-14 year old category.

The observation of a total of 35 hammer throw coaches revealed:

- There is no evidence of treatment of the variability of the throwing movement with dual task exercises based on neurological development.
- Lack of attention, coordination, and finding quick and effective solutions in different situations that arise during the execution of the technique.
- There are few instruments to evaluate neurological tests in hammer throw training.

Document analysis revealed that in the Athlete Preparation Program (PPD) (2020) there is no apparent relationship between neuroscience tools and instruments and sports training, particularly hammer throwing, since the exercises performed did not require the thrower to make quick and effective decisions in unforeseen situations.

An improvement in the execution of the technique was demonstrated before the intervention of the methodology for training the variability of hammer throwers with double task (Agalla, 2023).

It is important to note that there was an improvement in the departure angle from 25° to an average angle of 40°, which was rated as good.

In the survey of coaches:

- 100% of respondents said they were unaware of the neurological assessment test, and that there were no standardized neurocognitive, sensory, and motor tests to evaluate brain function.

- 100% of respondents recognize the need to find methodologies to work on dual tasking with neuroscience (Tables 3 and 4).

Table 3. *- Execution of the hammer throw technique with the dual task-evaluation*

Technical elements with the dual task	Quantitative evaluation	Qualitative evaluation
When executing the different types of volleys and turns with a dual task without any faults appearing that alter the variability of the movement	5 points	Excellent
When executing the different types of volleys and turns, he at least makes one technical error with a double task without any faults appearing that alter the variability of the movement	4 points	Good
When executing the different types of volleys and turns, he makes at least two technical errors with a double task without any faults appearing that alter the variability of the movement	3 points	Regular
When essential faults appear and concentration is lost, coordination is impaired and the variability of movement is altered.	2 points	Evil

Source: *own elaboration.*

Table 4. *- Evaluation before and after the intervention of hammer throwers, 13-14 year category*

Pitchers	Sex	Quantitative evaluation	Qualitative evaluation	Quantitative evaluation	Qualitative evaluation
		(Before the Intervention)		(After the Intervention)	
1	F	4 points	Good	5 points	Excellent
2	F	3 points	Regular	4 points	Good
3	F	2 points	Evil	3 points	Regular
4	M	4 points	Good	5 points	Excellent
5	M	3 points	Regular	5 points	Excellent
6	M	3 points	Regular	4 points	Good

Source*: own elaboration.*

CONCLUSIONS

The observation revealed technical deficiencies in the hammer throw due to a lack of attention, coordination, and finding quick and effective solutions in different situations that arise during the execution of the technique.

The results of implementing the methodology for training the variability of hammer throwers with dual tasks demonstrate speed and effectiveness in technique.

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The authors declare no conflicts of interest.

Authors' contribution:

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