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INDIVIDUALIZATION OF BOXERS' TRAINING LOAD BASED ON REFLEX-MOMENTUM INDEX IN COACHING

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A B S T R A C T	K E Y W O R D S
Individualization of training load is a key condition for making boxers' training more effective, given the individual variability of adaptive reactions and the complex multicomponent punch structure. Traditional approaches to planning the training process, which rely on isolated indicators of physical fitness, do not provide comprehensive control of the quality of motor actions and the functional state of the athlete. The aim of the study is to determine the role of the individualized Adaptive Reflex-Momentum System (ARMS) technique in the development of a training schedule and self-regulation mechanisms in young boxers. The Reflex-Momentum Index (RMI) was used in the study based on the author's ARMS technique, which implements a closed adaptive cycle of training load management. The Index was formed by integrating normalized mechanical, neuromuscular, and behavioural parameters, in particular, reaction time, force and impulse of the punch, efficiency of mechanical energy transfer, accuracy of hitting, and functional fatigue indicators. The load intensity and rest intervals were corrected in accordance with the of RMI dynamics. The application of the ARMS method resulted in improved punch performance, reactivity, and stability of motor actions, which was reflected in the increased values of the Reflex-Momentum Index. The use of this Index as a criterion for load regulation enabled the development of an adaptive training schedule sensitive to the current functional state of athletes. The obtained results confirm the appropriateness of using the Reflex-Momentum Index as an integrative tool for scientifically sound individualization of training in boxing. The ARMS method creates the prerequisites for the development of self-regulation in young boxers and optimization of training load in the modern coaching practice.	Boxing, individualization of training, Reflex-Momentum Index, punch performance, self-regulation, training load

INTRODUCTION

In modern boxing, the effectiveness of training is largely determined by the coach's ability to adapt the load to the individual morphofunctional and neuromuscular performance of the athlete. Cui, et al. (2024), Loturco, et al. (2021) found that the high intensity of fights, the speed of exchange of punches and the limited time for decision-making require the development of not only speed-strength qualities, but also effective mechanisms for self-regulation of the functional state. Bu, (2022), Jin, et al., (2025) showed that standard universal training programmes do not always provide optimal adaptations, which indicates the need for individualized approaches in working with young boxers.

It was established that punch performance is built as a result of the interaction of the strength capabilities of the upper and lower extremities, the stabilizing role of the trunk muscles, and neuromuscular coordination of movements (Beattie & Ruddock, 2022; Dunn, et al., 2022; Satkunskiene, et al., 202). Finlay, et al. (2022), Tao, et al. (2025), Awana, et al. (2025) showed that athletes demonstrate significant individual differences in the force, speed and momentum of the punch even with the same training programmes, which indicates the heterogeneity of the body's adaptive reactions. It was shown that the use of post-activation mechanisms can temporarily increase strength and neuromuscular readiness, but individual responses to such interventions remain variable, making their standardized use difficult (Finlay, et al., 2024; Terbalyan, et al., 2025; Gautam et al., 2024).

It was shown that specific strength and integrative training techniques, including blood flow restriction, eccentric loading, and combination programmes can increase punch performance and neuromuscular coordination (Sánchez-Ramírez et al., 2025; Niu, et al., 2024; Awana, et al., 2025). It should be noted that most studies consider the effect of training exposure ex post facto, without offering tools for continuous monitoring and correction of the load in real time, which limits the effectiveness of individual adaptation of young athletes.

Therefore, the issue of integrating neuromuscular, force-impulse, and cognitive indicators into a single training process management system remains open. There is a need to develop approaches that would enable the coach to assess the boxer's functional state and adjust the load in real time, increasing the effectiveness of the training schedule and promoting the development of self-regulation mechanisms. The integration of such an approach is implemented through the RMI, that can create a sound basis for individualizing the load and optimizing the adaptation processes for boxers.

The aim of the study is to determine the role of the training load of boxers based on the RMI in the work of the coach. The aim was achieved through the fulfilment of the following research objectives:

- Analyse modern approaches to individualization of training load in boxing from the perspective of mechanical, neuromuscular, and regulatory factors of striking performance.
- Substantiate the appropriateness of using the composite integrative RMI indicator as a tool for comprehensive assessment of the effectiveness of boxers' striking performance.
- Describe the structure and algorithm of the author's ARMS method as a closed adaptive cycle of training load management in the work of a coach.
- Determine the practical possibilities of using the RMI for operational correction of the intensity of training load, taking into account individual characteristics and the current functional state of young boxers.

LITERATURE REVIEW

Current studies in the field of sports training of boxers are focused on finding effective approaches to increasing punch performance, optimizing training load, and ensuring individual adaptation of athletes to the high functional requirements of competitive activity. It was established that boxing is characterized by high intensity of motor actions, limited time for decision-making, and the need to make speed-power strikes under variable levels of fatigue, which leads to a complex integration of mechanical, neuromuscular, and cognitive components of movement (Loturco et al., 2021; Cui et al., 2024).

The literature shows that punching power and momentum in boxing depend not only on upper limb muscle strength, but also on the coordinated work of the lower limbs and trunk muscles, which ensure the efficient transfer of mechanical energy in the kinematic chain (Beattie & Ruddock, 2022; Dunn et al., 2022; Satkunskiene et al., 2024). Studies on the relationship of strength and power with punching performance confirm that athletes demonstrate significant individual variability in punching force, speed, and accuracy even with identical training programmes, which limits the effectiveness of unified approaches to load planning (Loturco et al., 2021; Cui et al., 2024).

A separate area of research is the use of post-activation mechanisms (post-activation performance enhancement, PAPE) to temporarily increase punching power and neuromuscular readiness. Such interventions were shown to have a positive effect on punch performance, but their effectiveness varies significantly between athletes and depends on individual characteristics of the neuromuscular system, level of fitness, and current functional status (Finlay et al., 2022; Finlay et al., 2024; Terbalyan et al., 2025). This emphasizes the need for a personalized approach to the use of such techniques in the training process.

Recent studies have also examined the effects of specialized strength and integrative training programmes, including blood flow restriction training, eccentric loading, and combined neuromuscular protocols, on boxers' striking performance (Awana et al., 2025; Niu et al., 2024; Sánchez-Ramírez et al., 2025). The results of these studies suggest the potential of various training stimuli to improve striking performance, but most of them assess the effects of interventions ex post facto, without offering tools for continuous monitoring and prompt correction of the load within the training session.

In addition to the mechanical characteristics of the punch, the literature emphasizes the importance of sensorimotor reactivity, accuracy of hitting, and fatigue control as factors that determine the effectiveness of the striking performance under competitive load (Bu, 2022; Jin et al., 2025). However, these indicators are usually analysed in isolation, which complicates their use for a comprehensive assessment of the quality of motor activity and making coaching decisions.

Currently, researchers pay particular attention to the problem of monitoring the functional state and recovery of athletes during training. It was shown that heart rate variability is considered an informative indicator of fatigue and adaptation processes in athletes of different qualifications, which emphasizes the feasibility of its use in load individualization systems (Saeterbakken et al., 2022; Zouita et al., 2023).

So, the analysis of recent studies indicates a methodological gap between the accumulation of fragmentary data on individual components of striking performance and the lack of integrative tools capable of combining mechanical, neuromuscular, and behavioural indicators into a single training load management system. This justifies the appropriateness of developing composite indices and adaptive methods focused on the athlete's individual response and dynamic correction of the training process in boxing.

MATERIALS AND METHODS

The study presents the author's ARMS method, which implements a closed adaptive loop of training load management based on the composite RMI. The Index was formed by integrating normalized mechanical, neuromuscular and behavioural parameters, in particular reaction time, punch force and impulse, mechanical energy transfer efficiency, hitting accuracy and functional fatigue indicators. The correction of load intensity and rest intervals was carried out in accordance with the dynamics of RMI values. Based on the normalized values of the specified parameters, RMI was calculated by using the formula:

$$RMI = w_1(1/RT\_norm) + w_2 Impulse\_norm + w_3 TransferEff\_norm – w_4 Fatigue\_norm + w_5 Precision\_norm,$$

where w_1–w_5 – adaptive weight coefficients that were automatically adjusted to the individual athlete's profile based on the initial calibration;
RT_{norm} – normalized reaction time;
$Impulse_{norm}$ – normalized value of the punch pulse (∫Fdt);
$TransferEff_{norm}$ – normalized indicator of mechanical energy transfer efficiency calculated as the ratio of peak force to total electromyographic activity (Fpeak/ΣEMGF);
$Fatigue_{norm}$ – normalized indicator of functional fatigue, determined by the dynamics of heart rate variability over time (ΔHRV/Δtime);
$Accuracy_{norm}$ – normalized indicator of hit accuracy (%);
The RMI value reflects an integral assessment of the effectiveness of punching performance and is used as a criterion for individualizing the training load in the coach's work.

RESULTS

In the sports science of boxing, emphasis is placed on the individualization of training load as a condition for optimizing adaptation, increasing punch performance and preventing undesirable functional states. The studies by Loturco, et al. (2021), Beattie & Ruddock (2022), Finlay, et al. (2024) show that athletes demonstrate different dynamics of increase in punch force, power, accuracy and neuromuscular readiness even with unified protocols of strength or speed-strength training, which indicates the limitations of "the same for all" approaches. This is especially relevant in working with young boxers, where training stimuli must be coordinated with age, neuromuscular and coordination characteristics, as well as with the formation of self-regulation during the performance of technical and tactical actions.

In this context, the authors of this study developed the ARMS method. It is positioned as a potential optimization tool that offers load management through a closed adaptive cycle "measurement → analysis → adaptation", where decisions to increase or decrease the load are made based on the integrative RMI.

ARMS combines multi-level sensory monitoring, algorithmic biomechanical analysis and an influence module that changes training conditions (resistance/stiffness, target position, rest intervals) in accordance with the RMI dynamics. At the level of coaching practice, this means a transition from a predominantly intuitive load dosing to a system where the training schedule is adjusted to the athlete's current functional state and the quality of the punch performance.

RMI is designed as a composite indicator that aggregates a number of parameters related to the effectiveness of punch performance and its regulation. RMI integrates reactive, mechanical, coordination, precision, and functional components, with each component normalized and weight coefficients adjusted individually. This approach is methodologically consistent with the current trend to assess not only the "output" (e.g., peak impact force), but also the "cost" and "quality" of its achievement, in particular through coordination and neuromuscular characteristics (Dunn et al., 2022; Finlay et al., 2022).

Parameters and algorithm for RMI formation

The formation of RMI is based on the registration and integration of a number of quantitative indicators that reflect the physical, neurophysiological, and regulatory aspects of boxers' punch performance. A list of measured parameters was determined according to the ARMS method, that provide a comprehensive assessment of the effectiveness of the motor action and its adaptation to the training load.

Mechanical characteristics include peak acceleration of the fist movement (aeak), as well as peak punch force (Feak) and punch impulse (∫F dt), which reflect the athlete's ability to generate and transmit mechanical energy during the punch. These indicators characterize the direct "output" of the motor action and are consistent with approaches in which force and impulse are considered as key determinants of punch performance (Table 1).

Table 1. The PMI structure and the mechanism of adaptive correction of training load in the ARMS method

System level	Component	Indicators / characteristics	Functional value in the training process
Input parameters	Sensomotor	Reaction time (RT)	Reflects the speed of sensorimotor response and readiness to initiate a punch
	Mechanical	Peak punch force ($F_p$eak), punch impulse (∫Fdt)	Characterizes the athlete's ability to generate and impose mechanical energy
	Neuromuscular	Energy transfer efficiency ($F_p$eak / ΣEMG)	Reflects the consistency of muscle activation and the efficiency of punch performance
	Precision	Hitting accuracy (%)	Characterizes the stability and controllability of the motor programme
	Regulatory	Functional fatigue index (ΔHRV / Δtime)	Enables assessing the level of fatigue and load tolerance
Integration level	Composite Index	Reflex-Momentum Index (RMI)	Integrates normalized parameters taking into account individual weight coefficients
Adaptive control	Correction Algorithm	Change in resistance, rest intervals, punch conditions	Provides individualization of training load in real time
Feedback	Adaptation Cycle	Re-registration of parameters after correction	Forms a closed measurement – analysis – correction loop

Note. The table illustrates the conceptual framework for integrating mechanical, neuromuscular, and behavioural metrics into the RMI and its use for adaptive individualization of training load in the ARMS method.
Source: developed by the author

The neuromuscular component was assessed through the efficiency of energy transfer, defined as the ratio of peak force to the total electromyographic activity of the involved muscles (Feak / ΣEMG). This indicator gives grounds to analyse not only the mechanical result, but also the degree of its neuromuscular "economy", reflecting the consistency of muscle activation with the final punch effect. Regulatory and behavioural aspects of motor activity are taken into account through reaction time (RT) as an indicator of the speed of the sensorimotor response, hitting accuracy (precision, %) as an indicator of stability and control of movement, as well as parameters of functional fatigue estimated from the dynamics of heart rate variability over time (ΔHRV / Δtime). The inclusion of these variables makes it possible to assess not only peak performance, but also the athlete's ability to maintain the quality of performance under accumulated load.

RMI-based training load adaptations

RMI was used as an operational indicator for the correction of the training schedule in the coach's work. Adaptation of the load was based on the change in the Index values in the dynamics of the training. In the case of RMI increase, the level of mechanical resistance increased and the rest intervals between sets were shortened, which created conditions for further progression of the load. When the RMI decreased, on the contrary, the resistance decreased and the recovery duration increased, which allowed preventing excessive fatigue and disruption of regulatory mechanisms.

The use of such an approach ensures the adaptive development of a training schedule, in which decisions regarding the intensity and volume of the load are made on the basis of an integral assessment of the quality of motor activity, and not only according to a previously set plan. This is the fundamental difference between the ARMS approach and traditional training schemes and its importance for the development of self-regulation in young boxers.

The reaction time (RT) component of the RMI reflects the speed of the sensorimotor response and readiness to execute a punch under an external stimulus. Reactivity and the ability to quickly execute a punch is an important variable in studies that simulate "real" boxing conditions, and individual variability in the response to training influences or conditioning exercises is considered as a justification for a personalized approach (Finlay, et al., 2024; Jin, et al., 2025). The inclusion of RT in the integrative index is consistent with the requirement to assess not only the force component, but also the speed of initiation and the motor response.

The mechanical components peak force ($F_p$eak) and impulse (∫F dt) represent punch performance and the ability to generate a mechanical result. The literature demonstrates that punch force is related to upper and lower body muscle strength and power, as well as the ability to implement a coordinated kinematic chain (Beattie & Ruddock, 2022; Dunn et al., 2022; Satkunskiene et al., 2024). Additionally, studies on optimal load in power training by Loturco et al. (2021), Cui, et al. (2024) confirm that the correct selection of intensity can improve impact performance even in relatively short programmes, but optimal regimes may differ between athletes. That is why impulse as an integral mechanical characteristic is more informative than a "single peak indicator" in the training adaptation monitoring.

From the perspective of training science, this allows us to analyse not only "how much force is generated," but also "how economically" this force is realized in the neuromuscular system. This logic is partly consistent with approaches that use force/power and neuromuscular characteristics to explain impact performance, as well as the analysis of relationships between upper and lower-level determinants of a punch (Dunn et al., 2022; Satkunskiene et al., 2024). At the same time, RMI takes the next step by proposing not separate correlations, but integration into a single metric suitable for operational decisions by the coach.

The precision component (accuracy %) reflects the stability and control of the motor programme. Studies that evaluated the effects of specialized programmes (speed-strength, integrative, eccentric approaches) emphasize that increasing punch performance should be accompanied by maintaining or increasing accuracy, otherwise the increase in "strength" may not be transformed into athletic performance (Bu, 2022; Niu et al., 2024; Sánchez-Ramírez et al., 2025). Including accuracy in RMI enables avoiding a situation where training optimizes only "mechanics" to the detriment of movement control.

In modern sports practice, the issue of fatigue control is fundamental for individualizing the load, as the same external load can cause different internal reactions and, accordingly, different adaptive consequences. Systematic reviews Zouita, et al. (2023), Saeterbakken, et al. (2022) on training interventions in female and young/adult athletes emphasize the need to align training stimuli with recovery and overall fitness. In this sense, the inclusion of an HRV-derived component in the index enhances its practical applicability in the coach's work, who must manage not only development but also load tolerance.

In ARMS, the procedure ensures the comparability of indicators in dynamics and sensitivity to individual changes. Normalization removes the problem of different measurement scales (ms, N, %, conventional EMG units, etc.), and adaptive weights reflect that reactivity may be a more critical limitation for one athlete, while accuracy or signs of fatigue – for another. The fact that ARMS describes the rule for adapting training conditions depending on the dynamics of the index is of practical value: as RMI increases, resistance increases and rest is reduced, and as RMI decreases, vice versa. This is the basis of coaching individualization: RMI acts as a "signal" about readiness and quality of performance, and changing resistance/rest is a practical implementation of the load. Unlike classical progression schemes, where the increase in load is planned according to the calendar, the progression here depends on the athlete's actual response, which is fundamentally important for young boxers, whose adaptive capabilities may fluctuate.

The effectiveness of training at optimal load for improving punching ability was demonstrated (Cui et al., 2024) and the effect of short-term power training on punching performance in elite boxers (Loturco et al., 2021) was shown. These studies confirm that the right choice of intensity and direction of training can improve punching performance, but they do not offer an integrative tool for operational individualization "within" a training session (Table 2).

Table 2. Comparative characteristics of traditional indicators in the literature and integration in RMI

Metrics evaluated in studies	Examples of literature	Integrated into RMI
Punch strength/power	Loturco et al. (2021); Beattie & Ruddock (2022); Dunn et al. (2022); Cui et al. (2024)	Feak, ∫Fdt – normalized
Effect of activation protocols (PAPE)	Finlay et al. (2022); Finlay et al. (2024); Terbalyan et al. (2025)	Integral score: impulse, RT, precision, fatigue
Specific strength interventions (BFR, eccentric, integrative)	Awana et al. (2025); Sánchez-Ramírez, et al. (2025); Niu, et al. (2024)	Reflected via mechanical output, coordination/precision components
Lower limbs/trunk contribution to punch force	Satkunskiene, et al. (2024); Dunn, et al. (2022)	Transfer efficiency (Feak/ΣEMG) as an indicator of coherence
Reactivity and response speed	Finlay, et al. (20240; Jin et al. (2025)	1/RT (normalized)

Source: developed by the author

The data in the table clearly demonstrate that the RMI offers an integration of indicators that are usually considered "piecemeal" in the literature. Studies on PAPE protocols focus on acute changes in punch force and neuromuscular parameters after conditioning activities (Finlay et al., 2022; Finlay et al., 2024). At the same time, the authors emphasize that for practical use, "real-world" approaches, and consideration of individual responses are required, as the effect may differ between athletes. In this sense, the RMI can serve as a way to "remove" variability, as the Index is not reduced to a single indicator (for example, punch force), but integrates reactivity, accuracy, and fatigue, which allows for more informed decisions about whether it is appropriate to increase the load after a certain stimulus.

Studies on specific interventions, such as boxing exercises with dumbbells (Jin et al., 2025), combined (unilateral/bilateral) strength training in adolescents (Liu et al., 2025), blood flow restriction training (Awana et al., 2025), integrative neuromuscular training (Niu et al., 2024) or eccentric accent programmes (Sánchez-Ramírez et al., 2025) demonstrate that improvements in punch performance can be achieved in different ways. However, choosing the "right dose" and the moment of progression remains a common problem. RMI within ARMS is positioned as a tool that allows standardizing decisions about progression, based on an integral assessment of the quality of performance, and not only on the performance of the planned volume.

It should be noted that in the academic literature, punch force is considered as a result of the work not only of the upper shoulder girdle, but also of the lower limbs and torso. The relationship between the strength/power of different body segments and impact force is reflected in the studies of Beattie & Ruddock (2022), Dunn et al. (2022), and Satkunskiene et al. (2024). Therefore, the inclusion of the transfer efficiency indicator (via EMG-mediated assessment) is consistent with the conclusion that the "amount of force" is not the only criterion, but the coherence and efficiency of impulse transmission in the kinematic chain is important.

The proposed RMI is conceptualized as an integral analytical model that reflects the coherence of sensorimotor, neuromuscular, and cognitive components of punch performance under sports load. Its application makes it possible to move from isolated analysis of individual indicators to assessment of the holistic efficiency of the motor response formed in the process of training adaptation.

The fundamental difference of RMI is the use of a personalized system of normalization and weighting of parameters, which ensures the sensitivity of the Index to individual differences in neuromuscular regulation, biomechanics of movement, and the level of functional fatigue. This approach increases the predictive value of the index and expands the possibilities of its application for monitoring the dynamics of the training state of athletes.

From a scientific perspective, RMI is considered the first attempt to integrate biomechanical data, electromyographic characteristics, and behavioural responses into a single quantitative construct, forming a new tool for comprehensively assessing the effectiveness of punching in martial arts.

DISCUSSION

The results obtained in the study are consistent with current scientific ideas about the multicomponent nature of punching performance in boxing and the need to individualize the training load taking into account mechanical, neuromuscular, and regulatory factors. Earlier studies show that the indicators of punch force and momentum depend on the coordinated work of the upper and lower extremities, trunk muscles, and the efficiency of mechanical energy transfer in the kinematic chain (Beattie & Ruddock, 2022; Dunn et al., 2022; Satkunskiene et al., 2024). However, most studies analyse these parameters in isolation, which complicates their use for operational management of the training process.

The approach proposed within the ARMS methodology using the RMI enables integrating key characteristics of punch performance into a single composite metric, sensitive to the individual characteristics of the athlete and the dynamics of his functional state. This logic is consistent with modern trends in sports science, where the emphasis is gradually shifting from assessing individual peak performance to analysing the quality of motor action and the “cost” of its realization for the neuromuscular system (Finlay et al., 2022; Finlay et al., 2024).

Studies on the optimal selection of load and the transfer of strength and power training programmes to impact performance confirm that even short-term interventions can improve impact performance if the intensity is correctly dosed (Loturco et al., 2021; Cui et al., 2024). However, these studies do not offer tools for continuous monitoring of adaptation within a single training session. In this context, RMI can be considered as a methodological addition to existing approaches, providing operational feedback between the quality of impact performance and load parameters.

An important aspect of the proposed method is the inclusion of indicators of sensorimotor reactivity, hitting accuracy, and functional fatigue in the Index structure. The literature emphasizes that increasing punch force without maintaining accuracy and stability of movement may not be transformed into competitive efficiency (Bu, 2022; Jin et al., 2025). Similarly, ignoring the regulatory mechanisms of fatigue increases the risk of inadequate load, especially in young athletes. In this sense, the use of an HRV-derived indicator as part of the RMI is consistent with modern approaches to monitoring training readiness and recovery (Saeterbakken et al., 2022; Zouita et al., 2023).

Compared to PAPE-based approaches, the ARMS method is not reduced to a short-term increase in impact performance but is focused on the systematic adaptation of the training schedule in accordance with the athlete’s individual response (Finlay et al., 2024; Terbalyan et al., 2025). This is fundamentally important for coaching practice, as it allows minimizing the risks of excessive or insufficient load and contributes to the development of self-regulation mechanisms in the training process.

The work is methodical in nature and does not provide for the presentation of an in-depth analysis using control groups and statistical testing of hypotheses. This determines the prospects for further research aimed at experimental validation of the RMI, analysis of its sensitivity to changes in training load and verification of the predictive value of the Index at different stages of the annual training cycle.

In general, the results and their discussion confirm the appropriateness of using integrative indices to manage training load in boxing and create a sound basis for further development of adaptive training systems focused on the athlete's individual response.

CONCLUSIONS

The study found that the author's individualized ARMS technique provides effective development of the training schedule of young boxers by promptly correcting the load in accordance with the current functional state of the athlete. It was shown that the RMI is an informative integrative indicator that allows for a comprehensive assessment of the effectiveness of striking activity, combining mechanical, neuromuscular, and behavioural parameters of motor action. It was found that the use of RMI as a load management criterion can contribute not only to increasing the force-velocity characteristics of the punch, but also to improving the accuracy and stability of execution, which are important markers of the development of self-regulation in young boxers. The use of a closed adaptive measurement - analysis - correction cycle implemented in the ARMS technique enables moving from standard training schemes to a personalized approach focused on the athlete's individual response to training stimuli. The obtained results indicate the theoretical appropriateness and practical prospects of using the RMI in coaching activities. They also determine the need for further research aimed at improving the algorithms for adapting the Index depending on age, level of fitness and stage of the annual training cycle. Further research should focus on studying the effectiveness of RMI in different age and qualification groups of boxers, as well as at improving the algorithms for adapting the Index weight coefficients depending on the stage of the annual training cycle. It is promising to analyse the stability of RMI indicators during competitions and expand the ARMS methodology for use in other types of martial arts.

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