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The Role Of The Individualized Arms Methodology In The Formation Of The Training Regimen And Self-Regulation Of Young Boxers

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Abstract: Modern training of young boxers requires individualized approaches to the formation of the training regimen that are based on objective quantitative data and promote the development of self-regulation mechanisms in young athletes. Traditional methods of training load control do not fully account for individual variability in sensorimotor and neuromuscular reactions, which highlights the need for the development of new methodologies. The purpose of this study was to determine the role of the individualized Adaptive Reflex-Momentum System (ARMS) methodology in the formation of the training regimen and self-regulation of young boxers. The study involved 76 young boxers (mean age 15.6 ± 1.2 years), who were assigned to an experimental group ($n = 54$) and a control group ($n = 22$). The ARMS methodology was applied over an eight-week period and involved adaptive load regulation based on multisensory monitoring of punching activity and the integrative Reflex-Momentum Index (RMI). Punching force, reaction time, accuracy, and RMI were assessed before and after the intervention using between-group and within-group statistical analyses. In the experimental group, the application of ARMS resulted in statistically significant improvements in punching force (+20%), punching accuracy (+15%), a reduction in reaction time (–23%), and an increase in RMI (+23%) compared with baseline values and the control group ($p < 0.05$). The use of normalized values of these parameters was shown to account for individual differences in the initial functional state of the athletes. The ARMS methodology ensures effective formation of an individualized training regimen and promotes the development of self-regulation in young boxers based on objective quantitative control.

Keywords: Boxing, training individualization, self-regulation, Reflex-Momentum Index, adaptive methodologies.

Introduction: Recent research in the field of sports science indicates that the effectiveness of punching activity in boxing is determined by a complex interaction of biomechanical, neuromuscular, and coordination factors. Liu et al. (2022) and Esposito et al. (2025) demonstrated that the mechanical characteristics of the punch, particularly force and velocity, vary substantially depending on athletes' level of preparation and the organization of the kinematic chain of movement. It has been established that strength training plays an important role in the formation of punch impact; however, its effect is realized only under conditions of efficient impulse transmission and coordinated activation of muscle groups (Beattie & Ruddock, 2022; Hou & Bu, 2022).

Recent experimental studies have demonstrated that the application of specialized training interventions contributes to improvements in specific indicators of punching activity in boxers. In particular, a positive effect of optimized training load on punching force and power in female athletes has been reported (Cui et al., 2024a), as well as the effectiveness of post-activation potentiation applied at different velocity loss thresholds for enhancing punching capacity (Cui et al., 2024b). Sánchez-Ramírez et al. (2025) and Bu (2022) also showed that the inclusion of accentuated eccentric exercises can improve strength characteristics and force–time parameters in amateur boxers. In addition, positive effects of high-intensity programs incorporating technical elements on physical condition and motor activity under simulated bout conditions have been reported (Herrera-Valenzuela et al., 2021), along with adaptive effects of hypoxic training in national-level athletes (Ambroży et al., 2025). Researchers Cid-Calfucura et al. (2023) further confirm the effectiveness of strength training programs in combat sports, while emphasizing the substantial variability of applied protocols and methodological approaches.

At the same time, contemporary literature emphasizes the importance of individualization of the training process. Han et al. (2025) and Takamidoa et al. (2025) demonstrated that the load-velocity relationship in boxers exhibits specific patterns that can be used for personalized dosing of strength stimuli. Athletes' responses to velocity-based and percentage-based resistance training differ substantially depending on baseline characteristics, which limits the applicability of unified training models (Chen et al., 2025). Evidence from other high-performance sports likewise supports the feasibility of adaptive load management based on modeling individual training patterns (Hellard et al., 2017).

A separate line of research addresses the psychophysiological aspects of training and the development of self-regulation. It has been shown that the use of biofeedback in the training process of young boxers is associated with improvements in functional state and adaptive capacity (Kubiyeva et al., 2025). Kozin et al. (2021), who applied cluster analysis of biomechanical and psychophysiological indicators, identified the presence of relatively stable individual fighting styles that are relevant for training planning. Similar conclusions were reported in studies by Pustomelnik and Kozina (2025) and Melson (2025), which examined the regulation of physical activity in athletes of different combat styles and its impact on competitive performance. At the same time, psychological aspects of self-control, particularly in relation to boxing training practice, are predominantly analyzed using subjective assessment methods, which complicates their integration with objective indicators of punching activity.

An analysis of the reviewed studies indicates that, despite significant progress in investigating individual components of boxer preparation, the integration of biomechanical, neuromuscular, and psychophysiological data into a unified system for training regimen management remains insufficiently explored. Existing methods for monitoring punching force and reliable measurement tools are rarely used as a basis for the real-time correction of training load in young athletes (Finlay et al., 2023; Bishop et al., 2023). In this context, self-regulation is predominantly considered a complementary or indirect factor rather than a structural element of the training methodology.

In this context, the present study is relevant as it aims to provide an experimental substantiation of the individualized Adaptive Reflex-Momentum System (ARMS) methodology, which integrates key indicators of punching activity within a unified adaptive training management cycle. The use of the integrative Reflex-Momentum Index (RMI) enables the combination of mechanical, neuromuscular, and coordination characteristics of movement and their application to the formation of a training regimen oriented toward the development of self-regulation in young boxers.

The purpose of this study was to determine the role of the individualized ARMS methodology in the formation of the training regimen and self-regulation of young boxers. To achieve this purpose, the following scientific objectives were formulated:

1. To experimentally assess the effect of the individualized Adaptive Reflex-Momentum System (ARMS) methodology on the dynamics of key indicators of punching activity in young boxers (punching force, sensorimotor reaction time, punching accuracy, and the integrative RMI) over an eight-week training cycle.

2. To compare the effectiveness of training regimen formation in young boxers under conditions of applying the ARMS methodology and a traditional training program using between-group and within-group statistical analyses.

3. To analyze the role of the integrative Reflex-Momentum Index (RMI) as a tool for the quantitative assessment of coordinated adaptation of mechanical, neuromuscular, and coordination components of punching action under individualized load conditions.

4. To substantiate the potential of the ARMS methodology in developing mechanisms of self-regulation of motor activity in young boxers through adaptive correction of training parameters based on multisensory monitoring.

METHODS

The study involved 76 male young boxers with a mean age of 15.6 ± 1.2 years, who were at the stage of specialized basic training and engaged in a systematic training process in a sports section/club. All participants were assigned to an experimental group (ARMS) (n = 54) and a control group (n = 22). The sample was formed using a purposive sampling approach, taking into account group homogeneity in terms of age and training characteristics, which is critically important for the interpretation of changes in reactivity, accuracy, and punching effectiveness under conditions of individualized load.

Inclusion criteria were as follows: belonging to the age category of young athletes, at least two years of boxing experience, regular participation in training sessions with a frequency of no fewer than three sessions per week, and the absence of acute conditions that would limit the performance of high-intensity exercise. Only athletes with a stable level of training activity were admitted to the study, which allowed minimization of the influence of the “initial learning effect” of technique and enabled the analysis to focus on changes associated with the implementation of the ARMS methodology.

Exclusion criteria included the presence of acute injuries (in particular, of the hand, shoulder girdle, back, or lower extremities), medical contraindications to intensive physical exercise, as well as absence from more than 20% of training sessions during the study period.

The study was conducted in accordance with the ethical principles and standards of the Declaration of Helsinki of the World Medical Association. All participants were informed about the purpose and procedures of the study as well as its potential risks, and written informed consent was obtained from their parents prior to participation.

The study was conducted as a pilot experimental intervention with repeated measurements before and after the application of the methodology. An author-developed individualized Adaptive Reflex-Momentum System (ARMS) methodology was implemented, aimed at the formation of the training regimen and the development of self-regulation mechanisms in young boxers based on objective monitoring of punching activity. The ARMS methodology is structured as a three-level integrated ecosystem that combines sensory, analytical, and executive levels of training management.

The sensory level of ARMS ensures multi-channel acquisition of biomechanical and neuromuscular data during the execution of punching actions. Kinematic parameters were recorded using inertial measurement units (IMUs) with a nine-axis configuration, positioned on segments of the upper limbs and the trunk, with a sampling frequency of 200–500 Hz. The force characteristics of punch interaction were determined using an 8×8 force sensor array integrated beneath the surface of the punching bag, with a recording frequency of 1–2 kHz, which allowed the registration of peak punching force (F_{peak}) and punch impulse ($\int F dt$). Neuromuscular activity was assessed using surface electromyography (sEMG) with 4–8 electrodes within a frequency bandwidth of 20–450 Hz and a sampling frequency of 1–2 kHz. In addition, acoustic sensors were used to determine the moment of contact, trunk-mounted sensors were employed to analyze the kinematic chain “trunk–upper limb,” and an optical tracking system with a frame rate of no less than 120 frames per second was applied to assess movement trajectory and punching accuracy. Synchronization of all data streams was performed with a temporal error of no more than 5 ms, ensuring accurate signal integration.

The analytical level of ARMS involved processing the acquired signals and calculating quantitative indicators that characterize punching activity, sensorimotor reactivity, and the functional state of the athletes. Within the methodology, peak fist acceleration, peak punching force, and punch impulse were recorded, along with mechanical energy transfer efficiency, calculated as the ratio of F_{peak} to the cumulative electromyographic activity of the engaged muscles. In addition, sensorimotor reaction time, accuracy of target hits, and indicators of functional fatigue were assessed based on relative changes in heart rate variability ($\Delta HRV/\Delta time$).

The key analytical component of the methodology is the integrative RMI indicator, which was used as a generalized measure of punching activity effectiveness. The RMI was calculated as a weighted sum of normalized components according to the following 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 denote adaptive weighting coefficients that were automatically adjusted to the individual athlete profile based on baseline calibration.

This model enables the integration of velocity-related, strength, coordination, and regulatory components of punching action into a single quantitative index. The executive level of ARMS provided adaptive correction of training conditions based on current RMI values. It was established that with an increase in the index, the resistance of training exercises was progressively increased and rest intervals were shortened, whereas a decrease in RMI resulted in a reduction of training load intensity accompanied by a corresponding extension of recovery intervals. This approach enables the implementation of an individualized training regimen oriented toward maintaining an optimal functional state and promoting the development of self-regulation.

Training Protocol of ARMS Implementation

The ARMS methodology was implemented over an eight-week period within the regular training process. The program included an initial calibration phase lasting 1–2 training sessions, during which baseline individual data were collected. The main part of the protocol consisted of sets of explosive power exercises (3 × 6 sets) with monitoring of peak acceleration and punch impulse, reactive exercises with random light signals and registration of reaction time and accuracy, as well as exercises aimed at optimizing energy transfer using synchronized EMG–IMU measurements within the "trunk–fist" kinematic chain. The final element of each microcycle was a control test that included five maximal punches, with the construction of an individual RMI dynamics curve.

Outcome Measures and Quantitative Performance Indicators

The effectiveness of the ARMS methodology was evaluated based on the dynamics of key quantitative indicators of punching activity.

Statistical Analysis

Quantitative data were presented as mean values and standard deviations (M ± SD) for normally distributed variables. Normality of distribution was assessed using the Shapiro–Wilk test. Comparisons of indicators before and after the intervention were performed using a paired t-test or the Wilcoxon signed-rank test, with calculation of effect sizes (Cohen's d or r) and 95% confidence intervals. The level of statistical significance was set at $p < 0.05$.

Study Limitations. Given the pilot nature of the study and the relatively short duration of the intervention, the results should be interpreted as preliminary experimental evidence supporting the effectiveness of the individualized approach.

RESULTS

In the present study, the role of the individualized ARMS methodology in the training of young boxers was experimentally evaluated, with a focus on the integration of objective indicators of punching activity and their use for adaptive management of the training process (Figure 1). The analysis covered the dynamics of the indicators before and after the eight-week training intervention, as well as between-group differences.

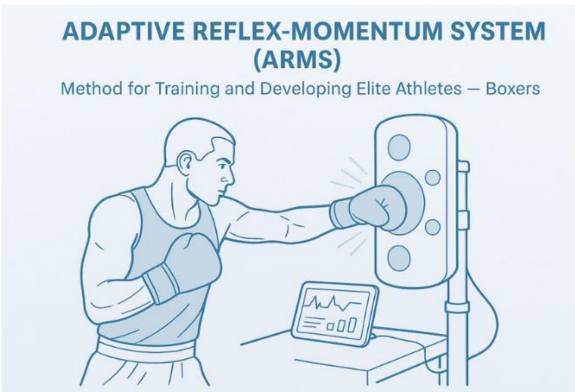

Fig. 1. Adaptive Reflex-Momentum System (ARMS): an author-developed individualized training system

Comparative analysis of baseline indicators revealed no statistically significant differences between the experimental (ARMS) and control groups for any of the studied parameters ($p > 0.05$), indicating their initial homogeneity (Table 1).

Table 1. Baseline indicators of punching activity (M ± SD)

Indicator	ARMS (n=54)	Control (n=22)	p
Punching force, N	2205 ± 210	2190 ± 225	>0,05
Reaction time, ms	322 ± 34	319 ± 36	>0,05
Accuracy, %	74,1 ± 6,2	73,8 ± 6,5	>0,05
RMI, arbitrary units	0,68 ± 0,07	0,67 ± 0,08	>0,05

Source: Compiled by the author

After eight weeks of applying the ARMS methodology, statistically significant positive changes were observed in the experimental group across all key indicators of punching activity (Table 2). Punching force increased by an average of 20%, sensorimotor reaction time decreased by 23%, punching accuracy improved by 15%, and the integrative RMI increased by 23% ($p < 0.001$).

Table 2. Dynamics of indicators in the groups before and after the intervention (M ± SD)

Indicator, unit of measurement	Group	Before	After p	p (before vs. after)
Punching force, N	ARMS	2200 ± 210	2650 ± 230	<0,001
	Control	2190 ± 225	2280 ± 240	>0,05
Reaction time, ms	ARMS	320 ± 35	245 ± 28	<0,001
	Control	319 ± 36	305 ± 34	>0,05
Accuracy, %	ARMS	74 ± 6	89 ± 5	<0,001
	Control	74 ± 6	77 ± 6	>0,05
RMI	ARMS	0,68 ± 0,07	0,84 ± 0,06	<0,001
	Control	0,67 ± 0,08	0,71 ± 0,07	>0,05

Source: Compiled by the author

In the control group, which trained according to a traditional program, moderate positive changes were observed; however, these did not reach statistical significance or were characterized by substantially smaller effect sizes.

A two-way analysis of variance with repeated measures revealed a statistically significant Group × Time interaction for all examined indicators ($p < 0.01$), indicating divergent adaptation patterns between the groups. The effect size for the experimental group was large (Cohen's d = 0.9–1.4), whereas effects in the control group were small to moderate (Table 3).

Table 3. Between-group analysis of the intervention effect before and after training (ARMS group)

Indicator	Group × Time, p	Cohen's d (ARMS)
Punching force	<0,001	1,2
Reaction time	<0,001	1,4
Accuracy	<0,001	1,1
RMI	<0,001	1,3

Source: Compiled by the author

The individualized ARMS methodology provides substantially higher effectiveness in the formation of the training regimen compared with traditional approaches. The combination of increased strength indicators, reduced reaction time, and improved punching accuracy reflects not only physical adaptation but also the development of self-regulation mechanisms of motor activity, as evidenced by the significant increase in the integrative RMI.

DISCUSSION

The results of the experiment indicate that the implementation of the individualized ARMS methodology over an eight-week period contributed to positive changes in punching force, sensorimotor reactivity, accuracy, and the integrative RMI. Taken together, these changes reflect not only improvements in individual physical qualities but also a restructuring of the regulatory mechanisms underlying punching activity. In this context, a key aspect is that ARMS does not isolate and “enhance” a single component (e.g., strength); rather, it ensures a controlled integration of mechanical, neuromuscular, and coordination components of movement through a closed-loop cycle of “measurement–analysis–correction,” which methodologically brings the training process closer to adaptive control systems.

Comparison with contemporary scientific studies shows that the literature most often describes the effects of isolated training interventions aimed at enhancing punching performance. In particular, Cui et al. (2024a) demonstrated that optimal load training can improve punching capacity in elite female boxers, while modifications of post-activation potentiation protocols using different velocity loss thresholds influence punching characteristics (Cui et al., 2024b). At the same time, despite their effectiveness, these approaches generally conceptualize the training stimulus as a fixed or semi-fixed program in which load adaptation is governed primarily by general rules. In contrast, ARMS implements a different logic: the training stimulus is modified based on the integrative RMI indicator, which accumulates information on reaction, impulse, energy transfer efficiency, accuracy, and fatigue. Accordingly, the data obtained before and after the application of the author-developed methodology should be interpreted as the outcome of systematic individualization rather than the effect of a single physiological mechanism.

Reactivity and accuracy indicators are particularly sensitive to methodologies that integrate technical and regulatory components of training. Herrera-Valenzuela et al. (2021) reported that a high-intensity interval training (HIIT) program incorporating specific technical elements can improve physical condition and activity in simulated bout conditions. Similarly, studies involving accentuated eccentric plyometric training by Sánchez-Ramírez et al. (2025) demonstrated improvements in punching performance and force-time parameters. The observed dynamics of accuracy and the reduction in reaction time in the present study are consistent with these findings in terms of effect direction; however, a key distinction lies in the fact that within ARMS these components are not treated as an “add-on” to strength or conditioning training but are embedded within the core model of load and recovery management through the RMI index, thereby enabling more targeted training regulation.

Importantly, a number of recent studies emphasize pronounced individual variability in athletes’ responses to training stimuli. Han et al. (2025) and Chen et al. (2025) identified specific load-velocity relationships in boxers and demonstrated that responses to velocity-based and percentage-based resistance training depend on baseline characteristics, indicating that “universal” dosing schemes have limited applicability. The results obtained in the present study, considering the architecture of ARMS, are consistent with this paradigm: adaptive coefficients and normalization of RMI components enable the translation of individual dynamics of reaction and fatigue into specific training decisions (e.g., resistance, target positioning, and rest intervals). This mechanism likely creates conditions for more stable gains in integrative efficiency in young athletes compared with a fixed training regimen.

Particular attention should be given to the relationship between the observed changes and the phenomenon of self-regulation. It has been shown that the use of biofeedback in young boxers can improve functional state during the preparatory period (Kubiyeva et al., 2025). The present findings are conceptually aligned with this line of research; however, ARMS extends beyond the regulation of a single physiological signal, as it establishes a learning loop of “perception – correction – outcome” based on integrated indicators of punching activity. The increase in RMI, combined with improved accuracy and reduced reaction time (RT), may be considered an indirect marker of the development of more effective sensorimotor organization mechanisms. Furthermore, Kozin et al. (2021), who analyzed psychophysiological profiles and fighting styles, demonstrated that individual differences play a substantial role in training planning, while regulation of training activity with consideration of fighting style influences performance outcomes (Pustomelnik & Kozina, 2025). In this context, ARMS can be interpreted as a tool that technologically enables individualization through controlled modification of training conditions rather than solely through general "adjustment of the training plan."

From a methodological perspective, the reliability of punching force measurements and the sensitivity of metrics to training-induced changes are also of critical importance. Finlay et al. (2023) demonstrated acceptable reproducibility and sensitivity in the assessment of maximal punching force using a force platform in boxers. This supports the validity of employing instrumental measurements in the present protocol and strengthens the rationale for including force- and impulse-related parameters in the integrative RMI model. In parallel, methodological reviews addressing the selection of performance metrics and the monitoring of neuromuscular fatigue emphasize the necessity of using indicators that are both sensitive and interpretable within the context of training load (Bishop et al., 2023), which is consistent with ARMS as a system for managing training decisions.

The scientific value of ARMS lies in the implementation of a comprehensive approach to the analysis and regulation of punching activity in boxers based on multidimensional objective data. The methodology enables the formation of complete multisensory punch profiles that integrate biomechanical, neuromuscular, and coordination parameters of movement, thereby expanding the possibilities for quantitative characterization of punching action compared with traditional assessment methods.

An important scientific contribution of the present study is the introduction of the integrative RMI indicator, which allows for a generalized characterization of punching activity effectiveness by accounting for the interaction of velocity-related, strength, and regulatory components. The use of such an indicator provides a foundation for standardized comparison of training adaptation dynamics in athletes with different individual profiles.

The ARMS methodology implements the principle of adaptive training process management through algorithmic optimization of overload in real time. The application of predictive analytical models allows not only the monitoring of the athlete's current functional state but also the forecasting of the direction and rate of changes in punching effectiveness within the training cycle. This approach shifts the preparation process of boxers from a predominantly subjective domain of coaching judgments to a sphere of objective, quantitatively justified, and algorithmically driven decision-making. The ARMS methodology thus establishes a methodological foundation for the development of a new scientific direction related to computerized analysis and management of movement kinetics in combat sports.

CONCLUSIONS

It was established that the application of the author-developed individualized ARMS methodology over an eight-week period resulted in statistically significant improvements in key indicators of punching activity in young boxers, including punching force, sensorimotor reaction time, and punching accuracy. It was demonstrated that the integrative RMI increased significantly following the implementation of ARMS, indicating coordinated adaptation of mechanical, neuromuscular, and coordination components of punching action.

Comparative analyses conducted before and after the application of the author-developed methodology, as well as between-group comparisons, demonstrated that training using ARMS is more effective than a traditional training regimen, as evidenced by the presence of a significant Group × Time interaction and large effect sizes. It was established that adaptive load regulation based on RMI dynamics contributes to the formation of an individualized training regimen that ensures stable progress without excessive increases in indicators of functional fatigue.

The obtained results confirm that the ARMS methodology creates conditions for the development of self-regulation mechanisms of motor activity, as manifested by reduced reaction time, improved accuracy, and increased efficiency of energy transfer during punching actions. Further research should be directed toward verifying the reproducibility of ARMS effects in boxers of different age groups, as well as toward analyzing the long-term dynamics of punching activity and self-regulation indicators under conditions of an extended training cycle.

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