THEORY and PRACTICE
of Physical Culture and Sports

https://tppcs.com.ua/
Vol. 4, No. 1, 2025

Received: 05.01.2025. Revised: 30.04.2025. Accepted: 23.06.2025

UDC 796.83

DOI: 10.69587/tppcs/1.2025.41

Scientific and methodological approaches to optimisation of training load based on the psychophysiological state of athletes (on the example of boxing and kickboxing)

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Abstract. The aim of the study was to develop scientific and methodological approaches to optimising training load, taking into account the psychophysiological state of athletes using the example of boxing and kickboxing. The methodology was based on analysis, which allowed to identify psychophysiological indicators, synthesis, which was used to build a closed-loop model of "state – load – response", comparison, which provided a comparison of styles and protocols, generalisation, which determined the principles of individualisation, induction, which revealed typical threshold solutions, and deduction, which checked their logical consistency in training scenarios. On this basis, practical recommendations were formed on the zonal logic of load correction and a roadmap for implementation in the training of boxers and kickboxers. The results of the study found that heart rate variability below the individual 20th percentile was regarded as a signal to reduce training intensity and extend rest intervals. The analysis showed that the optimal monitoring organisation included daily morning recordings lasting about 5 minutes; cognitive tests of simple and selective response (2-5 min) were performed 2-3 times a week; neuromuscular tests were performed 2 times a week on the days of key stimuli. In the pre-competitive period, discrete control of readiness at time points -72, -48, -24, -12 and -2 hours before the start was effective. Additionally, it was found that inter-round intervals (60 seconds) were appropriate for "quick recording" of heart rate (30/60 seconds) and ultra-short cognitive tests lasting 10-15 seconds with 6-8 stimuli. The combination of these procedures provided multi-level control of the athletes' condition and made it possible to adjust the load parameters in a timely manner. The results obtained have summarised and structured a system for monitoring and correcting training load in boxing and kickboxing, which included quantitative thresholds, measurement protocols and action algorithms. The proposed system can be used by coaches, sports scientists and training specialists to optimise loads, prevent overfatigue and increase the efficiency of the training process

Keywords: heart rate variability; latency; adaptation; neuromuscular readiness; recovery; zonal interpretation; cognitive-sensory motor tests

Introduction

Optimising training loads in boxing and kickboxing is a controlled process of matching external training doses to the athlete's internal psychophysiological state. This state is defined as a multidimensional indicator that integrates autonomous heart regulation, cognitive-sensory-motor functions, neuromuscular readiness, and emotional-stress reactivity, directly affecting speed-strength performance, the quality of tactical decisions, and fatigue resistance. Translating the dynamics of this state into load parameters (volume, intensity, density, alternation of means) at the micro-, meso- and macrocycle levels ensures phase synchronisation of adaptations and controlled fatigue/recovery changes. In practical terms, the key scientific and applied problem is the construction of a validated "state – load – response" circuit that formalises the rules for making decisions about load, incorporating individual variability, weight reduction modes, sparring exposure volume, sleep and transit factors, integrating objective and subjective data into a single training management system.

The psychophysiological state of athletes determines the effectiveness of martial arts, as it modulates reaction speed, decision-making stability, and the nature of the training response. Comparative age profiles of the psychophysiological characteristics of taekwondo athletes were

Suggested Citation: Aksiutin, V. (2025). Scientific and methodological approaches to optimisation of training load based on the psychophysiological state of athletes (on the example of boxing and kickboxing). *Theory and Practice of Physical Culture and Sports*, 4(1), 41-52. doi: 10.69587/tppcs/1.2025.41.

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described by L. Podrigalo *et al.* (2023), and the results showed differentiation in sensorimotor and vegetative indicators between age cohorts. The novelty was age stratification with applied interpretation for load dosage. Changes in the psychophysiological states of elite athletes after critical life events were recorded by I. Korobeinikova *et al.* (2024). These observations outlined predictive links between event stress and regulatory responses. A strong aspect was the event operationalisation and practical focus of stress management, but the lack of combat specialisation and formal decision triggers narrowed the applied validity. R. Pavelka *et al.* (2020) demonstrated a deterioration in latency and consistency of response under the influence of acute fatigue in mixed martial arts, which elevated cognitive metrics to the status of sensitive markers of stress. Causal sensitivity emphasised the advisability of including cognitive monitoring in intensity dosing, while species differences required cautious interpretation for boxing and kickboxing. The role of heart rate variability (HRV) in sports regulation mechanisms was summarised by E. Mosley & S. Laborde (2024), highlighting the potential of autonomic indicators for assessing readiness. At the same time, the heterogeneity of protocols and the lack of unified interpretation thresholds complicated the direct conversion of HRV signals into load assignment algorithms.

Monitoring and management of training load ensures the conversion of multi-channel data into manageable coaching decisions. The quantification of load distribution in Mixed Martial Arts was performed by C. Kirk *et al.* (2021), revealing a lack of clear periodisation and uneven management of volume and intensity between microcycles. The study performed a synchronous analysis of external load, internal responses, and training structure, which objectified planning practices. In international boxers, load dynamics correlated with creatine kinase and well-being indicators, as recorded by D. McCabe *et al.* (2023) in a twelve-week multi-stage training cycle. The integration of biochemical and questionnaire indicators into a single monitoring scheme provided an applied model for the operational correction of microcycles. The concept of using load indicators as a decision support system for elite sports was formulated by S. West *et al.* (2021), proposing to synthesise external stimuli, internal responses and contextual moderators. The emphasis on avoiding "metric myopia" and multi-channel integration created a methodological basis for evidence-based load management.

The style of fighting determines the starting conditions for individualising training loads in boxing and kickboxing. Cluster analysis of biomechanical and psychophysiological indicators in skilled veteran boxers, performed by V. Kozin *et al.* (2022), demonstrated reproducible style profiles with clear differences in sensorimotor and regulatory parameters. These profiles set differentiated planning goals and coordinated the volume, intensity, and technical and tactical emphases with individual performance determinants. According to Y. Myroshnychenko *et al.* (2020), skilled kickboxers developed model characteristics of psychophysiological indicators consistent with the specifics of striking techniques. A set of key indicators created a benchmark for testing and served as a basis for style-dependent load assignment in preparatory and pre-competitive microcycles. During official competitions and in simulated conditions, as shown by Ł. Rydzik *et al.* (2024), neuroendocrine markers were consistent with the nature of physical activity and situational requirements. The comparison of hormonal and neurophysiological responses with training activities confirmed the practical validity of style-specific monitoring for operational load correction.

Despite numerous studies, verified thresholds and algorithms for translating psychophysiological indicators into decisions regarding the volume and intensity of training loads in boxing and kickboxing remained undefined, protocols and measurement time windows were heterogeneous, and the integration of objective and survey data remained fragmentary. The study aimed to scientifically and methodologically justify the integration of psychophysiological indicators into the decision-making system for optimising training load parameters in boxing and kickboxing. The main objectives of the study were: to systematise and operationalise psychophysiological indicators for load management; to develop principles for their translation into parameters (volume, intensity, density, alternation of means) and feedback criteria; to determine monitoring protocols and measurement time windows in preparatory and pre-competitive microcycles of boxing and kickboxing.

Materials and Methods

The study was theoretical and methodological in nature, using a comparative and analytical strategy based on boxing and kickboxing. The chronological scope of the source base covered 2019-2025. The source base included methodological developments in boxing, in particular studies by L. Pérez (2019), E. Franchini (2020), J. Hernandez-Martinez *et al.* (2024), as well as in kickboxing by T. Ambroży *et al.* (2021), M. Babić *et al.* (2023). In addition, empirical examples from striking and mixed martial arts presented by M. Slimani *et al.* (2022), O. Kaya & G. Gül (2025), C. Wu *et al.* (2025), and general sports guidelines for monitoring and periodisation were provided by A. Coutts *et al.* (2021) and L. Montull *et al.* (2022). Based on these sources, a preliminary list of indicators and load parameters (with typical protocols and time windows) was identified and used as the starting point for formalisation of the rules in the "state – load – response" loop.

The analysis was used to decompose the subject area: domains of psychophysiological indicators (autonomic regulation of the heart, cognitive-sensory-motor functions, neuromuscular readiness, psychoemotional reactivity), specific variables and measurement protocols (HRV, latency/consistency of response, indicators of power and speed fatigue). Comparisons were used to compare fighting styles (power, tempo, etc.), training phases (micro-/mesocycle), observation situations (inter-session, pre-competition, inter-round windows) and load types to identify stable correspondences between "status profile → training priority". The generalisation was used to formulate the principles of individualisation and monitoring standards, refine the definitions of variables and criteria for the transition from observations to load assignment rules.

Synthesis ensured the integration of domains into a comprehensive taxonomy of indicators and the construction of a conceptual-operational model of a closed-loop "state – load – response" circuit with a correspondence matrix "indicator → load parameter (volume, intensity, density, alternation of means) → control action". Induction was used to derive typical triggers and threshold decisions from repetitive patterns (e.g., relative deviations of HRV from the individual baseline or shifts in reaction latency as a basis for correcting volume/intensity). Deduction was used to verify the logical consequences of the formulated rules in training process scenarios: typical micro- and mesocycles with different density, intensity, weight reduction and sparring exposure were modelled, and the necessary corrections (redistribution of intensity, change in density, insertion of recovery modules) were recorded.

Based on the model, proceduralisation and formalisation were conducted in the form of algorithms, thresholds and protocols. As a result, practical recommendations and a step-by-step implementation plan were formed: minimum monitoring profile (HRV, cognitive latency/consistency of response, neuromuscular indicators, self-reported well-being indicators), measurement windows (inter-session, pre-competition, inter-round), zone thresholds ("green/yellow/red") and load correction algorithms (volume, intensity, density, alternation of means, recovery). The roadmap included the following phases: preparation, calibration, piloting on microcycles, scaling to mesocycles, and retrospective audit.

Results

Standardised description of psychophysiological domains and training load parameters

Standardisation covers four interrelated domains: autonomic regulation (BPR), cognitive-sensory-motor functions, neuromuscular readiness, and psycho-emotional reactivity. Their coordination with load parameters (volume, intensity, density, alternation of means) is achieved through the logic of operational decision-making in training micro- and mesocycles, as well as in pre-competition and inter-round intervals. In the autonomous domain, the key indicator is HRV with priority on short morning recordings of lnRMSSD under standardised conditions (≈5 minutes in a lying/sitting position, calm breathing) and/or within the orthostatic test; interpretation is performed relative to an individual baseline through zonal deviations, which can be used to assess "stress/recovery" balance and readiness for a stimulus of a certain intensity (Montull *et al.*, 2022). At the same time, a summary of the evidence indicates that the relationships between psychophysiological factors and HRV are heterogeneous, therefore, it is advisable to use autonomic markers as part of a multi-domain profile rather than as the sole trigger for exercise decisions (Lapo *et al.*, 2024). The relevance of including autonomic indicators in the monitoring of load/recovery cycles is supported by neurophysiological measures of central fatigue and recovery phases, which reinforce the validity of combined decisions regarding the density and alternation of means (Reichel *et al.*, 2022).

The cognitive domain is structured by the choice/inhibition reaction (CRT/Go-NoGo), simple psychomotor reaction (PVT) and response stability metrics (coefficient of variation), which reflect readiness for speed-tactical actions and stability of perceptual-motor control under the influence of fatigue (Coutts *et al.*, 2021). For boxing, the relevance of such monitoring is reinforced by empirical data on the disruption of temporal prediction under the influence of mental fatigue and the degradation of sensorimotor synchronisation, which directly reduces the quality of technical and tactical decisions in a fight (Wu *et al.*, 2025). Therefore, shifts in latency/reaction variability are interpreted as a basis for correcting intensity, local density, and simplifying tactical tasks on days when there are high demands for rapid decision-making.

The neuromuscular domain is described by the power capacity and fatigue of speed-strength work based on indicators such as height/power (CMJ), rate of force development (RFD), sprint/strike metrics and, where available, biochemical/hormonal markers reflecting the phasing of recovery after intense cycles (Reichel *et al.*, 2022). For kickboxing, systematic reviews emphasise the advisability of using complex biomarkers and functional tests precisely as a reflection of the specifics of striking-series training, which are useful triggers for the distribution of volume and intensity in power-oriented mesocycles (Kaya & Gül, 2025). In practical terms, this means that a decrease in power/increase in fatigue indicators serves as a signal to redistribute intensity, increase rest intervals, and adjust the sequence of exercises in favour of technical-tactical or recovery modules. The psycho-emotional domain represents validated short-format survey instruments (wellness, sRPE, recovery/mood indices) that demonstrate high sensitivity to cumulative load and may precede objective deviations, especially in competitive stress conditions (Coutts *et al.*, 2021). The study established that changes in emotional states are consistent with training load and determine behavioural decisions, therefore, inclusion of this component in the control loop increases the predictive potential and timeliness of corrections (Vacher *et al.*, 2023).

The typical regimen involves daily morning HRV recordings at rest (5 minutes under standardised conditions), cognitive-sensory motor tests (PVT/CRT, 2-5 min) and CMJ/speed tests, as well as session-by-session collection of subjective indicators (total sRPE, short wellness). Pre-competition windows are organised according to a -24/-12/-2-hour schedule with an emphasis on autonomous regulation and short cognitive tests; inter-round intervals can be used for "rapid removal" of heart rate and a simplified cognitive test to control response stability without interfering with the combat strategy (Coutts *et al.*, 2021). The presence of neurophysiological indicators of central fatigue/recovery further justifies the choice of these windows, which ensures the coordination of the stimulus and recovery phases.

The broadcast algorithm is based on relative normalisation (to an individual baseline) and zonal interpretation: the "green" zone maintains the planned volume/intensity; "yellow" initiates local correction (change in intensity, lengthening of pauses, redistribution of density); "red" causes rejection of peak stimuli, emphasis on recovery and tactical simplicity (Coutts *et al.*, 2021). The procedural reflection of the relationship between psychophysiological state and training dosage is based on generalised correspondences between "domain → variable → protocol/window → control action". Table 1 presents standardised domains and their operational indicators with interpretation guidelines, measurement regulations in inter-session, pre-competition and inter-round windows, as well as typical decisions on the volume, intensity, density and alternation of means with standardisation to the individual base and zone thresholds.

Table 1. Comparison of psychophysiological domains, variables and control actions

Domain	Key changes (area)	Typical protocol and window	Load decisions
Autonomous	lnRMSSD/HRV (↓ = stress)	Morning 5 min, orthostatic; daily	Intensity/density correction depending on the area
Cognitive-sensory-motor	PVT/CRT latency, CV (↑ = worse)	2-5 min, 2-3×/week; -12/-2 hours; between rounds (simplified)	Simplification of tactics, reduction in the intensity of speed series
Neuromuscular	CMJ, RFD (↓ = fatigue)	2-3 times per week; on days of key stimuli	Redistribution of intensity, prolongation of rest, change of alternation of means
Psycho-emotional	sRPE, wellness (↑ sRPE at a stable volume = accumulation of stress)	Every session/every day	Density restrictions, introduction of renewable modules

Note: ↑/↓ – relative increase/decrease in the indicator; lnRMSSD – natural logarithm of RMSSD (root mean square of successive interval differences) (for distribution normalisation); CV – coefficient of variation (response stability); RFD – rate of force development); wellness – short questionnaire indices of well-being (sleep, stress, muscle pain, etc.)

Source: compiled by the author based on analysis of A. Coutts *et al.* (2021), T. Reichel *et al.* (2022), M. Babić *et al.* (2023), C. Pruneti *et al.* (2023), P. Vacher *et al.* (2023), H. Lapo *et al.* (2024), C. Wu *et al.* (2025)

A summary of the data in Table 1 shows that daily 5-minute morning HRV recordings form a "background limit" of acceptable total stress, while two or three 2-5-minute PVT/CRT and CMJ tests per week serve as operational triggers for session correction. In the pre-start windows of -24/-12/-2 hours, readiness for peak stimuli is refined, and inter-round "quick removals" of heart rate combined with a short cognitive test provide micro-correction of tactics in real time. Dosage decisions are based on the convergence of at least two of the four domains and zonal interpretation (three zones: "green/yellow/red"): in the "yellow" zone, the redistribution of intensity and prolongation of pauses prevail; in the "red" zone, peak stimuli are abandoned and recovery modules are activated, even at an acceptable HR, if cognitive latency/variability or CMJ power show negative dynamics. The subjective sRPE, recorded at each session, is used as an early indicator of fatigue accumulation (increase at a constant volume) and initiates a decrease in density without losing the target direction. This three-level time-scale organisation (inter-session, pre-competition, inter-round) ensures consistency of decisions over time, while style-specific weighting (tempo versus strength profile) is determined by the ratio of changes in cognitive and neuromuscular indicators relative to the individual baseline.

The standardisation of domains, variables, protocols, and time windows created the functional conditions for further formalisation of the "state – load – response" model, where the convergence of at least two signals determines the control actions regarding the volume, intensity, density, and alternation of means in boxing and kickboxing. The substantive differentiation of domain roles, style-specific weighting, and multi-scale organisation of measurements ensured the practical applicability of the description for the transition to the "indicator → parameter → action" matrix and the construction of algorithms for assigning and correcting loads with controlled fatigue and recovery dynamics.

Monitoring protocols for preparatory and pre-competition microcycles and inter-round intervals

In preparatory and pre-competition microcycles, the basic set includes: BHR in the morning at rest as an indicator of autonomous regulation; short cognitive-sensory motor tests (PVT/CRT) to control latency and response stability; neuromuscular tests of explosiveness and speed fatigue (CMJ, RFD or shock-speed metrics); subjective questionnaire indicators (sRPE, short well-being scales) to record cumulative fatigue and emotional reactivity (Coutts *et al.*, 2021). Morning HRV recordings (≈5 min in a standardised position) are recorded daily to form an individual baseline; PVT/CRT (2-5 min) and CMJ/speed tests are performed 2-3 times per week on key stimulus days; sRPE and short well-being indices are collected every session to track load accumulation (Coutts *et al.*, 2021). In the pre-competition period, discrete readiness monitoring (-72/-48/-24/-12/-2 hours) is used: autonomous indicators and short cognitive tests refine tolerance to peak stimuli, while neuromuscular tests are used sparingly to avoid induced fatigue (Franchini, 2020). Inter-round intervals (≈60 s) are supplemented by "quick removal" of heart rate (HR30/HR60) and an ultra-short cognitive test (10-15 s, 6-8 stimuli), which provides micro-correction of the pace, complexity of combinations and tactical emphases of the next round (Wu *et al.*, 2025). For kickboxing (serial striking with frequent tempo changes), a slightly higher frequency of neuromuscular screening in the microcycle is considered appropriate to control speed fatigue (Babić *et al.*, 2023).

ECG recording is performed using validated optical or electrocardiographic devices with a fixed protocol for time of day, body position and breathing; artefacts are eliminated by automated filters with subsequent visual control, and interpretation is performed relative to an individual base (percentile zones, sliding medians), which increases the stability of thresholds in dynamics (Pruneti *et al.*, 2023). Given the heterogeneity of the links between HRV and psychophysiological factors, decisions are not based on the autonomic channel as the sole predictor: the principle of convergence of at least two domains (autonomic + cognitive/neuromuscular or subjective) is applied (Lapo *et al.*, 2024). Cognitive tests are conducted according to standardised instructions (time of day, duration, number of stimuli) with control of the coefficient of variation as an indicator of stability; neuromuscular tests are conducted with the same warm-ups and rest intervals; observations with protocol violations are marked as invalid. Short questionnaires (sRPE, recovery indices) are mandatory, as in several scenarios, subjective data precede objective deviations and signal the accumulation of stress. The distribution of volume, intensity, and alternation of means in microcycles is consistent with the principles of structured load planning in boxing. When high-intensity interval training is required in pre-start modules, the dosage is correlated with autonomic and cognitive signals, which minimises the risk of excessive fatigue (Table 2).

Table 2. Calendar and monitoring windows in the microcycle

Indicator	Preparatory microcycle	Pre-competition period	Between rounds
HRV (lnRMSSD)	Daily, morning, 5 minutes	-72/-48/-24/-12/-2 hour	-
PVT/CRT	2-3×/week (2-5 min)	-24/-12/-2 hours (short)	10-15 s (6-8 stimuli)
CMJ / speed tests	2×/week; on stimulus day	1× light screening	-
sRPE / well-being	Each session	Each session	-
"Rapid reduction" of HR (30/60)	-	-	Each break (≈60 s)

Note: "-" stated that the indicator was not applied in the corresponding window or was not provided for by the protocol
Source: compiled by the author based on analysis of A. Coutts *et al.* (2021), T. Reichel *et al.* (2022), M. Babić *et al.* (2023), C. Pruneti *et al.* (2023), P. Vacher *et al.* (2023), H. Lapo *et al.* (2024), C. Wu *et al.* (2025)

The combination of daily 5-minute morning HRV recordings and 2-3 times a week short cognitive (PVT/CRT, 2-5 min) and neuromuscular (CMJ/speed) tests provides a combination of high temporal resolution of background control with operational sensitivity to training stimuli. Before the start, discrete points -72/-48/-24/-12/-2 hours can be used to sequentially refine readiness without inducing fatigue, and each 60-second break between rounds with "quick removals" of HR (30/60) and an ultra-short 10-15-second cognitive test serves as a means for instant micro-correction of the pace and complexity of combinations. The calendar reduces the risk of false positive decisions: local fluctuations in one domain are confirmed or refuted by data from another (for example, increased sRPE at a constant volume initiates a decrease in density, even with acceptable autonomous indicators), while a drop in CMJ twice a week on stimulus days signals the need to redistribute intensity and extend rest without losing the target focus of the session. The "-" marks in the inter-round column for HRV and CMJ emphasise the methodological unsuitability of these procedures in minute breaks and preserve the ecological validity of the protocol.

Thus, the analysis showed that the key elements of monitoring in boxing and kickboxing are daily recordings of HRV, regular cognitive-sensory-motor and neuromuscular tests 2-3 times a week, as well as pre-session questionnaire indicators. Additional checkpoints are used in the pre-competition period, while inter-round intervals are used for quick heart rate measurements and short cognitive tests. Collectively, these approaches provide multi-scale monitoring and reduce the risk of misjudgments by integrating subjective and objective data.

Closed-loop model "state – load – response" and translation matrix "indicator → parameter → action"

The closed control loop is summarised as a typical load management concept, in which the psychophysiological state acts as an input signal, the training load as a control action, and the body's response as an output parameter. Information flows function in a cyclical logic: from measurements of state (autonomic, cognitive, neuromuscular, emotional) to decisions about correction of volume, intensity, density, or alternation of means, after which the result obtained is interpreted as a new input signal. This architecture integrates different data channels into a single control loop and reduces the risk of misinterpreting individual fluctuations.

The generalised unit of this approach is a translation matrix in which psychophysiological indicators are correlated with specific decisions regarding workload. For example, a decrease in HRV below the individual 20th percentile serves as a signal to limit intensity; a deterioration in the cognitive stability of reactions is identified as a reason to simplify tactical tasks; a decrease in power in jump tests indicates the need to extend rest periods and change the sequence of exercises; an increase in subjective load at a constant volume is interpreted as an indicator of the need for recovery modules. Thus, the translation matrix summarises four blocks of variables (autonomic, cognitive, neuromuscular, subjective) and four key parameters of training load, forming a system of "indicator → parameter → action". The generalised correspondences between these variables are shown in Table 3.

Analysis of the data presented in the table shows that consistency between different indicator domains can be used to structure decision-making regarding training load. A decrease in HRV below individual thresholds, combined with a decline in cognitive stability, is interpreted as a sign of high stress and a reason to reduce intensity and simplify tactical tasks. Neuromuscular indicators, in particular a decrease in power in jump tests or the RFD, are interpreted in various sources as a marker of fatigue, requiring a redistribution of density or the insertion of recovery modules. Subjective indicators (sRPE, well-being indices) serve as an early signal of accumulated load: even with stable autonomous parameters, they indicate the need to adjust the volume or density. Together, this matrix reflects the logic repeated in several works: the decision is not based on an isolated indicator but requires confirmation from at least two domains. Feedback is determined by the following criteria: stable recovery of autonomous, cognitive and neuromuscular indicators to individual average values (positive feedback) or their progressive deviation towards deterioration (negative feedback). In the case of negative feedback, not only a reduction in volume and intensity is expected but also changes in the structure of the microcycle (for example, replacing sparring days with technical and tactical days).

Table 3. Translation matrix "indicator → parameter → action"

Indicator	Parameter	Guidance action
HRV <20th percentile	Intensity	Reduction in intensity, longer rest intervals
↑ latency / ↓ stability in PVT/CRT	Tactical tasks	Simplification of combinations, reduction in tempo

Table 3, Continued

Indicator	Parameter	Guidance action
↓ CMJ power/RFD	Density/alteration	Load transfer, inclusion of recovery modules
↑ sRPE at a stable volume	Volume / density	Local reduction in volume or density, introduction of active restoration
Positive response (increased BSR, stable cognitive and neuromuscular indicators)	All parameters	Maintenance or gradual increase in the load

Note: ↑/↓ – relative increase/decrease in the indicator
Source: compiled by the author based on analysis of A. Coutts *et al.* (2021), T. Reichel *et al.* (2022), M. Babić *et al.* (2023), C. Pruneti *et al.* (2023), P. Vacher *et al.* (2023), H. Lapo *et al.* (2024), C. Wu *et al.* (2025)

The logic of the model is illustrated by scenarios that reflect typical challenges in combat disciplines. Under conditions of weight reduction, autonomous and cognitive indicators are central: significant deviations in HRV or reaction latency are identified as grounds for reducing the intensity and adjusting nutritional recovery modules. In microcycles with high sparring exposure, the emphasis is on neuromuscular signals: a decrease in CMJ power or strength development speed is interpreted as a marker of the need to redistribute loads and insert recovery days. In pre-competition blocks, the convergence of positive signals from two or more domains is interpreted as confirmation of readiness for peak stimuli, while negative trends are considered as a basis for minimising the risk of overtraining.

Thus, the closed-loop model of "state – load – response" and the translation matrix of "indicator → parameter → action" serve as a conceptual framework for integrating autonomous, cognitive, neuromuscular, and subjective signals into decisions about the volume, intensity, density, and alternation of means. The combination of feedback criteria with typified scenarios is defined as a theoretical mechanism for minimising the risk of overtraining and maintaining the athlete's target readiness for peak stimuli in boxing and kickboxing.

Practical algorithms for load correction in boxing and kickboxing

Training parameters in boxing and kickboxing are standardised based on the principle of relative deviations of psychophysiological indicators from the individual baseline. For this purpose, a three-level scale of zonal interpretation is used: "green", "yellow" and "red". The scale is based on deviations of 10-20% from personal control values, which can be used to address interindividual differences while maintaining a unified approach. Each zone corresponds to specific management actions regarding volume, intensity, density, alternation of means, and inclusion of recovery procedures. Generalised algorithms for management actions are presented in the form of zonal logic, where each level of deviation of psychophysiological indicators corresponds to specific decisions regarding training load parameters (Table 4).

Table 4. Zonal logic of training load parameter correction

Zone	Volume	Intensity	Density	Alteration of means	Restoration
Green	Scheduled	Scheduled	Scheduled	Maintenance of structure	Basic (sleep, nutrition)
Yellow	-10-15%	-10-15%	Prolongation of delays by 30-60 s	Slight simplification of tactics	Massage, breathing techniques, active recovery
Red	-20-30%	Elimination of peak stimuli	Significant spacing, extended pauses	Exclusion of sparring, emphasis on technical and tactical modules	Recovery days, sleep ≥9 hours, physiotherapy

Note: "-" denoted a decrease relative to planned values
Source: compiled by the author based on analysis of A. Coutts *et al.* (2021), T. Reichel *et al.* (2022), M. Babić *et al.* (2023), C. Pruneti *et al.* (2023), P. Vacher *et al.* (2023), H. Lapo *et al.* (2024), C. Wu *et al.* (2025)

Analysis of the table data shows that the gradation of zonal logic provides for step-by-step regulation of the load depending on the depth of deviations in psychophysiological indicators. In the "green" zone, the full training plan is maintained, corresponding to the state of optimal readiness. The "yellow" zone reflects the accumulation of stress and requires a 10-15% reduction in intensity and density with longer breaks, which prevents adaptation breakdown. The most critical is the "red" level, where deviations exceed 20% and require a radical redistribution: a 20-30% reduction in volume, elimination of peak stimuli, and a transition to recovery modules. Subjective signals (sRPE, well-being) are substantial, often preceding objective changes and acting as an early trigger for correction. This structure prevents decisions based on a single indicator, as confirmation from at least two domains reduces the risk of missteps.

Style-specific recommendations detail the application of zonal logic depending on the conduct of combat. For a power style characterised by short explosive exchanges, neuromuscular indicators (CMJ, RFD) are critical. In the "yellow" zone, lengthening pauses and reduction of the frequency of explosive series are prioritised, while in the "red" zone, the emphasis is shifted to technical modules with the complete exclusion of power stimuli. For the tempo style, which involves a long series of strikes and high cognitive stability, in the "yellow" zone, the speed component is limited, and combinations are simplified; in the "red" zone, the total number of series is reduced, and recovery blocks are inserted to maintain cognitive control. The implementation roadmap defines the sequence of steps for the transition from algorithm development to its practical application (Fig. 1).

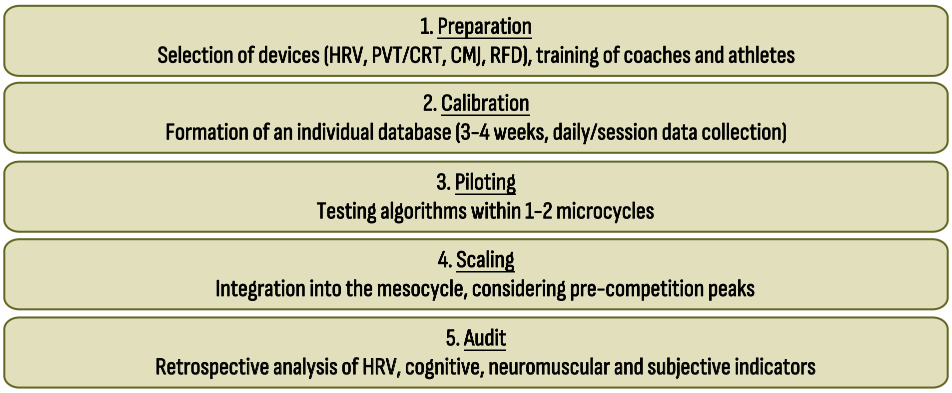

Figure 1. Roadmap for the implementation of zone-based logic for monitoring and adjusting training loads in boxing and kickboxing

Source: compiled by the author based on analysis of A. Coutts *et al.* (2021), T. Reichel *et al.* (2022), M. Babić *et al.* (2023), C. Pruneti *et al.* (2023), P. Vacher *et al.* (2023), H. Lapo *et al.* (2024), C. Wu *et al.* (2025)

Analysis of the roadmap data shows that the sequence of five stages can negate key methodological errors and ensures a gradual increase in the validity of the decision-making system. The initial stage of preparation, with an emphasis on device selection and training, creates the technical and methodological foundation without which the subsequent steps would not be reliable. Calibration over 3-4 weeks ensures the formation of an individual base, which minimises the risk of false alarms and stabilises the thresholds for zonal interpretation. Piloting on microcycles acts as an intermediate filter: this is where the logic of signals and the realism of control actions are tested on a controlled scale. Scaling at the mesocycle level is justified only after such testing, which can be used to maintain competitive readiness without overload. The final audit, based on a retrospective analysis of HRV, cognitive, neuromuscular and subjective data, guarantees not only the correction of algorithms, but also the accumulation of practical experience. This structure emphasises the combination of scientific and methodological logic with applied adaptability, making the roadmap suitable for use in different styles and phases of training. Thus, the proposed zonal system with action algorithms and a roadmap for implementation is considered a theoretically sound basis for further practical implementation. Its structure potentially ensures a balance between volume, intensity, density and recovery, as well as incorporating the style of combat and the individual characteristics of the athlete.

Discussion

The results obtained showed that psychophysiological indicators can serve as control variables in the training load regulation system. The proposed monitoring protocols and the "indicator → parameter → action" translation matrix ensured the formalisation of decision-making in preparatory, pre-competition and inter-round conditions. Zonal logic and a roadmap for implementation outlined the practical potential for individualising training in boxing and kickboxing. These provisions provided a basis for comparison with existing approaches and assessment of the prospects for their application in modern sports practice.

The results of the analysis showed that HRV, in particular the lnRMSSD indicator, served as a basic indicator of background adaptation in athletes. In several studies, a decrease in values below the individual 20th percentile was interpreted as a reason to reduce the intensity of training loads and extend rest intervals. This interpretation was consistent with the results of G. Korobeynikov *et al.* (2022), where HRV in wrestlers served as a marker of tolerance to stress stimuli and was used to regulate the load. In a study by Ľ. Benedik & K. Görner (2020) among karate practitioners, the stability of autonomic indicators also determined the level of readiness for intensive training, confirming the universality of this criterion for combat disciplines. At the same time, N. Malikov *et al.* (2021) expanded the use of HRV by combining it with comprehensive functional fitness tests and highlighted that the autonomic profile did not always fully reflect the physical condition of the athlete, requiring integration with other markers. Furthermore, I. Yoda *et al.* (2024) emphasised the relevance of combining HRV with recovery strategies, as the isolated use of autonomic indicators did not guarantee the reliability of the prediction. At the same time, S. Russell *et al.* (2024) highlighted the limitations of using HRV as the sole predictor of mental fatigue in elite sports, noting the need for additional monitoring of psychological markers.

The analysed materials indicated that monitoring cognitive-sensory-motor functions using PVT and CRT was key to regulating training tasks: increased latency and decreased reaction stability were interpreted as grounds for tactical adjustments. To this end, short tests (2-5 minutes, 2-3 times a week), discrete checks in the pre-competition period (-72/-48/-24/-12/-2 hours) and ultra-short inter-round tests (10-15 seconds, 6-8 stimuli) were used. A similar approach was confirmed by the results of Y. Shestak *et al.* (2020), where the cognitive indicators of young boxers (15-16 years old) showed sensitivity to the effects of special exercises, and deviations in reaction latency served as a criterion for adaptive reserve. Similar conclusions were drawn by A. Tuxtaevich (2023), emphasising that the accumulation of fatigue was reflected primarily in cognitive markers, even with stable physiological parameters. According to A. Thompson *et al.* (2023), the combination of cognitive tests with the assessment of muscle readiness provided a comprehensive explanation of the tactical stability of athletes in stressful conditions, which was consistent with the logic of integrated control. D. Crivelli & M. Balconi (2022) noted that neuroassessment of cognitive stability in sport improved accuracy of prediction of readiness for peak loads than isolated somatic indicators. At the same time, S. Stephen *et al*. (2020) demonstrated that style specificity (aggressive vs. technical fighting) significantly modified cognitive profiles, which partially limited the universality of standard protocols. Thus, digitally structured control regimes (2-5 minute tests several times a week, discrete checks in the hours before competition, and ultra-short inter-round tests) were consistent with previous observations about the sensitivity of cognitive indicators to load and, at the same time, highlighted the need to address style and age specificity to improve the accuracy of their interpretation.

In the analysed materials, neuromuscular indicators, in particular the height and power of the jump with a preliminary squat and the speed of strength development, were considered reliable markers of accumulated fatigue. A decrease in these indicators on the days of key training stimuli, especially more than 10-15% from the individual baseline, was interpreted as a signal to redistribute intensity, lengthen pauses between sets, and shift the focus to technical and tactical tasks. This stratification was consistent with the data of V. Kozin *et al*. (2021), where cluster analysis of psychophysiological and biomechanical indicators differentiated between the fighting styles of veteran boxers. The study by A. Yongtawee *et al*. (2022) also confirmed that leading cognitive functions differed depending on the sport, and therefore on the athlete's style of work, which coincided with the interpretation of the cognitive domain as critical in tempo styles. In the study by N. Neumann *et al*. (2025), network analysis demonstrated the interdependence of psychological and physiological determinants of performance, reflecting the multidimensional nature of style-specific adaptations. Additionally, J. Chmiel & J. Nadobnik (2025) demonstrated the potential of electroencephalographic metrics in identifying differences in the neurocognitive readiness of athletes in different combat disciplines, which was consistent with the emphasis on cognitive indicators in tempo styles. At the same time, the results of M. Bertollo *et al*. (2021) emphasised the role of body-mind integration in sport, indicating that styles cannot be explained solely by individual markers; a comprehensive combination of cognitive and physiological signals is required. The comparison confirmed that the style-specific approach to interpreting indicators was justified and consistent with the idea of the multidimensional nature of combat profiles.

As a result of the analysis, an implementation roadmap was proposed, which included five stages: preparation, calibration, piloting, scaling, and auditing. This sequence can create an individual database within 3-4 weeks, testing of algorithms within 1-2 microcycles, and further integration of the system into mesocycles with subsequent analysis of the stability of key indicators (HRV, cognitive latency, CMJ, sRPE). This approach ensured the structure and controllability of the process, which was substantial for combat disciplines with high load dynamics. Similar principles of research process organisation were traced in a study by V. Potop *et al*. (2023), which emphasised the significance of a set methodological sequence and proceduralisation to improve the reproducibility of results. S. Horokhov & S. Yaremenko (2024) also emphasised the need for consistency in the professional training of athletes, which corresponded to the idea of step-by-step implementation of monitoring protocols. Parallels were also observed in the study by R. Braun-Trocchio *et al*. (2022), which emphasised the gradual introduction of recovery strategies into the training process, reflecting the logic of multi-level auditing. The adaptability of the roadmap to different disciplines was consistent with the findings of A. Enes *et al*. (2023) demonstrated that psychophysiological responses and muscle adaptations were largely dependent on the organisation of the process and the gradual increase in stimuli. These comparisons confirmed the validity of the developed roadmap as a systematic approach consistent with current trends in sports science.

A summary of the materials showed that the most effective approach to load management was a convergent combination of psychophysiological indicators of different natures. Autonomic indicators (HRV), cognitive tests (latency and reaction stability), neuromuscular characteristics (CMJ, RFD) and subjective questionnaire data performed a complementary function: each individually could demonstrate a high level of variability or be sensitive to contextual factors, but their combination formed a more reliable picture of the athlete's condition. This logic was consistent with the data of N. Jai *et al*. (2020), emphasising that psychophysiological responses during exercise in boxers correlated with heart rate dynamics and reflected cognitive load, but that several channels needed to be integrated simultaneously to increase reliability. Similar conclusions were made by N. Limani & B. Bulica (2024), emphasising that modern combat disciplines were characterised by complex interactions between cognitive and physiological mechanisms; therefore, a separate analysis provided an incomplete overview. In turn, A. Zadeh *et al*. (2021) showed that wearable sensors and data analysis technologies made it possible to identify the risks of injury and fatigue much earlier when both physiological and psychophysiological markers were addressed, in particular, indicators of cardiovascular adaptation and cognitive functions.

The summary of the results showed that the integration of psychophysiological indicators into the decision-making system provided a structured basis for regulating the volume, intensity, density, and recovery in combat disciplines. The use of HRV thresholds, cognitive tests, neuromuscular indicators, and subjective scales can be used for the timely identification of overload risks and adjustment of the training process. Comparison with other studies confirmed the feasibility of a multi-domain approach, while the emphasis on style-specific characteristics (power or tempo profile) broadened the practical relevance of the findings. Thus, the formulated model has the potential to increase the specificity of training and minimise the risk of overtraining in boxing and kickboxing.

Conclusions

Analysis of psychophysiological indicators demonstrated their effectiveness for managing training loads in boxing and kickboxing. HRV (lnRMSSD, 5-minute morning recordings) was a key marker of background adaptation: its decrease below the individual 20th percentile indicated overload and required correction of the intensity and density of loads. Cognitive tests (PVT/CRT) lasting 2-5 minutes, performed 2-3 times a week, reflected the latency and stability of reactions, and their deterioration was considered a reason to simplify tactical tasks. Neuromuscular indicators (CMJ, RFD) signalled speed-strength fatigue and the need for longer rest periods, while subjective assessments (sRPE, short questionnaires) often preceded objective changes, demonstrating the accumulation of stress. Daily HRV recordings, regular cognitive and neuromuscular tests 2-3 times a week, and subjective indicators at each session proved to be optimal for preparatory microcycles. In the pre-competition period, effectiveness was ensured by discrete control at time points -72/-48/-24/-12/-2 hours, which can be used for timely refinement of tolerance to peak stimuli without inducing fatigue. Inter-round intervals (≈60 s) were supplemented by "quick removal" of HR30/HR60 and ultra-short cognitive tests (10-15 s, 6-8 stimuli), which ensured prompt correction of pace and tactical emphasis. The convergence of signals from at least two domains minimised the risk of wrong decisions and increased the specificity of load regulation.

The matrix "indicator → parameter → action" coordinated decisions: HRV <20th percentile predicted a decrease in intensity; increased latency of reactions in PVT/CRT – simplification of tactics; a drop in CMJ/RFD – redistribution of density; an increase in sRPE with a constant volume of recovery modules. A positive response was a return to individual baseline indicators, while a negative response was a progressive deterioration requiring structural adjustments in the microcycle. This model integrated autonomous, cognitive, neuromuscular, and subjective signals into a single decision-making loop. The zonal system provided a practical interpretation: the "green zone" meant maintaining the plan; the "yellow" zone meant reducing the intensity by 10-15% and extending the rest period by 30-60 seconds; the "red" zone required a 20-30% reduction in volume and the exclusion of peak stimuli. For the power style, the priority was to control power and speed of strength development, while for the tempo style, the priority was reaction stability and speed endurance. The implementation roadmap included five stages: preparation, calibration, piloting, scaling, and auditing, which ensured the systematicity and controllability of the process. As a result, this approach balanced the volume, intensity, density, and recovery, reducing the risk of overtraining and increasing the specificity of training in boxing and kickboxing. The limitation of the study was that the analysis was based solely on theoretical and methodological sources without empirical verification of the models. In future studies, it would be advisable to test the proposed protocols and algorithms in real training and competition conditions to assess their effectiveness and validity.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Ambroży, T., Rydzik, Ł., Obmiński, Z., Klimek, A.T., Serafin, N., Litwiniuk, A., Czaja, R., & Czarny, W. (2021). The impact of reduced training activity of elite kickboxers on physical fitness, body build, and performance during competitions. *International Journal of Environmental Research and Public Health*, 18(8), article number 4342. doi: 10.3390/ijerph18084342.

[2] Babić, M., Pobrić, I., & Čular, D. (2023). Physiological response and biomarkers in kickboxing – systematic review. *Physical Activity Review*, 11(2), 120-137. doi: 10.16926/par.2023.11.27.

[3] Benedik, Ľ., & Görner, K. (2020). Psycho-physiological aspects in karate sports preparation. *Sport i Turystyka*, 3(2), 79-90. doi: 10.16926/sit.2020.03.14.

[4] Bertollo, M., Berchicci, M., & Di Fronso, S. (2021). Mind-body interaction in sport psychophysiology. In E. Filho & I. Basevitch (Eds.), *Sport, exercise and performance psychology: Research directions to advance the field* (pp. 118-132). Oxford: Oxford University Press. doi: 10.1093/oso/9780197512494.003.0009.

[5] Braun-Trocchio, R., Graybeal, A.J., Kreutzer, A., Warfield, E., Renteria, J., Harrison, K., Williams, A., Moss, K., & Shah, M. (2022). Recovery strategies in endurance athletes. *Journal of Functional Morphology and Kinesiology*, 7(1), article number 22. doi: 10.3390/jfmk7010022.

[6] Chmiel, J., & Nadobnik, J. (2025). Application of electroencephalography (EEG) in combat sports – review of findings, perspectives, and limitations. *Journal of Clinical Medicine*, 14(12), article number 4113. doi: 10.3390/jcm14124113.

[7] Coutts, A.J., Crowcroft, S., & Kempton, T. (2021). Developing athlete monitoring systems: Theoretical basis and practical applications. In M. Kellmann & J. Beckmann (Eds.), *Recovery and well-being in sport and exercise* (pp. 17-31). London: Routledge. doi: 10.4324/9781003258117.

[8] Crivelli, D., & Balconi, M. (2022). Neuroassessment in sports: An integrative approach for performance and potential evaluation in athletes. *Frontiers in Psychology*, 13, article number 747852. doi: 10.3389/fpsyg.2022.747852.

[9] Enes, A., Leonel, D.F., Oneda, G., Alves, R.C., Zandoná-Schmidt, B.A., Ferreira, L.H., Prestes, J., McAnulty, S.R., & Souza-Junior, T.P. (2023). Muscular adaptations and psychophysiological responses in resistance training systems. *Research Quarterly for Exercise and Sport*, 94(4), 982-989. doi: 10.1080/02701367.2022.2096843.

[10] Franchini, E. (2020). High-intensity interval training prescription for combat-sport athletes. *International Journal of Sports Physiology and Performance*, 15(6), 767-776. doi: 10.1123/ijspp.2020-0289.

[11] Hernandez-Martinez, J., Cid-Calfucura, I., Valdés-Badilla, P., Franchini, E., García-García, J. M., & Herrera-Valenzuela, T. (2024). Acute and chronic effects of muscle strength training on physical fitness in boxers: A scoping review. *Applied Sciences*, 14(21), article number 9706. doi: 10.3390/app14219706.

[12] Horokhov, S., & Yaremenko, S. (2024). Methodological approaches in professional training of future specialists in physical culture and sports. *Pedagogical Sciences*, 27(1), 96-102. doi: 10.33989/2524-2474.2024.1.308746.

[13] Jai, N.A., Rosly, M.M., & Abd Razak, N.A. (2020). Correlating psychophysiological responses of exergaming boxing for predictive heart rate regression models in young adults. *IEEE Transactions on Games*, 12(4), 398-405. doi: 10.1109/TG.2020.3039838.

[14] Kaya, O., & Gül, G. (2025). The effect of 8-week fast strength training on mixed martial athletes and boxers. *European Journal of Physical Education and Sport Science*, 12(3), 114-125. doi: 10.46827/ejpe.v12i3.5880.

[15] Kirk, C., Langan-Evans, C., Clark, D.R., & Morton, J.P. (2021). Quantification of training load distribution in mixed martial arts athletes: A lack of periodisation and load management. *PLoS One*, 16(5), article number e0251266. doi: 10.1371/journal.pone.0251266.

[16] Korobeinikova, I., Kokun, O., Raab, M., Korobeinikova, L., Korobeynikov, G., Kostiuchenko, V., Akustin, V., & Dekha, N. (2024). Psychophysiological states of elite athletes after critical life events. *Pedagogy of Physical Culture and Sports*, 28(2), 141-146. doi: 10.15561/26649837.2024.0208.

[17] Korobeynikov, G., Korobeinikova, L., Raab, M., Korobeinikova, I., Danko, T., Kokhanevich, A., Cynarski, W., & Mytskan, T. (2022). Psychophysiological state and decision making in wrestlers. *Ido Movement for Culture*, 22(5). doi: 10.14589/ido.22.5.2.

[18] Kozin, V., Omelchenko, M., Turchyk, I., & Yesman, I. (2022). Biomechanical and psychophysiological features of qualified veteran boxers of various fighting styles. *Health, Sport, Rehabilitation*, 8(1), 8-27. doi: 10.34142/HSR.2022.08.01.01.

[19] Kozin, V.Y., Falova, O.Y., Cretu, M., & Cieślicka, M. (2021). Determination of fighting styles of qualified veteran boxers based on cluster analysis of biomechanical and psychophysiological indicators. *Health, Sport, Rehabilitation*, 7(4), 19-34. doi: 10.34142/HSR.2021.07.04.02.

[20] Lapo, H.M., Chacon-Mikahil, M.P., & Sardeli, A.V. (2024). Psychophysiological factors are not directly associated to heart rate variability in athletes: A meta-analysis. *Journal of Mental Health*, 8(3), 7-16. doi: 10.29245/2578-2959/2024/3.1323.

[21] Limani, N., & Bulica, B. (2024). Insights into contemporary dynamics of combat sports: A holistic analysis. *International Journal of Sport Sciences and Health*, 11(23-24), 61-71. doi: 10.62792/ut.sport.v11.i23-24.p2541.

[22] Malikov, N., Tyshchenko, V., Bogdanovska, N., Savchenko, V., Moskalenko, N., Ivanenko, S., Vaniuk, D., Orlov, A., & Popov, S. (2021). Functional fitness assessment of elite athletes. *Journal of Physical Education and Sport*, 21(1), 374-380. doi: 10.7752/jpes.2021.01036.

[23] McCabe, D., Martin, D., & McMahon, G. (2023). Training load is correlated with changes in creatine kinase and wellness over a 12-week multi-stage preparatory training block for a major competition in international boxers. *Physiologia*, 3(4), 585-597. doi: 10.3390/physiologia3040043.

[24] Montull, L., Slapšinskaitė-Dackevičienė, A., Kiely, J., Hristovski, R., & Balagué, N. (2022). Integrative proposals of sports monitoring: Subjective outperforms objective monitoring. *Sports Medicine-Open*, 8(1), article number 41. doi: 10.1186/s40798-022-00432-z.

[25] Mosley, E., & Laborde, S. (2024). A scoping review of heart rate variability in sport and exercise psychology. *International Review of Sport and Exercise Psychology*, 17(2), 773-847. doi: 10.1080/1750984X.2022.2092884.

[26] Myroshnychenko, Y., Tropin, Y., & Kovalenko, J. (2020). Model characteristics of psychophysiological indicators of qualified kickboxers. *Slobozhanskyi Herald of Science and Sport*, 8(5), 34-44.

[27] Neumann, N.D., Van Yperen, N.W., Arens, C.R., Brauers, J.J., Lemmink, K.A., Emerencia, A.C., Meerhoff, L.A., Frencken, W., Brink, M., & Den Hartigh, R.J. (2025). How do psychological and physiological performance determinants interact within individual athletes? An analytical network approach. *International Journal of Sport and Exercise Psychology,* 23(4), 672-693. doi: 10.1080/1612197X.2024.2344108.

[28] Pavelka, R., Třebický, V., Třebická Fialová, J., Zdobinský, A., Coufalová, K., Havlíček, J., & Tufano, J.J. (2020). Acute fatigue affects reaction times and reaction consistency in mixed martial arts fighters. *PloS One*, 15(1), article number e0227675. doi: 10.1371/journal.pone.0227675.

[29] Pérez, L.R. (2019). The interconnection of the loads in the planning of the training, in the sport of boxing. *Podium: Revista de Ciencia y Tecnología en la Cultura Física*, 14(2), 181-203.

[30] Podrigalo, L., Romanenko, V., Podrihalo, O., Iermakov, S., Huba, A., Perevoznyk, V., & Podavalenko, O. (2023). Comparative analysis of psychophysiological features of taekwondo athletes of different age groups. *Pedagogy of Physical Culture and Sports*, 27(1), 38-44. doi: 10.15561/26649837.2023.0105.

[31] Potop, V., Ciorbă, C., Mihaila, I., Mihai, I., Mihailescu, L.E., & Acsinte, A. (2023). Carrying out the methodological approach of the scientific research in the physical education and sport science field. *Physical Education of Students*, 27(4), 201-211. doi: 10.15561/20755279.2023.0407.

[32] Pruneti, C., Ferrari, S., & Guidotti, S. (2023). A narrative review of heart rate variability as a good index of psychophysical health in athletes and in biofeedback training. *Journal of Clinical Sport Psychology*, 18(4), 422-449. doi: 10.1123/jcsp.2022-0016.

[33] Reichel, T., *et al.* (2022). Neurophysiological markers for monitoring exercise and recovery cycles in endurance sports. *Journal of Sports Science & Medicine*, 21(3), 446-457. doi: 10.52082/jssm.2022.446.

[34] Russell, S., Johnston, R.D., Stanimirovic, R., & Halson, S.L. (2024). Global practitioner assessment and management of mental fatigue and mental recovery in high-performance sport: A need for evidence-based best-practice guidelines. *Scandinavian Journal of Medicine & Science in Sports*, 34(1), article number e14491. doi: 10.1111/sms.14491.

[35] Rydzik, Ł., Obmiński, Z., Wąsacz, W., Kopańska, M., Kubacki, R., Bagińska, M., Tota, L., Ambrozy, T., Witkowski, K., & Pałka, T. (2024). The effect of physical exercise during competitions and in simulated conditions on hormonal-neurophysiological relationships in kickboxers. *Biology of Sport*, 41(3), 61-68. doi: 10.5114/biolsport.2024.133662.
[36] Shestak, Y., Mulyk, V., & Okun, D. (2020). Influence of the use of special exercises on the psychophysiological indicators of young boxers aged 15-16 years old. *Slobozhanskyi Herald of Science and Sport*, 8(6), 85-94.
[37] Slimani, M., Miarka, B., Azevedo Teixeira, R.P., Znazen, H., Tod, D., Nikolaidis, P.T., & Bragazzi, N.L. (2022). Effect of acute boxing training session on cognitive function and psychological states. *Medicina Dello Sport*, 75(3), 404-412. doi: 10.23736/S0025-7826.22.04166-7.
[38] Stephen, S.J., Shan, G., Banks, S.J., Bernick, C., & Bennett, L.L. (2020). The relationship between fighting style, cognition, and regional brain volume in professional combatants: A preliminary examination using brief neurocognitive measures. *Journal of Head Trauma Rehabilitation*, 35(3), 280-287. doi: 10.1097/HTR.0000000000000540.
[39] Thompson, A.G., Ramadan, J.H., Alexander, J.S., & Galster, S.M. (2023). Psychophysiology, cognitive function, and musculoskeletal status holistically explain tactical performance readiness and resilience. *Journal of Strength & Conditioning Research*, 37(12), 2443-2456. doi: 10.1519/JSC.0000000000004580.
[40] Tuxtaevich, A.T. (2023). Features of fatigue and recovery of athletes. *American Journal of Biomedical Science & Pharmaceutical Innovation*, 3(12), 42-47. doi: 10.37547/ajbspi/Volume03Issue12-08.
[41] Vacher, P., Martinent, G., & Nicolas, M. (2023). From training load to emotional states: A combined transactional and biopsychological approach. *International Journal of Stress Management*, 30(1), 38-46. doi: 10.1037/str0000201.
[42] West, S.W., Clubb, J., Torres-Ronda, L., Howells, D., Leng, E., Vescovi, J.D., Carmody, S., Posthumus, M., Dalen-Lorentsen, T., & Windt, J. (2021). More than a metric: How training load is used in elite sport for athlete management. *International Journal of Sports Medicine*, 42(4), 300-306. doi: 10.1055/a-1268-8791.
[43] Wu, C.H., Yang, Y., Xu, X., Wang, N., Li, Q., Geng, L., & Bao, S.J. (2025). Mental fatigue impairs temporal perceptual prediction: A study on boxing performance across skill levels. *Sports*, 13(5), article number 154. doi: 10.3390/sports13050154.
[44] Yoda, I.K., Tisna, G.D., Suwiwa, I.G., Kusuma, K.C., & Junior, N.K. (2024). Recovery methods to reduce fatigue among athletes: A systematic review and future directions. *Journal Sport Area*, 9(2), 217-234. doi: 10.25299/sportarea.2024.vol9(2).16928.
[45] Yongtawee, A., Park, J., Kim, Y., & Woo, M. (2022). Athletes have different dominant cognitive functions depending on type of sport. *International Journal of Sport and Exercise Psychology*, 20(1). doi: 10.1080/1612197X.2021.1956570.
[46] Zadeh, A., Taylor, D., Bertsos, M., Tillman, T., Nosoudi, N., & Bruce, S. (2021). Predicting sports injuries with wearable technology and data analysis. *Information Systems Frontiers*, 23(4), 1023-1037. doi: 10.1007/s10796-020-10018-3.

Науково-методичні підходи до оптимізації тренувального навантаження з урахуванням психофізіологічного стану спортсменів (на прикладі боксу та кікбоксингу)

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Анотація. Метою дослідження було сформувати науково-методичні підходи до оптимізації тренувального навантаження з урахуванням психофізіологічного стану спортсменів на прикладі боксу та кікбоксингу. Методологія ґрунтувалася на аналізі, що дозволив виокремити психофізіологічні індикатори, синтези, за допомогою якого була побудована модель замкненого контуру «стан – навантаження – відгук», порівнянні, що забезпечило зіставлення стилів і протоколів, узагальненні, яке визначило принципи індивідуалізації, індукції, що виявила типові порогові рішення, та дедукції, яка перевірила їхню логічну узгодженість у тренувальних сценаріях. На цій основі були сформовані практичні рекомендації щодо зональної логіки корекції навантаження та дорожньої карти впровадження у підготовці боксерів і кікбоксерів. У результатах дослідження було встановлено, що варіабельність серцевого ритму нижче індивідуального 20-го перцентиля розцінювалася як сигнал для зменшення інтенсивності тренувань і подовження інтервалів відпочинку. Аналіз показав, що оптимальна організація моніторингу включала щоденні ранкові записи тривалістю близько 5 хвилин; когнітивні проби простої та вибіркової реакції (2-5 хв) виконувалися 2-3 рази на тиждень; нейром’язові тести проводилися 2 рази на тиждень у дні ключових стимулів. У перед змагальний період ефективним виявився дискретний контроль готовності у часових точках -72, -48, -24, -12 та -2 години до старту. Додатково встановлено, що між раундові інтервали (60 секунд) були доцільними для «швидкого зняття» частоти серцевих скорочень (30/60 секунд) і ультракоротких когнітивних проб тривалістю 10-15 секунд із 6-8 стимулами. Сукупність цих процедур забезпечувала багаторівневий контроль стану спортсменів і давала змогу своєчасно коригувати параметри навантаження. Отримані результати узагальнили та структуровано представили систему моніторингу й корекції тренувального навантаження у боксі та кікбоксингу, що включала кількісні пороги, протоколи вимірювань і алгоритми дій. Запропонована система може бути використана тренерами, спортивними науковцями та фахівцями з підготовки для оптимізації навантажень, профілактики перевтоми та підвищення ефективності тренувального процесу

Ключові слова: варіабельність серцевого ритму; латентність; адаптація; нейром’язова готовність; відновлення; зональна інтерпретація; когнітивно-сенсомоторні проби