Bioadaptive Strategies in Programming the Training Load of High-Performance Wrestlers

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Received: 2024-09-15
Accepted: 2024-10-19
DOI: https://doi.org/10.5281/zenodo.15346207

Annotation. This article presents a comprehensive study of the theoretical and applied foundations of the bioadaptive approach to programming training loads for elite freestyle wrestlers. The relevance of the topic lies in the growing need to enhance the efficiency of training processes under conditions of high individual variability in adaptation responses, the intensification of competitive schedules, and the increasing physiological risks faced by top-level athletes. The paper substantiates the expediency of transitioning from static periodization models to a dynamic system of training programming that integrates both objective biomarkers and subjective indicators of the athlete's functional state.

Drawing on the analysis of contemporary scientific literature, best practices of leading sports schools, and innovations in sports physiology, the article outlines the key biomonitoring tools applicable to wrestling training: HRV, heart rate, sleep quality, fatigue index, perceived exertion scales, and others. Their potential in individualizing workloads is highlighted, along with the risks of misinterpreting digital data without contextualizing it within the specifics of the sport.

An integrated model of bioadaptive training programming is proposed, comprising monitoring, analytical interpretation, and the formation of an adaptive training decision. The model is visualized through a dynamic SmartArt diagram and further illustrated with a table of variable training scenarios based on athlete condition. Methodological guidelines for the implementation of this model are detailed, considering both individual and team-based training formats, the use of digital platforms, and strategies for preserving adaptive potential throughout the macrocycle.

The practical significance of the study lies in the creation of an actionable instrumental model for load adaptation in high-performance sport, aligned with the principles of evidence-based physiology, digital security, and sporting effectiveness. The findings are applicable both in training elite athletes and in developing coach education programs that incorporate modern bioanalytical tools.

Keywords: freestyle wrestling, bioadaptation, HRV, training load, digital monitoring, sports physiology, periodization, adaptive model, training process.

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Introduction

The development of a modern training system for high-performance wrestlers requires the implementation of qualitatively new approaches to the planning, monitoring, and adjustment of training load. In the context of an increasingly dense competition calendar, rising psychophysiological complexity of loads, and a growing risk of overtraining, traditional programming models are losing their flexibility and fail to fully account for the individual reactivity of the athlete's body. Consequently, greater importance is being placed on concepts that envisage the dynamic alignment of training stimuli with each athlete's biological response.

One of the most promising directions in this context is bioadaptive programming—a system based on the integration of biomonitoring data, subjective well-being assessments, digital analysis of functional state, and flexible adaptation of training load in real time [1]. This approach is particularly relevant in sports involving a mixed type of workload, such as freestyle wrestling. The combination of high-intensity muscular activity, tactical thinking, variable pacing, and short-duration peak loads requires a precise balance between stimulation and recovery, which is only achievable with continuous physiological feedback.

Previous scientific studies—including those by Guo and Mu (2024), He, Liu, and Zhao (2022), Dorofieieva (2016), and Makhud (2021)—have addressed specific aspects of biomonitoring in endurance sports, focusing primarily on HR, HRV, VO_2max, and fatigue indexes. However, at the systemic level, in the context of wrestling, such questions remain underexplored. There is a distinct lack of models that combine analytical logic, physiological substantiation, and coaching practice into a unified adaptive framework.

This gap determines the scientific novelty of this study, the subject of which is the development of a comprehensive bioadaptive model for programming the training load of wrestlers, considering changes in physiological state, readiness indicators, and self-regulation skills.

The purpose of this article is to design and justify a model of bioadaptive training load programming in freestyle wrestling that integrates biomonitoring tools, the logic of physiological adaptation, and the coach's interpretation of data.

Results

The concept of bioadaptation in sports science is grounded in the idea of dynamic restructuring of the body's functional systems in response to external stimuli, particularly physical training loads. Within the framework of training elite athletes, especially wrestlers, bioadaptation is not merely a physiological response but evolves into a targeted and controlled transformation that can be programmed and regulated based on current objective indicators [1, 2].

The physiological essence of the adaptation process in sport is based on the principle of supercompensation, whereby appropriately dosed load induces not only a temporary reduction in functional capacity but also a subsequent increase beyond the initial level. However, in practice—particularly in sports with high neuromuscular demand, such as freestyle wrestling—this process is extremely delicate: any imbalance between training load and recovery can lead to a decrease in adaptive potential, overtraining risk, motivational suppression, and general physiological destabilization [3].

The bioadaptive approach accounts not only for external load (volume, intensity, duration of training sessions) but also for internal load—the athlete's physiological response to those stimuli. This approach is based on a set of markers that reflect the status of the adaptive system: heart rate variability (HRV), resting heart rate, cortisol levels, pulse recovery rate, perceived fatigue, sleep quality, among others. In particular, HRV serves as a key indicator of the autonomic nervous system's capacity to respond to stress: high HRV indicates efficient recovery and readiness for work, whereas low HRV signals the need to reduce stress. Likewise, a consistently elevated morning HR or diminished sleep quality indicates cumulative fatigue, which may remain undetected in classical training plans [4].

In the context of freestyle wrestling—where training stressors are often hybrid (anaerobic power, strength load, psycho-emotional stress)—bioadaptation should be viewed as a multidimensional process. This approach involves not only muscular perception of load but also active engagement of the central nervous system, endocrine profile, and the cognitive resource of the wrestler. Training efficiency can only be improved by combining subjective data (the athlete's sensations, mood, fatigue) with objective bioindicators that track physiological responses in real time [5].

In this way, modern bioadaptive understanding is based not only on load theory, but also on the integration of evidence-based physiology, enabling the individualization of training and dynamic adjustment of load parameters within a single cycle—crucial for maintaining high performance and preventing overload in elite-level wrestlers.

With the rising demand for individualized training programming, especially in high-performance sport, biomonitoring is shifting from a secondary support tool to a strategic element in planning adaptive responses. Freestyle wrestling, as a discipline with complex neuromuscular and cardiorespiratory loads, particularly benefits from the application of digital technologies that allow real-time tracking, interpretation, and adaptation of training loads in accordance with the athlete's current physiological state.

The use of wearable technology—sensors, smart bracelets, rings, and specialized sports platforms—enables the registration of a broad spectrum of indicators: from HRV and blood oxygen saturation to sleep quality, respiratory rate, and fatigue indexes [6]. These devices function through continuous monitoring, accumulating large data sets that, when properly analyzed, allow coaches and athletes to make well-grounded decisions regarding the volume and intensity of upcoming training loads.

Table 1 presents a comparative analysis of the main biomonitoring solutions currently used or potentially integrable in the training process of high-performance wrestlers, considering the topicality of the issue.

Table 1

Functional Capabilities of Modern Biomonitoring Systems in the Context of Wrestlers' Training

Device	Key Measured Indicators	Application in Wrestling	Advantages	Limitations
WHOOP Strap 4.0	HRV, HR, sleep quality, respiratory rate, strain index	Used during recovery cycles and overtraining analysis	High HRV accuracy, convenient for night wear, analytics dashboard	Limited movement tracking, not specifically tailored to wrestling
Oura Ring Gen3	HRV, sleep, temperature, HR, activity	Passive wearing during sleep phases, detection of micro-stress	Reliable night-time readings, non-intrusive	Narrow focus (sleep/recovery), lacks training mode
Polar H10 + Flow App	Real-time HR, HRV, training load	Used during sparring and loading cycles	High accuracy during movement, compatibility with multiple platforms	Requires manual interpretation adjustments, lacks multi-metric tracking
Garmin	HRV, VO_2max,	Monitoring of	Broad data set,	Less sensitive to

Forerunner 955	recovery status, pulse, stress, breathing	training blocks, short load cycles	coach-friendly interface	strength and power-speed efforts
Firstbeat Sports System	Internal training load, HRV, load-recovery balance	Systematic use in team monitoring	Professional analytics, comprehensive assessment	High cost, needs adaptation for combat sports
Smartabase (Human Performance Software)	Individual medical-physiological profiles, training load, well-being, subjective scales	Integration with other devices, adaptation analysis at team level	Powerful adaptive analytics system, training individualization	Requires staff digital literacy, implementation complexity

Summarized by the author [4, 6–9]

All of the mentioned systems offer significant potential for enhancing the training process, yet their effectiveness directly depends on the quality of data interpretation, integration into daily coaching practice, and the athlete's sensitivity to digital feedback mechanisms. Therefore, the next step is to develop a bioadaptive model that combines objective physiological indicators with variable training loads in a personalized context.

In modern sports science, bioadaptive programming of training load is viewed as a strategy that not only accounts for the periodization of training, but also responds to real-time biological feedback from the athlete's body in each training cycle [2]. This approach departs from the traditional static model of periodization and evolves into a dynamic system, in which external training stimuli remain in constant interaction with the athlete's physiological adaptation.

The key principles of the bioadaptive approach include individualization, variability, dynamic balancing between training load and recovery, as well as regular reassessment of readiness based on biomarkers. In freestyle wrestling, training process programming aligned with these principles enables flexible responses to fluctuations in the athlete's functional state, helps to prevent overtraining, and supports sustained competitive effectiveness during the tournament phase.

To visualize the general logic of the bioadaptive approach in wrestling, it is advisable to use a structured diagram (Figure 1), which reflects the dynamic integration of training parameters with the athlete's biophysiological responses.

The presented model allows for structuring the wrestler's training process in such a way that each subsequent training load is based not only on the pre-planned volume but also on the biological appropriateness for a particular athlete at a specific moment. As a result, the adaptive efficiency of training increases, the risk of overfatigue decreases, and the alignment between training actions and the athlete's physiological responses is improved—this being the very essence of the bioadaptive model.

The intensity and variability of modern competitive wrestling requires both the coach and the athlete to not only apply flexibility in training process design but also to clearly understand the relationship between the training load and the athlete's physiological response. In this context, the bioadaptive strategy should not be viewed as a set of disconnected actions but rather as a comprehensive model that integrates biomonitoring, state interpretation, adaptive planning, and objective effectiveness evaluation.

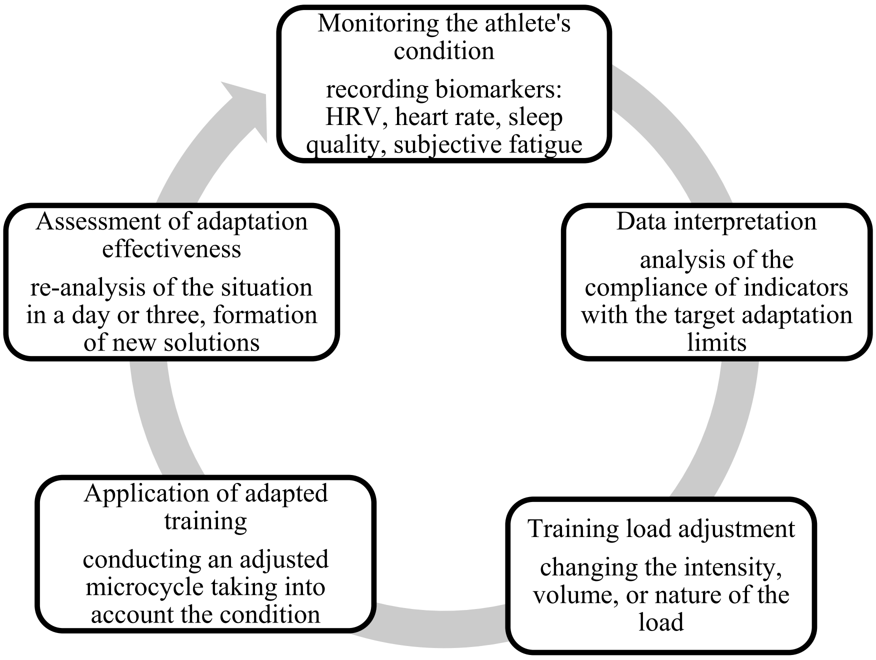

Figure 1. Structure of bioadaptive training load programming in freestyle wrestling
Developed by the author

The proposed bioadaptive programming model for freestyle wrestling is an integrated system operating in the format of "input – interpretation – output." The model relies on daily (or cycle-based) updates of athlete status data, which are analyzed automatically or semi-automatically, followed by the generation of an adapted training decision. Its advantage lies in the flexible combination of digital analysis with coaching expertise, enabling both individual sensitivity and precise load programming.

Structure of the bioadaptive programming model:

1. Input Data
    a. Biomarkers: HRV, resting HR, sleep quality, SpO_2, skin temperature, strain index;
    b. Subjective data: perceived wellness, motivation level, mood, RPE scale;
    c. Fatigue metrics: recovery percentage, time elapsed since last intensive session.
2. Interpretive Module
    a. Adaptation logic algorithm (simple or AI-enhanced);
    b. Matrix matching "current state – allowable load level";
    c. Contextual parameters: microcycle phase, recovery vs. peak, seasonal period.
3. Output (Adaptive Training Decision)
    a. Type of load: strength, technical, interval, tactical;
    b. Intensity: low, moderate, peak;
    c. Duration: short, full, segmented;
    d. Real-time adjustment notes (for intra-session status changes).

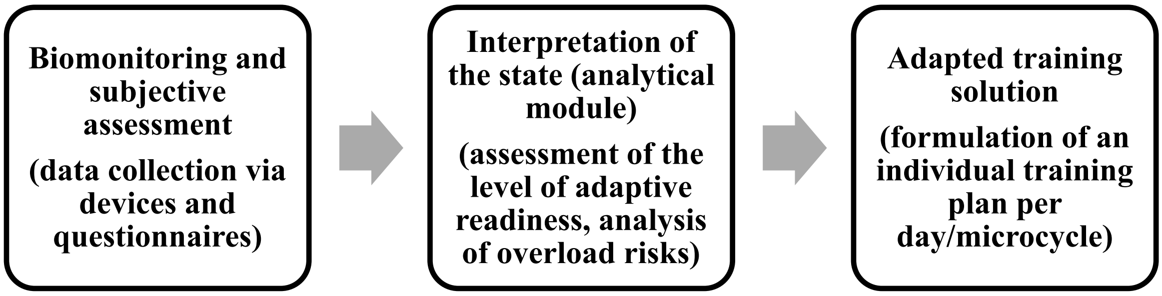

Figure 2. Integrated model of bioadaptive regulation of training load in wrestlers

Table 2

Examples of bioadaptive model application in wrestlers' training process

Situation	Input Data	Interpretation	Recommended Action
High HRV, subjective freshness, normal HR	HRV > 80, RPE < 4, 8+ hours of sleep	High readiness for training	Strength session with peak intensity, additional sparring
Low HRV, subjective fatigue, disturbed sleep	HRV < 50, RPE > 7, fragmented sleep	Accumulated fatigue, overtraining risk	Replace core block with recovery session: yoga, light technical training
Stable indicators but high competition-related stress	Normal HRV, elevated cortisol (based on test)	Psycho-emotional overload	Replace sparring with tactical simulation and visualization, breathing exercises
Peak load phase, mixed biodata	Moderate HRV, stable HR, mood fluctuations	Ready for load, but with limited duration	Short interval block with biofeedback pauses

The model presented in this article is the first attempt to formalize a bioadaptive logic specifically within the context of freestyle wrestling, a sport that integrates elements of strength, flexibility, reactivity, tactics, and psychological stability. Its application enables the transformation of training into a high-precision and dynamic system capable of responding to even the slightest fluctuations in an athlete's functional state.

This model can be implemented both in individual training settings and team-based formats, especially with the integration of digital solutions such as Smartabase, TrainerRoad, and Polar Flow. Through this, coaches and athletes are equipped with a scientifically grounded, adaptable framework for optimizing training loads and ensuring peak performance readiness.

Conclusions

The modern training system for elite-level freestyle wrestlers requires a rethinking of traditional load programming approaches in the context of individualization, scientific precision, and dynamic responsiveness to physiological signals of the athlete's body. The conducted study has shown that, although classical periodization models proved effective in previous decades, under current high-performance demands and increasing prevalence of overtraining, they fail to fully account for the variability of individual biological responses.

A theoretical understanding of bioadaptation as a systemic process, encompassing reactions of the cardiorespiratory, neuromuscular, hormonal, and cognitive subsystems, has enabled the formulation of conceptual foundations for a new paradigm of training regulation. Tools of biomonitoring — such as HRV, subjective fatigue scales, sleep quality indices, oxygen saturation levels — in combination with analytical software modules, offer the potential for daily, evidence-based decision-making in training management.

The proposed model of bioadaptive programming for training load in freestyle wrestling demonstrates the potential for systemic integration of input data on athlete status, interpretation through an adaptive logic module, and real-time generation of training decisions. Of particular importance is the model's applicability not only during loading phases but also during recovery periods, pre-competition preparation, and post-tournament adaptation.

The novelty of this study lies in the development of a comprehensive structure for a bioadaptive approach tailored to the sport of wrestling, taking into account the mixed nature of exertion, tactical cognition, and the critical role of psychophysiological factors in competitive readiness. Practical implementation of this model, both in individual and team training contexts, may significantly enhance the effectiveness of the training process, reduce the risk of overtraining, and contribute to achieving higher athletic performance at the international level.

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