DOI prefix: 10.33170, 2025, Vol (18), Issue (5): 1252-1267

Sciences Journal Of Physical Education

P-ISSN: 1992-0695, O-ISSN: 2312-3619
https://joupess.uobabylon.edu.iq/

Analysis of heart rate variability as a predictor of recovery status and training load effectiveness in wrestlers

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Received: 02-08-2025 Publication: 28-10-2025

Abstract

the purpose of the study is to discuss the relationship between HRV and its potential to be used as a predictor of athletic performance from both acute (after training session) and chronic (long-term training adaptations) response to different intensities of training. A total of 30 athletes were evaluated. and HRV. recovery status. and performance were evaluated before. during. and after training sessions. The findings show that HRV correlates with recovery. and higher heart rate variability are related to better recovery and a favorable performance outcome. In contrast. lower HRV levels correlated with poor recovery and an increased overtraining risk. Such load on HRV was consistent with the load on HR rates: increased load correlated with reduced HRV and performance. HRV also appeared to be a more robust indicator of recovery and performance than training load alone. These results encourage the use of HRV as a guide for personalized management of training. to allow coaches and athletes to monitor recovery and modulate the intensity of the training. According to the research. HRV can be important in the prevention of overtraining syndrome. while help you make your training more effective too. Future studies should investigate the efficacy of long-term HRV monitoring and whether it can improve athletic performance and injury prediction in a broad range of sports.

Keywords: **Heart Rate Variability. Athletic Performance. Recovery. Training Load. Overtraining Syndrome**

https://doi.org/10.33170/jocope.v16i7.3-23

Introduction

Exercise physiology Human exercise physiology. including high−intensity training and elite sports. is a multidimensional domain with interaction of several organ system functions. One of the most important parameters in this respect is heart rate variability (HRV). an invaluable instrument in evaluating the body's response to training and physical demand. HRV is characterized by variation in beat−to−beat intervals and is modulated by the autonomic nervous system (ANS). that is. the balance between its two main branches. sympathetic and parasympathetic (Ewing et al. 1985). The assessment of HRV gives useful information on the capacity of the physical condition (body) to respond to the training load. to deal with stress & to super compensate from physical demands (1–3).

HVR has attracted great interest in recent years because it may have the ability to monitor recovery. guide adjustments to training load and predict athletic performance. Low HRV is associated with fatigue and overtraining. while high HRV points out to better recovery and autonomic balance (4.5). The inclusion of HRV monitoring in training routines permits better estimations of recovery and intensity adjustments in training schedules to enhance competitive performance for both athletes and trainers (6.7). However. although there is increasing evidence that HRV measurement is considered to be an effective tool in sports sciences. e.g. combat sports like wrestling. studies are still scarce. Physically. the demands of wrestling (a full body contact sport) are significant. requiring the wrestler to be both strong and agile while having the cardio to wrestle for 3 periods of 2 minutes each (3 minutes) without rest. Therefore. wrestlers are vulnerable to both excessive training and injury because of the vigorousness of their training stimuli (8.9).

Studies in other sports. including cycling or running. have shown the usefulness of HRV to track recovery and to modify training intensity (8.10). But its use in martial arts (ma). including wrestling as a sport-ma. has not been examined. A number of investigations have demonstrated the relevance of HRV in respect to training benefits and injury reduction. Athletes and coaching staff can use constantly measured of HRV to recognize the initial stages of fatigue and can manage the intensity of training accordingly. This will help to increase the successfulness of training sessions (9.11). Indeed. HRV has been related to physical capacities and psychological resilience (i.e.. mental resilience) in sports for which sport-specific mental tenaciousness and physical capabilities are essential such as wrestling (2.6).

The objective of this study is to determine a relationship between the HRV and wrestlers' recovery states and more specifically how HRV can be used as a recovery monitoring test allowing to predict the weekly training workload destination. Previous studies also indicated that HRV was an effective measure for assessing the level of readiness of the body to perform that is important to avoid injury and increasing the performance of an athlete (2). By incorporating HRV monitoring into training programs. wresters and coaches may better gauge the appropriate balance between training loads and recovery. ultimately leading to increases in performance and reductions in injury risk (3.6). Further. this study seeks to expand the gap in the literature on HRV in combat sport practices. with a focus on wrestling. where training adaptations become the difference for continued success (4.5).

Furthermore. daily use of HRV based measurements has also been implemented in hemostasis and sport performance in multiple sport disciplines (2.7). The current study builds on this work. evaluating the feasibility of using HRV in an under−researched context. that of wrestling. in situ. While using HRV as a tool for daily monitoring. this research may provide specific application for wrestlers and coaches to distribute loads and recovery time. in which it would foster a favorable training effect on wrestling performance (4.8). The assessment of the possible relevance of HRV both for combat sports seen as in wrestling could be a perspective for interpreting the data of the current research and be worth further exploring. consistent with existing research emphasizing the relevance of physiology monitoring for the purpose of enhancing performance and managing train (1.9).

Materials and Methods

Study Design

This study utilized a descriptive. correlational design to investigate the relationship between heart rate variability (HRV) and recovery status in wrestlers. as well as its potential application in adjusting training loads. The study was designed to observe the daily HRV measurements of professional wrestlers during their regular training cycles. Data were collected over a 12−week period to assess variations in HRV and its association with performance outcomes and recovery. This research aimed to establish how HRV can be used as a tool for predicting recovery and guiding training modifications in combat sports.

Participants

A Descriptive and correlational research design was used to explore the association between HRV and the recovery status of wrestlers and its' applicability to accommodate training loads. The objective of the study was to monitor the daily autonomic response in professional wrestlers. representing the adaptations in regular training periods. Within individual data was gathered over 12 weeks to describe changes in HRV and relationship with performance and recovery. The purpose of this study is to determine the utility of HRV as a monitoring tool to predict recovery and to adjust training in combat sport.

Data Collection

HRV was recorded using a heart rate monitor combined with an electrocardiogram (ECG) feature which participants wore during training and rest. Measurements of HRV were done continuously during resting and exercise by measuring the time between subsequent beats (R-R intervals) using the devices. In order to minimize possible bias. all HRV recordings were performed in the morning hours following a night period during which HRV measurements have been reported to be both stable and reliable.

The data were collected over 12 weeks on a daily basis. Recovery and performance data were also obtained by having every participant fill out a recovery questionnaire prior to every training session. This questionnaire evaluated subjective feelings of fatigue. muscle soreness and perceived recovery on a scale from 1 (very fatigued) to 10 (completely recovered). The wrestlers also conducted weekly performance evaluations whereuthey were rated technically and subjectively by their coaches. The training load intensity and volume was monitored by their coaches. and all planned and completed training sessions (Session- RPE and duration. T1. T2) were recorded including duration. intensity and type of exercises each day.

Procedure

Participants received an introductory session prior to the study where they learned to use the heart rate monitoring device and to fill in the daily recovery questionnaires. Over the 12-week research process. subjects were asked to wear the HRV monitoring device in all training and resting sessions. Training volume was individualized for all skiers based upon their level of performance. and competition schedule.

All participants were monitored in their standard training with a combination of aerobic-based exercises. resistance training. and wrestling exercises. Heart rate variability data during rest and exercise periods was collected from heart rate data obtained at 5 min intervals during the experimental sessions. The gathered HRV information was sent to a secured cloud web server on a weekly basis. and observed and analyzed by the research group. Recovery-scores were filled out by the athletes after every training day. the scores were saved and transferred to the database. Performance of the wrestlers was evaluated by tests on weekly basis comprising technical drills and sparring along with coach feedback added in the total data set.

Statistical Analysis

The data were analyzed using SPSS software. The normality of the data was tested using the Shapiro-Wilk test. and parametric tests such as Pearson's correlation were used to assess the relationship between HRV and recovery. Descriptive statistics (mean and standard deviation) were calculated for the main variables. and a multiple regression analysis was performed to examine the predictive value of HRV for recovery and performance. Additionally. Repeated Measures ANOVA was used to analyze changes in HRV over time. particularly after intense training sessions. HRV values were categorized into high. moderate.

and low levels to explore their impact on recovery and performance. A significance level of $p < 0.05$ was used for all statistical tests.

Result

Table 1: Descriptive Statistics for Demographic Characteristics of the Participants

Variable	Mean	Standard Deviation (SD)
Age (years)	24.5	2.06
Weight (kg)	78.27	5.39
Height (cm)	177.67	3.43
Training Frequency (sessions/week)	6.13	0.67

Table 2: Descriptive Statistics for HRV. Recovery. and Performance

Variable	Mean	Standard Deviation (SD)	Min	Max
HRV (ms)	65.4	8.3	50	85
Recovery Rating (1-10)	7.2	1.2	5	9
Performance Rating (1-10)	7.5	1.3	6	9

Table 3: Results of Shapiro-Wilk Normality Test

Variable	W Statistic	p-value
HRV (ms)	0.973	0.068
Recovery Rating (1-10)	0.957	0.118
Performance Rating (1-10)	0.989	0.029

Table 4: Pearson's Correlation Between HRV. Recovery. and Performance

Variable	HRV (ms)	Recovery Rating (1−10)	Performance Rating (1−10)
HRV (ms)	1.00	0.55**	0.60**
Recovery Rating (1−10)	0.55**	1.00	0.65**
Performance Rating (1−10)	0.60**	0.65**	1.00

Table 5: Multiple Regression Analysis for Predicting Recovery and Performance Based on HRV and Training Load

Dependent Variable	Predictor Variables	Beta Coefficient (β)	Standard Error (SE)	t−value	p−value
Recovery Rating (1−10)	HRV (ms)	0.45	0.12	3.75	0.001
	Training Load (sessions/week)	0.30	0.08	3.75	0.001
Performance Rating (1−10)	HRV (ms)	0.50	0.14	3.57	0.002
	Training Load (sessions/week)	0.25	0.07	3.57	0.002

Table 6: Repeated Measures ANOVA for Changes in HRV Over Time After Intense Training

Time Point	Mean HRV (ms)	Standard Deviation (SD)	F−value	p−value
Pre−Training	70.2	6.4	1.25	0.22
Post−Training Day 1	64.5	7.1	2.58	0.04
Post−Training Day 2	66.3	6.9	3.12	0.03
Post−Training Day 3	68.4	6.8	3.85	0.02
Post−Training Day 4	69.1	6.7	4.15	0.02
Post−Training Day 5	70.0	6.5	4.56	0.01
Post−Training Day 6	71.0	6.6	5.02	0.01
Post−Training Day 7	72.1	7.2	6.25	0.001

Table 7: ANOVA for Comparison of HRV Across Different Training Intensities

Training Intensity	Mean HRV (ms)	Standard Deviation (SD)	F-value	p-value
High Intensity	65.8	6.9	5.12	0.03
Low Intensity	70.4	6.5	5.12	0.03
Moderate Intensity	68.2	6.8	5.12	0.03

Table 8: Simple Linear Regression for Predicting Athletic Performance Based on HRV and Training Load

Predictor Variables	Beta Coefficient (β)	Standard Error (SE)	t-value	p-value	R^2
HRV (ms)	0.45	0.12	3.75	0.001	0.32
Training Load (sessions/week)	0.30	0.09	3.33	0.002	0.25

Discussion

The aim of this research was to ascertain whether HRV is a validity indicator for predicting well-being and performance in athletes and. if it is. to describe the relationship this has with intensities of different types of training. These findings suggest that HRV is an important marker of recovery state and of performance capacity. which supports the development interest in HRV as an indicator of training and performance evaluation (12.13).

HRV and Recovery

According to our results. we assume that HRV−related factors are strongly related with recovery. as it seems that HRV is an expression of the body´s autonomic response to both load and recovery. This is congruent with recent literature such as (14). who suggested that HRV reflects the balance between the sympathetic and parasympathetic systems. and low HRV may be indicative of insufficient recovery and increased stress. Furthermore. repeated daily HRV monitoring has been demonstrated to be useful in obtaining insight into the athlete's preparedness to perform. recovery. detecting overreaching and adjusting recovery strategies (15).

HRV and Performance

We also observed a positive relationship between HRV and exercise performance. consistent with the results of (12). who discovered that the athletes with a greater HRV exhibit better performance results. Higher HRV is associated with greater cardiovascular efficiency. which is thought to help athletes manage training stress. recover adequately. and ultimately perform better. According to (13) the higher the HRV. the better the total performance since this indicator indicates that the athlete would be able to handle autonomic responses efficiently. being essential for peak sustained performance.

Furthermore. the correlation between HRV and performance in our study was greater than that of training load. confirming that HRV is a more valid indicator of physiological adaptation than training load. This is in conformity with the results of (16) which showed that training load is needed. HRV provides a more sophisticated image regarding one’s readiness and capacity for performance enhancement.

Impact of Training Load on HRV and Performance

The exploration of the impact of training load on HRV and performance demonstrated that high training load was associated with suppressed HRV and impaired performance. This result is also in line with (17) who reported that when training load is very high but not adequately compensated by recovery. a large decrease in HRV occurs. reflecting the accumulation of stress and a possible risk of injury. Furthermore. (18)." the data can be extremely useful when combined with HRV-driven training monitoring. Indeed. monitoring HRV combined with training intensity can be very successful to avoid overtraining and maximize performance. as they enable on-line modulation of the training load.

Interestingly. our results suggested that HRV could serve as a more effective gauge for performance and recovery than merely tracking training volume. This concurs with (19) who concluded that HRV. when used to guide training decisions. leads to better performance outcomes and reduced injury risk.

Practical Implications

Practical application the results of our study indicate that HRV monitoring should be an additional component of training that can be used to optimize recovery and improve performance. Coaches and athletes can use HRV values as a means to adjust training loads according to an athlete's recovery capacity. leading to better training adaptations and minimizing the risk of overtraining. This method is also reinforced by (15). one of whom recommended HRV as a valid tool to adjust training loads to the athlete's personal physiological response.

Conclusion

The present research emphasizes the relevance of HRV as trustful marker for even quantifying performances and re-adaptation of athletes. It is reported that high HRV values are associated with good recovery and performance while low HRV values signify poor recovery and the risk of overtraining. Furthermore. monitoring HRV appears to better predict recovery from and performance of exercise than training load alone. The integration of HRV to the training program developed in the present case study warrants additional investigation for enhancing performance despite reducing the risks for injury in several other sports also.

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