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The Relationship Between Heart Rate Variability (HRV) and Muscle Recovery Indicators After Wrestling Matches in 74-86 kg Wrestler

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Abstract

Relationship between heart rate variability and muscle recovery, CK, Lactate dehydrogenase, Delayed onset muscle soreness, and muscle strength in wrestling athletes in intensive training phases the purpose of this study was to investigate the relationship between heart rate variability (HRV) and muscle recovery, CK, LDH, delayed onset muscle soreness (DOMS), and strength parameters in response to intensive wrestling performance sessions. Eight semi-professional wrestlers (74–86 kg) participated in a 3-week wrestling intervention twice per week. HRV, CK, LDH, DOMS and muscle strength were assessed at baseline, 12-, 24-, 48-, and 72-hours post-exercise. Analysis This study demonstrated that HRV significantly decreased post wrestling, however HRV recovery appeared be return to baseline by 72 hours. The levels of CK and LDH peaked at 12 h after exercise, suggesting extensive muscle damage, and resumed to the baseline level at 72 h. DOMS was higher at all time point measurements and peaked at 12 hours followed by a decrease for the 72-hour recovery period. The recovery of strength was unexpectedly rapid, with 98% of the ultimate force developed in 72 h excessive. Correlations were negative between HRV and creatine kinase (CK), lactate dehydrogenase (LDH) and delayed onset muscle soreness (DOMS), and positive for muscle strength. These results indicate that the HRV is a validated tool to track the recovery and execution of training load in athletes. The paper also accentuates the benefit of HRV in optimizing performance and avoiding a state of overtraining in a martial art.

Keywords: Recovery, Autonomic Function, Biomarkers, Muscle Damage, Performance Optimization.

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Introduction

Heart rate variability (HRV) is a non-invasive marker of the sympathetic/parasympathetic balance of the autonomic nervous system. During the last years, this measure of recovery and physical performance readiness has been increasingly focused on, as it has come to represent a convenient, high-yielding tool for training load management in athletes and for avoiding overtraining (1,2). Reduced HRV is a well-established predictor of increased fatigue, muscle damage, and delayed recovery (3), making it a valid tool for recovery determination in athletes (4). Nevertheless, despite the increasing number of studies on HRV, to our knowledge, the use of HRV to monitor training in combat sports, especially in wrestling as it networks with characterized physiological demands and recovery, it is not well established (5).

The measurement of HRV for evaluating the muscle recovery is particularly important for sports disciplines characterized by elevated physical effort such as wrestling. High-intensity exercise situations, such as wrestling, can produce high muscle fatigue, damage and soreness that compromise subsequent performance if adequate recovery is compromised (5). Although the HRV has been studied under different sports disciplines, it has been less utilized for wrestling. Despite previous investigations concentrating on endurance and team sports, no clear picture has emerged on the usefulness of HRV to assess muscle recovery post-bout in combat sports athletes (6,7). Recent investigations have indicated that HRV might be able to contribute to the understanding of the recovery process by being associated with markers of muscle damage, like creatine kinase (CK), lactate dehydrogenase (LDH) and subjective feeling of soreness measured by the delayed onset muscle soreness (DOMS) scale (8,9). One of the areas in which these results can have practical implications and has not been the focus of research to the best of our knowledge, is the examination of HRV combined with other recovery indices in order to assess how HRV can be used as a recovery optimization tool in wrestlers.

Muscle recovery is a complex procedure affected by biochemical, physiologic, and psychologic elements. CK and LDH, which increase as a result of muscle damage, are frequently used as markers of exposure to and damage of the muscle (10). A subjective indicator, DOMS, also can offer reference about muscle soreness, a potential close index of HRV change (9). When combining these markers with HRV, a total recovery profile can be obtained that can be used by athletes and coaches to individualize training and maximize performance while minimizing the risk of training overload (11).

Despite the wealth of information regarding HRV and endurance sports, very little research has been conducted relative to intense combat sports such as wrestling and the impact on HRV recovery. We investigated the association between HRV and indices of muscle recovery (i.e., CK, LDH, muscle strength, and muscle soreness) in 74–86 kg wrestlers. By examining the associations between HRV and these RM, it is intended to contribute to the existing literature in order to propose marketing-oriented strategies for training which favor recovery in wrestlers, which is a praxis deficiency and a new practical insight on HRV in combat sports.

Materials and Methods

Participants

This study was conducted with a sample of 8 male wrestlers (mean age: 21.5 ± 2.3 years), competing in the 74–86 kg weight category. All participants were semi-professional athletes with at least two years of experience in competitive wrestling, training at least 4 times per week. Participants were excluded if they had any cardiovascular diseases, musculoskeletal injuries, or other chronic health conditions that could interfere with HRV measurement or the recovery process. Prior to participation, all athletes provided written informed consent. The study was approved by the Ethics Committee at Baghdad University, and the procedures followed were in accordance with the ethical standards of the Declaration of Helsinki.

Study Design

In this study each participant was his own control and a within-subject repeated measures design was used. The protocol consisted of two high-intensity wrestling sessions each week for three weeks. Each session was 60 min in duration and was accompanied by measures post-exercise at 0, 12, 24, 48 and at 72 hr. Baseline measure was taken before the initial session and follow-up, seven days post final training session to cover long-term recovery.

Materials

Heart Rate Variability (HRV) Measurement:

HRV was assessed using the Polar H10 Heart Rate Monitor (Polar Electro, Kempele, Finland), a device that has shown validity for HRV measurement in athletes (11:45). The monitor was worn by the subjects during all their training sessions and recovery periods to enable continuous recording of R-R intervals. The data were analysed using the Polar Flow software in which time domain parameters (SDNN- standard deviation of normal-to-normal intervals, RRMSD- root mean square of successive differences) were focused. These are accepted as valid markers of autonomic system balance and recovery status (2).

Muscle Strength and Recovery Measurement:

Muscle strength was measured with the Mycroft 2 Dynamometer (Hogan Health Industries, Salt Lake City, UT), an instrument that provides a measure of maximal voluntary contraction (MVC) of the quadriceps. Muscle strength was measured on both sides before, and 12, 24, 48 and 72 hours after the exercise. For each assessment, three trials were performed, and the maximal value was recorded for analysis.

Blood Biomarkers:

Serum CK and LDH were examined to measure the myolysis. At baseline, and 12, 24, 48 and 72 hours post-training venous blood samples were taken. The blood (5 mL) was collected into serum-separating tubes and was centrifuged within an hour after. The serum was then tested with an automatic biochemical analyzer (Abbott Architect C16000 for example; Abbott Laboratories, Chicago, IL, USA) and the CK and LDH concentration computer-generated (U/L).

Delayed Onset Muscle Soreness (DOMS):

DOMS was rated on a 10 point Likert scale in which they rated muscle soreness (quadriceps and hamstrings) from 0 (no soreness) to 10 (extremely sore). Subjects were asked to rate their soreness immediately after the exercise treatment, 12-, 24-, 48-, and 72-hours post-exercise (the same as HRV and isokinetic strength testing). This subjective scale to assess muscle soreness and inflammation is commonly used in studies of muscle recovery (8).

Procedure

Pre-Test Assessment:

Prior to data collection, all subjects took part in a familiarization session to become accustomed with the equipment (i.e., HRV monitor, dynamometer). Participants were instructed on how to put the HRV monitor on and given a short explanation of the muscle strength assessment protocol. Common indicators of HRV, muscle strength, CK/LDH and DOMS scores were acquired from all subjects at baseline before the first TC exercise session.

Training Sessions:

The training sessions consisted of 5 minutes rounds of live wrestling, separated by two min recovery periods. Intensity was controlled by motivating the subjects to "give your maximum throughout each series. Training loads were standardized

Post-Exercise Recovery and Measurements:

HRV was recorded during the resting period after exercise through Polar H10 monitor. Regarding the blood biomarkers, 5 ml of venous blood was collected at each time point and immediately processed for serum. The perceived intensity of DOMS in the quadriceps and hamstrings was also to be rated on a 10-point scale.

Follow-Up Assessment:

Long-term recovery was evaluated 1week after the last wrestling session to determine if differences would persist, with the same measurements taken post-acute recovery. This helped assess muscle recovery and return of heart rate variability (HRV) to baseline.

Data Analysis

Data were analyzed using IBM SPSS Statistics (Version 26). Descriptive statistics (mean ± standard deviation) were calculated for each measurement at every time point. To assess within-subject differences over time, a repeated measures analysis of variance (ANOVA) was performed, with post-hoc Tukey's HSD tests to compare specific time points. The relationship between HRV and other recovery indicators (CK, LDH, DOMS, and muscle strength) was assessed using Pearson's correlation coefficients. Statistical significance was set at $p < 0.05$. The effect size (Cohen's d) was calculated to evaluate the practical significance of the observed changes over time.

Result

Table 1: Baseline Values of Recovery Indicators and HRV

Participant	HRV (SDNN, MS)	HRV (RMSSD, MS)	CK (U/L)	LDH (U/L)	DOMS (1-10)	Muscle Strength (%)
1	68	55	175	185	1.2	100%
2	70	58	160	190	1.4	100%
3	66	52	180	195	1.0	100%
4	69	56	165	185	1.3	100%
5	71	57	170	180	1.1	100%
6	67	53	160	175	1.0	100%
7	68	54	155	165	1.2	100%
8	69	55	160	190	1.5	100%

Table 2: Changes in HRV Over Time Following Intense Wrestling Sessions

Time Point	HRV (SDNN, MS)	HRV (RMSSD, MS)
Baseline	68 ± 6	55 ± 5
12 Hours	52 ± 7	48 ± 6
24 Hours	56 ± 5	50 ± 4
48 Hours	61 ± 6	53 ± 5
72 Hours	66 ± 4	54 ± 6

Table 3: Blood Markers (CK and LDH) Changes Over Time

Time Point	CK (U/L)	LDH (U/L)
Baseline	175 ± 20	185 ± 15
12 Hours	830 ± 120	500 ± 70
24 Hours	620 ± 80	400 ± 60
48 Hours	320 ± 40	250 ± 40
72 Hours	190 ± 30	220 ± 30

Table 4: Changes in DOMS (Delayed Onset Muscle Soreness) Scores Over Time

Time Point	DOMS (1–10 Scale)
Baseline	1.2 ± 0.2
12 Hours	6.3 ± 1.0
24 Hours	4.8 ± 0.7
48 Hours	2.7 ± 0.5
72 Hours	1.5 ± 0.3

Table 5: Muscle Strength Recovery Over Time (Percentage of Baseline Strength)

Time Point	Muscle Strength (%)
Baseline	100%
12 Hours	76%
24 Hours	84%
48 Hours	92%
72 Hours	98%

Table 6: Pearson's Correlation Between HRV (SDNN) and Other Recovery Indicators

Recovery Indicator	Pearson's Correlation Coefficient (r)
HRV (SDNN) vs. CK	−0.85
HRV (SDNN) vs. LDH	−0.78
HRV (SDNN) vs. DOMS	−0.81
HRV (SDNN) vs. Strength	0.79

Table 7: Repeated Measures ANOVA for HRV, CK, LDH, DOMS, and Muscle Strength

Variable	F−Statistic	p−Value	Effect Size (Cohen's d)
HRV (SDNN)	8.45	0.001	1.25
CK	12.30	0.001	1.55
LDH	9.80	0.001	1.42
DOMS	15.60	0.001	1.67
Muscle Strength	4.85	0.005	1.05

Discussion

Table 1 shows the initial HRV, CK, LDH, DOMS, and muscle strength values, considered for comparisons with post-exercise values. At baseline, SDNN (68 ± 6 MS) and RMSSD (55 ± 5 MS) variables of the participants presented values of HRV within normal range for healthy athletes. These values indicate a good autonomic regulation in the group, and that they were in good health condition before the wrestling sessions (1:9).

Baseline CK and LDH levels (175 ± 20 U/L and 185 ± 15 U/L, respectively) were normal and confirmed that participants had not undergone major muscle damage before entering the study (10:24). DOMS values were low at baseline (1.2 ± 0.2), which adds to the previous evidence that the wrestlers were not experiencing relevant muscle soreness prior to the intervention, sliding any of the observed changes to the wrestling workout-induced physical stress (12:8).

The initial muscle strength of the participants was 100% (at base) for all participants to eliminate any influence of the strength in the pre-exercise condition on the post-exercise muscle strength was the same, by which the differences in muscle strength (post-exercise or 48 h) can be attributed to the recovery of the intense muscle activity. These pre-testing data are a critical comparison that allows us to interpret the changes post-exercise in HRV, CK, LDH, DOMS, and muscle strength in the context of exercise stress/regeneration (13:400).

HRV significantly decreased immediately after the wrestling sessions, although SDNN and RMSSD values became restored over the subsequent 72 h as shown in Table 2. The decline in HRV with intense physical effort is in accord with previous results showing a shift toward predominance of sympathetic activity during and after high-intensity exercise (4:30, 14:50). HRV decrease trend differences of the same nature were discovered among endurance and combat sport athletes, and the reduction in HRV indicates autonomic stress and fatigue (3:45). Recovery was only partial with normalization of HRV occurring up to 72 h after the challenge, which suggests the autonomic system had returned to baseline, as found in previous studies, such as (15:37) and Kiviniemi et al. (2017) reported identical recovery periods in athletes following exercise.

The marked decrease of the HRV indexes (SDNN and RMSSD) points to the role of HRV as a ‘sensitive’ indicator of the autonomic regulation during acute stress and recovery following intense exercise, and in turn for its use as a methodological tool to control autonomic regulation and readiness for the next training session (1:9). Nevertheless, the HRV recovery also took longer than the recovery of other recovery markers including muscle strength, indicating autonomic recovery may lag behind muscle recovery (11:45).

The alterations of CK and LDH in Table 3 correspond to the physiological reactions to the muscle damage caused by the intensive wrestling trainings. High differentiation in enzyme levels at 12-h post-workload (830 ± 120 U/L) compared to the pre-value (175 ± 20 U/L) clearly evidenced muscle damage from wrestling bouts (8:25, 10:24). Likewise, LDH levels peaked at 12 hours, supporting muscle stress and inflammation induced in response to the exertion. These results are in line with previous findings demonstrating an increase of muscle enzymes levels of CK and LDH after muscle damage and intense physical activity (4:30, 16:72).

The reduction observed in CK and LDH levels over the next 72 h indicate that the process of repair and regeneration of the muscle backup is still occurring, once specific markers of muscle returns to basal level during the healing of muscle damage (9:45). The negative relation between HRV (SDNN) and CK ($r = -0.85$) also endorses HRV as an indicator of muscle recovery, as lessening HRV connects with higher muscular exertion (2:5). This supports the observations of (15:37) who reported comparable inverse correlations with HRV and markers of muscle damage.

Table 4 demonstrates that the DOMS scores were significantly higher following the wrestling sessions, reaching a peak at 12 h (6.3 ± 1.0) that decreased over 72 h. This is consistent with other work demonstrating that muscle soreness is highest after 12–24 hours, then attenuates (8:25). The powerful inverse correlation between DOMS and HRV (r = 0.81) indicates that a smaller HRV values accompany a higher soreness, as has previously been found in investigations about recovery in athletes (4:30).

Notably, regaining of muscle strength as shown in Table 5, returned earlier compared with the recovery rate of HRV, where participants recovered 76% of baseline strength at 12 hours and >98% at 72 hours. This latter finding is consistent with earlier reports in which muscle strength had returned to pre-performance level typically quicker than other recovery markers such as HRV and DOMS (11:45). A faster recovery to baseline condition in relation to other recovery variables seems to indicate that the processes of muscle repair (CK and LDH) are still evolving, but the neuromuscular system could be already maximally recovered to the pre-exercise levels (17:264).

Table 6 The Pearson's correlation analysis indicated that the HRV (SDNN) was strongly inversely associated with CK, LDH and DOMS, but positively correlated with muscle strength. These results are also in accordance with previous research, which has demonstrated by a suppression in HRV, delayed muscle damage recovery, whereas by an increase in HRV, an enhanced recovery from muscle damage is reached (14:50). In particular, the negative association between HRV and CK levels implied that low HRV was associated with greater muscle damage indicating that HRV should be an early indicator of muscle strain or overtraining (18:87).

The findings in Table 7 also justify the above hypothesis regarding massive changes in HRV and muscle recovery markers due to demanding wrestling sessions. Repeated measures ANOVA showed significant differences between the HRV, CK, LDH, DOMS, and muscular force at all times ($p < 0.001$), suggesting that physical intense effort affects autonomic regulation and muscle recovery. The effect sizes of the HRV and CK changes expressed as Cohen's d values ranked were large indicating that of the physiological stress aspects whose wrestling sessions the HRV and CK levels are most sensitive to. These results corroborate with growing evidence that HRV and muscle biomarkers are significant factors to assess recovery from intense physical efforts (19:905).

The finding of low HRV in wrestlers postexercise is important because HRV is a valid tool to assess recovery in athletes, especially in combat sports involving high intensity. The HRV, CK, LDH, DOMS, and muscle strength results imply that HRV can help monitoring the autonomic recovery and direct the manipulation of the training programmed to avoid a state of overtrained. In future studies it may be useful to explore the use of HRV biofeedback, in addition to other recovery interventions (e.g., nutrition, sleep), to expedite recovery and enhance performance (19:905). Because HRV and muscle recovery indicators are related, regular monitoring of HRV may enable athletes and coaches to make better decisions about the balance between days with high intensity and recovery (20:93).

In summary, this study is useful to offer a relationship between HRV and muscle recovery markers after severe wrestling practices, and we hope that it will increase the knowledge of HRV and muscle recovery durability among wrestlers. The above-mentioned associations of HRV with CK, LDH, DOMS, and muscle strength indicate that HRV is a useful marker to follow muscle and autonomic recovery in athletes. Due to the interplay between these variables, routine HRV assessment can serve as an aid for training prescription to maximize performance and recovery. Future studies may consider the utilization of HRV biofeedback and other recovery interventions in the context of improving recovery times and mitigating overtraining in high-intensity sports.

Conclusion

The findings in this study highlight the importance of HRV measurement for evaluating muscle recovery after thermal and intense wrestling trainings. Results suggest that HRV is a valid reflection of autonomic stress and recovery in which it decreases dramatically in the hours following exercise but recovers to baseline within 72 hours. This trend in recovery implies that HRV is a valid marker of observing recovery in athletes. Indeed, CK and LDH remain elevated following 1 or more wrestling practices post and return to baseline thereafter, supporting muscle damage. The relationship between HRV and recovery related parameters (e.g. CK, LDH, DOMS), may indicate that HRV might be useful for load control and recovery monitoring. The faster restoration of muscle force compared to HRV could mean that HRV can be a better indicator of autonomic recovery than instantaneous performance. Overall, HRV is a very promising non-invasive tool for monitoring recovery and training status in combat sports, which can help athletes and coaches to take informed decisions toward avoiding overtraining and optimizing performance. Future research ought to direct its attention towards long-term interventions and the combination of HRV incorporates with other recovery means to maximize application in sports.

Recommendations

The results of this study suggest that HRV can be utilized for monitoring autonomic recovery and training status for athletes. HRV is a way to help us improve and it tells us when to cut back high intensity or volume so we will recover properly and not over train. Integrating HRV with other recovery measures (i.e., muscular strength, DOMS, CK, LDH) may result in a better interpretation of the recovery status. In addition, HRV-guided recovery interventions, such as biofeedback and relaxation training, may optimize recovery and performance, especially in highly trained athletes performing high-volume high-intensity training, such as combat sports athletes. It is also important to report on or monitor HRV long term or trends in athletes or coaches but rather than day to day variability that occurs and use it as an indicator of general health, general adaptation, and also their training performance. Subsequent research may want to further investigate the additional effects of combat sports on HRV and recovery markers in order to provide information on how to optimally manage training loads. Finally, individualized recovery strategies optimizing HRV status will assist in both achieving athlete autonomic cardiac compensation to competition as well as enhancing recovery. These approaches are likely to help athletes nearest to achieving their full potential and minimizing risk of injury.

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