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Acute muscle damage as a metabolic response to rapid weight loss in wrestlers

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Abstract

Study aim: Dietary and non-dietary weight loss methods are highly prevalent among combat sports athletes (CSA). Most CSA undergo rapid weight loss (RWL) usually a week before the competition to reduce their body mass and thus compete in the lowest weight category possible. The objective of the study was to distinguish the impact of high-intensity sport-specific training (HISST) combined with RWL (phase 1 – P1) on muscle damage markers as well as the effects of HISST alone (phase 2 – P2).
Material and methods: This crossover study was carried out on 12 male wrestlers. It consisted of initial measurement (IM), high-intensity training combined with RWL of 5% (P1), and high-intensity training without RWL (P2). After each phase, muscle damage markers were measured, including myoglobin, aldolase, creatine kinase, aspartate aminotransferase, alanine aminotransferase, and lactate dehydrogenase.
Results: A substantial increase in analyzed biomarkers was evident in both phases (P1 and P2). However, higher levels of almost all biomarkers were observed in the phase that included RWL compared to the second phase, with a greater significance level.
Conclusions: Our study revealed that 5% RWL combined with HISST impacted the assessed biomarkers to a greater extent than HISST alone, thus providing strong evidence of the influence of RWL on muscular damage in wrestlers. In order to minimize the adverse health-related effects induced by weight reduction, coaches and athletes should use caution when considering weight management methods.

Key words: Weight reduction – Combat sports – High-intensity training – Martial arts – Muscle metabolism

Introduction

Optimizing body composition in various sports can contribute to a competitive advantage [34]. Combat sports such as wrestling are highly demanding from the physical, physiological, and metabolic standpoint. Wrestlers achieve an average of 3–4 victories during a competition to reach the medal fight. Accordingly, among considerable physical and mental preparation, an athlete must also maintain high energy levels to withstand vigorous bouts on a competition day. Besides strenuous training, wrestlers often undergo rapid weight loss (RWL) procedures to compete in a desired weight class [32]. Acute body mass reduction is a widely known phenomenon amongst combat sports athletes (CSA). It has been established that most CSA implement some weight-cutting techniques before a competition [5]. CSA often use various weight cycling strategies since heavier fighters are considered to have an advantage over lighter fighters [7, 13, 26, 29]. These strategies are characterized by reducing around 5% of an athlete's body mass within the last week before the

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competition [17]. The most prevalent RWL methods practiced by CSA are fluid and caloric intake reduction, increased physical activity, plastic suit training, sauna use, heated room training, and prohibited substances such as diuretics and laxatives [1, 5, 23, 32].

Scientific evidence suggests that certain weight-control behaviors are particularly common among wrestlers and might even influence eating disorders [8]. Researchers have warned of potential negative consequences of RWL, such as lean body mass reduction, dehydration, and depletion of intramuscular glycogen depots, which could reduce performance among competitors in combat sports [2]. Additionally, harmful effects of RWL on various body systems have been reported. Namely, it can instigate acute kidney damage due to intentional dehydration [22] and negatively affect psychological well-being and mood [9, 11, 12, 16]. Furthermore, it has been found that Olympic-style wrestlers may suffer nearly twice the injury rate during weight reduction periods compared to regular training [19] and it can impact hormone disturbances and restriction of normal growth patterns in younger athletes [15].

Muscle damage (MD) is typical in professional and amateur sports, and the causes can differ. It can be provoked by long-term intensive training or metabolic or mechanical factors [4]. Therefore, highly demanding training and rapid weight reduction ahead of the competition could elicit skeletal MD and increase the risk of damage to other tissues [33]. Depending on the cause of the MD, there are indicators by which such changes can be monitored.

We used a set of reliable biochemical markers to gain insight into muscular adaptation to high-intensity sport-specific training (HISST) and RWL. In addition to the loss of muscle function and reduced force production, MD is accompanied by an increase in myoglobin (Mb) concentration and creatine kinase (CK) activity in the bloodstream [6, 28]. Along with the mentioned indicators, enzymes such as aldolase (ALD), aspartate aminotransferase (AST), alanine aminotransferase (ALT), and lactate dehydrogenase (LDH) are also considered plausible markers for assessing muscle tissue adaptation to training [18, 25].

The literature suggests that intensive exercise can provoke damage to skeletal muscle tissue in athletes [4]. Bearing in mind that one of the most commonly practiced RWL methods is increased exercise (in terms of volume and intensity), whether the MD occurs due to extensive training or body mass reduction is still uncertain. The study aimed to establish the influence of HISST in combination with RWL on MD markers and the impact of HISST without RWL. Namely, the authors hypothesized that weight reduction together with high-intensity training would affect skeletal MD to a greater extent than the same specific training without RWL.

Material and methods

Participants

The sample of respondents consisted of 12 national-level Greco-Roman style wrestlers (average body weight 73.48 ± 4.52 kg, age 24.30 ± 5.10 years, body height 175.22 ± 3.68 cm). Each participant had attended a minimum of 10 h of training weekly for the past four years. Only those who had already implemented RWL techniques over the last 2 years were selected for the study. Before starting the experimental treatment, a detailed medical examination was performed to determine the athletes' health condition. The study was conducted in agreement with the Declaration of Helsinki. Ethical approval for the study was obtained by the Institutional Review Committee of the University of Novi Sad (Ref. No. 46-06-02/2020-1). All respondents were informed about the requirements of the research and the possibility of withdrawing from the study at any time. Written informed consent for participation in the study was provided by all respondents.

Body composition

A bioelectrical impedance Omron weight scale BF511 (Omron, Japan) was used to measure body composition, including body weight, body mass index (BMI), visceral fat, and muscle and fat mass percentage. Participants were instructed not to have dinner after 9 pm, as well as not to eat in the morning before the measurement. Body height was measured to the nearest 0.1 cm using a Martin anthropometer (GPM, Switzerland).

Experimental design

Following the initial measurement, the experimental treatment took place in two phases to examine the acute effects of RWL on biochemical markers of MD when HISST is performed together with body mass reduction (first phase – P1) and the effects of an identical training protocol (HISST) without weight loss (second phase – P2). Body composition and biochemical parameters were determined in all stages (IM, P1, and P2). HISST is a non-standardized test protocol created explicitly for highly trained competitive wrestlers and composed of performing throws and sprinting (15 s) interspersed with low-intensity running (45 s), as explained elsewhere [31].

In the first experimental phase (P1), the athletes were instructed to reduce their total body mass by 5% in relation to the values obtained at the initial measurement. In this phase, which lasted for 3 days, the athletes attended their regular training sessions and applied self-chosen RWL methods. On the last day of the P1 (3rd day), all the subjects performed the specific training session (HISST) in the morning, followed by the second measurement. Given that all participants were competitors, they regularly attended their training sessions between the phases (P1 and P2) as well as before the IM.

The experimental treatment's second phase (P2) was conducted 7 days after the first phase. In this phase, the influence of a single training session on body composition and biochemical parameters was examined. Also, the respondents did not reduce their body mass during P2. Body composition assessment and blood sampling were carried out immediately after the training session in the morning, 10 hours following the last meal. Weight measurements and body composition assessments were carried out by three researchers with expertise in the field of combat sports. Blood sampling was done by trained laboratory staff. Blood collection was performed immediately after body composition measurement in both (P1 and P2) phases by collecting an 8 mL venous blood sample into a serum BD vacutainer.

During each of the experimental phases (P1 and P2), upon completion of the high-intensity sport-specific training and body composition assessment, blood samples were taken to determine the following biochemical markers: Mb, CK, ALD, AST, ALT, and LDH (Figure 1). Biochemical indicators and markers of MD were determined in the polyclinic with the laboratory EUROLAB in Novi Sad, Serbia.

Blood sampling and analysis of biochemical and hematological parameters

Blood sampling was carried out as follows: During each of the measurements (IM, P1, and P2), blood samples were collected from the anterior cubital vein in the morning between 9 and 10 am, at least ten hours after the last meal (after HISST for phases P1 and P2).

An 8 mL venous blood sample was collected in test tubes (BD vacutainer). CK levels were measured using CK-NAC reagent (creatine kinase, activated by N-acetyl cysteine) by utilizing the Dirui apparatus recommended by the International Federation of Clinical Chemistry (IFCC). Determination of Mb concentration was carried out by the EIA method using the TOSOH diagnostic analyzer (Tosoh, Tokyo, Japan). Fructose-1,6-diphosphate (F-1,6-DP) was used to establish the levels of ALD. The reaction rate of ALD was measured by the subsequent reduction in absorbance at 340 nm due to the conversion of NADH to NAD+, RANDOX reagent.

Statistical analysis

The results are presented as mean values and standard deviations. Statistical analysis was performed with one-way repeated measures ANOVA (within-subjects design) and post hoc Bonferroni analysis using IBM SPSS Statistics for Windows, Version 20.0 (Armonk, NY: IBM Corp.). The Shapiro-Wilk normality test was performed to evaluate the

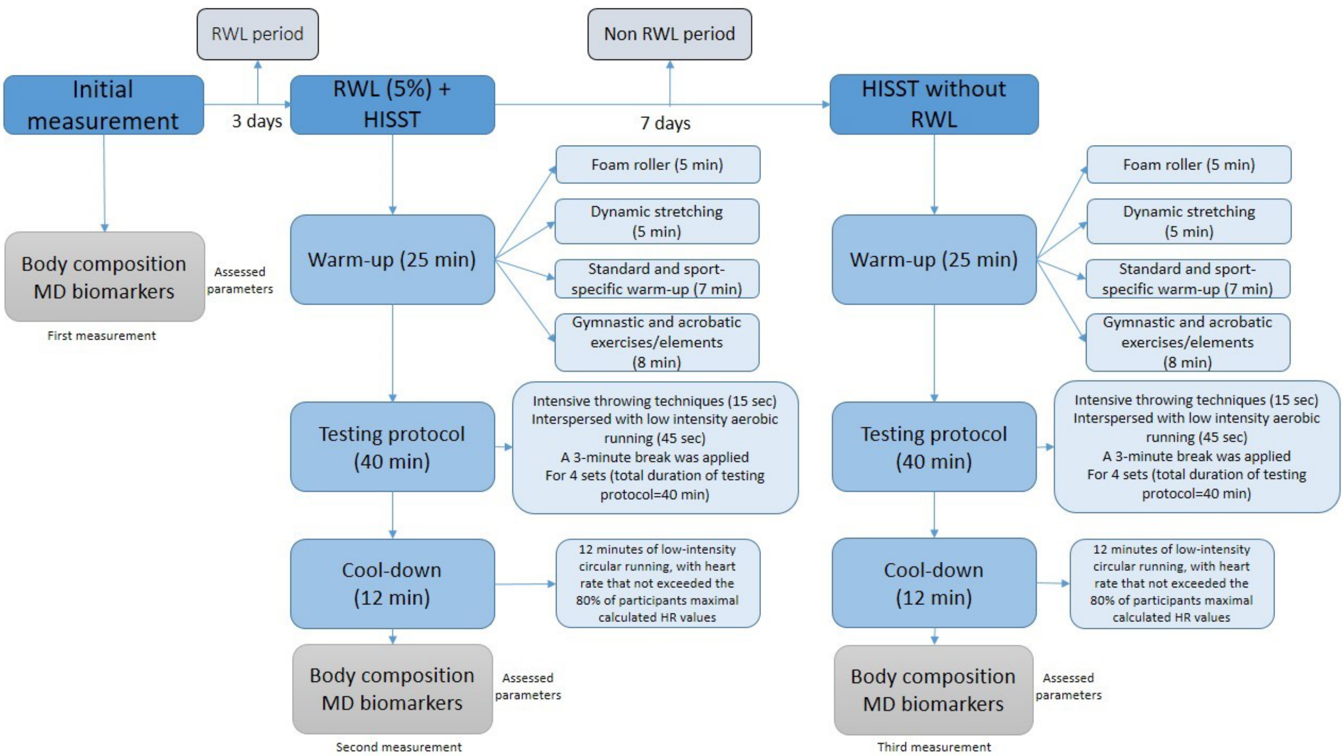

Figure 1. Flow chart of the study design

distribution of the variables. For all applied tests, the alpha level of statistical significance was determined at $p \leq 0.05$. The sample size for this study was calculated using power analysis (G-Power 3, Heinrich-Heine-Universität Düsseldorf, Germany) for the primary outcome measures (effect size d = 0.4, α = 0.05, power = 0.80).

Results

Body composition

Table 1 depicts the body composition parameters of the athletes during the initial measurement (IM) and the two experimental phases (P1 and P2). All examined parameters changed substantially within both experimental stages. Body mass decreased significantly following a 3-day RWL of 5% coupled with high-intensity specific training ($p \leq 0.001$). Consequently, BMI, fat mass and visceral fat decreased, while muscle mass increased in P1 ($p \leq 0.001$).

In P2, the body composition parameters also decreased but with a lower level of significance for BMI, fat mass ($p < 0.01$), and visceral fat ($p < 0.05$), and with an increase in the percentage of muscle mass ($p < 0.01$). Comparing P2 and P1, significantly higher body mass and BMI ($p \leq 0.001$) values were recorded, as well as for fat and visceral fat percentage ($p < 0.01$) in favor of the values obtained in P2. At the same time, participants demonstrated a lower muscle mass percentage ($p < 0.01$).

Biochemical parameters

Considerable changes in all analyzed MD biomarkers were noted in each experimental phase. Nonetheless, alterations in MD biomarkers were evident to a greater extent in P1 in each parameter except for ALT. The concentration of Mb increased significantly during P1 compared to the values obtained from the initial measurement, with an even higher level of significance ($p = 0.001$) compared to the second phase ($p = 0.002$) (Figure 2). Both in P1 (252.05 ± 123.51 ug/L) and P2 (236.70 ± 162.14 ug/L) Mb concentration exceeded the normal reference range (0.0–73.0 ug/L). Increased ALD activity was observed during P1 and P2 (7.54 ± 2.83, $p = 0.003$ and 7.63 ± 4.21 U/L, $p = 0.027$, respectively) compared to the initial measurement, and the values were at the upper limit of the normal reference range (0.0–7.6 U/L) in both phases.

CK activity was significantly increased during P1 ($p = 0.000$) and P2 ($p = 0.042$), whereas higher values were obtained in P1 (514.22 ± 201.66 U/L) in comparison to P2 (504.11 ± 432.29 U/L). Serum CK values were elevated more than twice the upper limit of the reference range (26–200 U/L) in each phase. AST values were also increased during the first ($p = 0.009$) and second ($p = 0.026$) experimental phases. Serum ALT level was significantly higher during P2 compared to IM (37.77 ± 11.22 U/L, $p = 0.008$). Elevated LDH levels were observed in the experiment's first (238.55 ± 56.00 U/L, $p = 0.001$) and second (211.00 ± 40.00 U/L, $p = 0.018$) phases, with the values in P1 exceeding the upper limit of the reference range (81–234 U/L). No statistically significant differences were observed between P1 and P2 for all the parameters.

Discussion

This study investigated the influence of HISST combined with an RWL of 5% and the same training without RWL on MD markers. Based on the obtained results, HISST with RWL has a remarkable effect on MD markers compared to HISST without RWL.

The body composition parameters changed in both P1 and P2, while a higher level of significance was recorded in P1.

Few studies have monitored biochemical markers in response to vigorous physical activity in combat sports. A study carried out by Kinaci et al. [20] demonstrated an increase in circulating biomarkers after a single bout in wrestlers. MD markers (CK, ALT, and AST) increased significantly after a six-minute match ($p < 0.01$). Such results are in accordance with our study, as the levels of CK, ALT, and AST ($p \leq 0.05$, $p < 0.01$, and $p \leq 0.05$, respectively) were

Table 1. Body composition of wrestlers at three time points (n = 12)

	IM	P1	P2
Body mass [kg]	73.48 ± 4.52	69.18 ± 3.98***	72.98 ± 4.26‡‡‡
BMI [kg/m^2]	24.08 ± 0.95††	22.72 ± 0.97***	23.85 ± 1.02‡‡‡
Fat mass [%]	16.45 ± 2.41††	12.64 ± 3.12***	14.95 ± 2.44‡‡
Muscle mass [%]	42.55 ± 1.39††	44.59 ± 2.10***	43.46 ± 1.69‡‡
Visceral fat [%]	6.13 ± 1.04†	4.86 ± 1.17***	5.64 ± 1.34‡‡

Legend: Values are presented as arithmetic mean and standard deviation; IM – initial measurement; P1 – RWL and training phase; P2 – training phase only; BMI – body mass index; *** significantly different compared to IM, $p \leq 0.001$; ‡‡‡ significantly different compared to P1, $p \leq 0.001$; ‡‡ significantly different compared to P1, $p < 0.01$; †† significantly different compared to P2, $p < 0.01$; † significantly different compared to P2, $p < 0.05$.

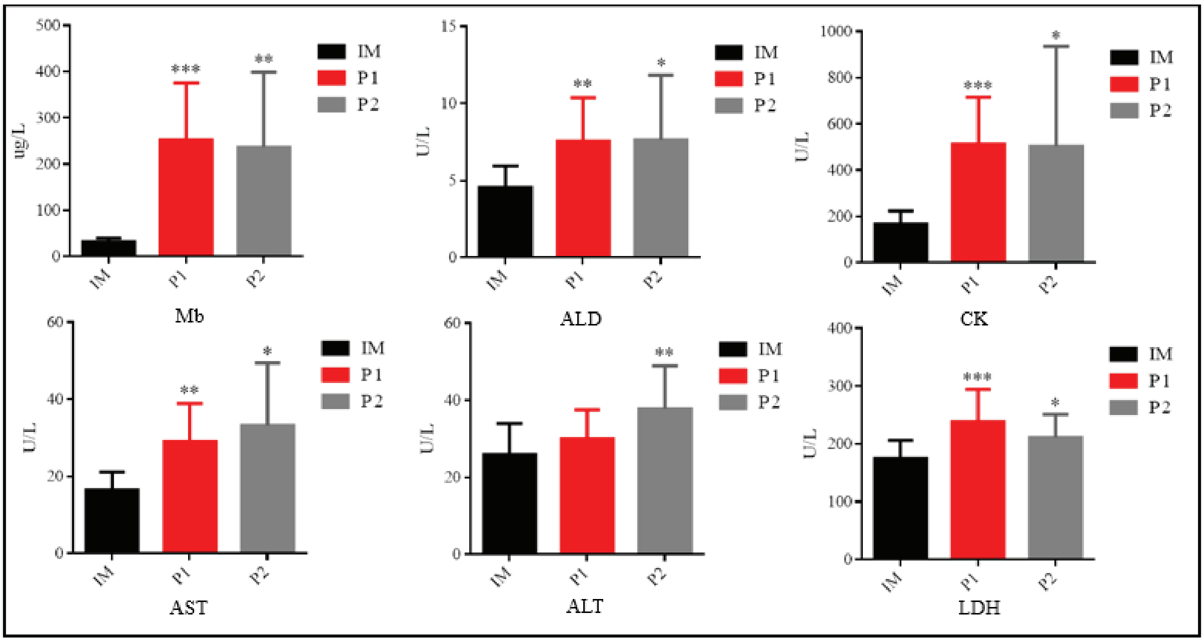

Figure 2. Effects of experimental treatment on biochemical muscle damage markers

Legend: IM – initial measurement; P1 – RWL and training phase; P2 – training phase only; Mb – myoglobin; ALD – aldolase; CK – creatine kinase; AST – aspartate aminotransferase; ALT – alanine aminotransferase; LDH – lactate dehydrogenase; *** significantly different compared to IM, $p \leq 0.001$; ** significantly different compared to IM, $p < 0.01$; * significantly different compared to IM, $p \leq 0.05$.

elevated after P2. Additionally, simulated five-match tournaments caused CK elevation after each bout in elite Greco-Roman style wrestlers following ~6% weight loss. However, CK values peaked after the last match [3]. Comparably, the post-match circulating CK level in freestyle wrestlers increased after a two-day tournament following the same percentage of weight loss [21]. Progressively elevated CK, with the highest values recorded on the second day, might have resulted from the previous 3 bouts completed on the first day of the competition. On the other hand, insignificant CK and LDH increases were reported after a single training session consisting of a 20 m shuttle run test in Kyrgyzstan national team Greco-Roman wrestlers [10]. Considering such responses of athletes, the results of the study may imply that highly trained and experienced athletes are well adapted to exercise of high intensities.

The scientific literature which concerns weight management and biochemical markers in wrestlers is rather scarce. Isik et al. [14] reported significant muscular damage due to ~5% weight loss in junior freestyle wrestlers, as an increase in ALT, LDH, and CK levels was recorded. Additionally, a similarly designed study demonstrated that dehydration and daily training could provoke a significant increase in serum AST, LDH, and CK levels in wrestlers [27]. Athletes reported RWL methods such as fluid and food restriction, together with strenuous exercise and using a sauna to lose weight over 1-7 days. However, the mentioned study did not specify the extent of fluid and food restriction, which can contribute to biomarker variation. For instance, it was found that a 3-day RWL of 5% among judokas caused a significant elevation in Mb, CK, and ALD levels [30], which is highly comparable to the results of our study, as judo and wrestling are considered analogous sports. Apart from combat sports, there is evidence that RWL negatively affects strength and sport-specific performance in other sports as well [35].

All respondents in our study reduced their body weight by 5% using self-chosen RWL methods by performing intensive specific training in P1, whereas in P2 only the HISST was carried out. It is interesting to highlight that the values of MD markers during P1 were greater than P2. Based on the obtained results, it is evident that RWL with HISST can lead to significant MD. It is crucial to emphasize that the values of CK and Mb were elevated over the upper limit of the reference range, which indicates a high degree of muscle function impairment.

Losing weight rapidly is unsustainable from many perspectives, as reducing body mass too quickly could lead to various issues. Undoubtedly, such behaviors lead to metabolic adaptations, further affecting athletes' performance and health. Thus, intentional weight reduction methods among wrestlers attracted the attention of physicians, sports workers, and scientists. Sports scientists have a key role in providing the background knowledge to encourage athletes to avoid or change common weight loss strategies to conserve energy and minimize adverse effects. In order to prevent the practice of manipulating athletes' body mass, one of the recommendations could be to encourage the sporting organizations to bring the official weigh-ins of the competitors closer to the beginning of the competition itself. In that case, athletes would not have enough time to regain body mass drastically, thus achieving a significant weight advantage over their opponents. Second, body weight reduction should be approached gradually by modifying the diet in such a way as to achieve small energy deficits.

Despite the adverse health-related consequences, CSA still undergo voluntary weight cycling procedures. Bearing this in mind, more studies are needed to explore the phenomenon of RWL and modalities to overcome all its adverse outcomes.

This study has some limitations that should be pointed out. The number of subjects participating in this study was limited to twelve male athletes. Moreover, the RWL methods employed by athletes were not reported. Additionally, HISST presents a non-standardized training protocol designed to emulate high-intensity training sessions in wrestlers. Further, serum aminotransferases lack the tissue specificity to allow researchers to differentiate muscle injury from liver injury [24]. Although the sample consisted mainly of national-level competitors, it included 3 gold medalists at the Youth U23 National Championship who regularly participated in international competitions. On the other hand, selecting highly conducive biochemical markers for analysis to monitor MD throughout the study could be considered a strength. No studies are available related to the degree of MD caused by exercise-provoked MD versus RWL and exercise-induced MD in wrestlers.

Conclusion

Particular attention should be paid to the global weight reduction phenomenon in CSA due to potentially harmful health consequences. The results obtained in this study demonstrated that HISST with RWL (5% of body mass) induces an increase in the assessed biomarkers to a greater extent than HISST without RWL. Such a finding corroborates the meaningful influence of body mass reduction strategies on muscular damage in wrestlers. Coaches and athletes must be aware of the harmful metabolic response that weight reduction can cause. Considering that fact, future research in this area is essential to provide them with safer and more efficient approaches to weight management.

Conflict of interest: Authors state no conflict of interest.

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