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Original Article

Dehydration, skeletal muscle damage and inflammation before the competitions among the elite wrestlers

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Abstract. [Purpose] The present study aimed to identify weight-loss and hydration levels before competitions among elite wrestlers and determine the skeletal muscle damage and inflammation levels after dehydration. [Subjects] Seventy-two elite wrestlers who participated in the Turkish Wrestling Championship. [Methods] With the help of specialists, 5 cc of blood were drawn from the forearm veins of the wrestlers. Laboratory analyses of Na^+, BUN, Glucose, CK, LDH, AST, ALT, C-RP levels were performed. Using a mathematical formula for hydration the P_{Osm} levels of the athletes were calculated. [Results] The wrestlers were divided into two groups based on hydration status. There were significant correlations between hydration indicators of Na^+, BUN and PBWL values. There were significant differences between AST, LDH, CK values and skeletal muscle damage indicators of the two groups, but there were no significant differences between the inflammation levels and C-RP values of the groups. [Conclusion] No differences existed in inflammation levels among the wrestlers, although dehydrated wrestlers suffered from higher level of skeletal muscle damage than wrestlers who were not dehydrated.

Key words: Dehydration, Skeletal muscle damage, Inflammation

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INTRODUCTION

The amateur wrestling community and maybe the entire sports community across the world were shocked by the deaths of 3 college wresters in the USA in six weeks in 1997. The deaths of the athletes were attributed by autopsy to weight-loss performed in a short time the victims having undergone dehydration of up to 15%[1)]. Following these deaths in 1997, the National Collegiate Athletic Association (NCAA) initiated and developed new safety precautions in order to prevent unsafe weight practices[2)]. After studies of this subject, NCAA decided that competition-weighing should be conducted nearer to the competitions and new weight classes should be determined by adding nearly +3 kg to each weight class[3)]. Besides, NCAA recommended that weekly weight-loss should not exceed 1.5% of body weight as a part of the Wrestling Weight Certification (WWC) program[4)]. However, the most important reason why athletes lose weight is that they want to compete in the lowest weight-class possible, and they think that the time between weighing and competition (~16 hours) is sufficient for rehydration after dehydration[5)]. Nevertheless, studies report that this time period of ~16 hours is not enough to regain the body-weight lost[6)] and dehydration decreases athletes' performances, too[7)]. It was reported that when athletes of particularly combat sports such as judo, karate, boxing and wrestling perform excessively severe dehydration in a short time (1–7 days), they undergo some hematologic changes[8, 9)]. There would be changes not only in P_{Osm} levels, but also in Na^+, BUN and glucose levels due to P_{Osm}[10, 11)]. It was reported that athletes who perform weight-loss before competitions undergo not only change their hydration status, but also experience health problems such as sleep disorders, learning and memory difficulties, anxiety, depression, irregular body temperature, vasoconstriction, low sexual performance and dysfunctions in skeletal muscles[12)].

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Skeletal muscle damage can be hematologically detected by analyzing serum levels of CK, and such indicators as LDH, AST and ALT enzymes in the cells of many tissues[13]. The most important indicator of skeletal muscle damage is serum CK level, because CK in skeletal muscle tissues is the enzyme that exists in higher amounts in the sarcolemma and mitochondrial cells of healthy muscle cells, and is primarily responsible for regulating anaerobic metabolism[14]. Observing serum CK and LDH levels may provide useful information about the status of the muscles and their adaptation to physical load because serum CK and LDH levels demonstrate the degree of metabolic adaptation of skeletal muscles to physical exercise. Both enzymes exist in muscle metabolism and their serum intensity is rather low. These values increase considerably after intense exercise[15].

In physical tissue damage and other inflammatory conditions, C-RP is the main acute phase protein and a very sensitive and objective indicator[16, 17]. Indeed, Abramson and Vaccarino reported that the C-RP level increased after one exercise dependent on the duration and intensity of the exercise[18]. On the other hand, Booth et al. reported that C-RP, which was one of the indicators studied in a 12-day military exercise, was 5.00±5.9 g/L before the military exercise, but 1.2±1.2 g/L after the military exercise[19]. It was also reported that the serum C-RP level of athletes increased with one exercise protocol[20], but in prospective studies; that the serum C-RP level of the athletes decreased[21].

There are studies in literature of dehydration, skeletal muscle damage and inflammation among elite wrestlers[22–24]. However, no study has been conducted to determine whether skeletal muscle damage or inflammation occur with dehydration. Accordingly, the present study aimed to identify weight-loss and hydration levels before competitions among elite wrestlers and explore skeletal muscle damage and inflammation levels after dehydration. Trainers and athletes will benefit from information on skeletal muscle damage and inflammation levels caused by dehydration.

SUBJECTS AND METHODS

The study subjects were 72 volunteer elite wrestlers who competed in the Turkish Inter-university Wrestling Championship A Division, who had at least 5 years sport experience and did at least one exercise on a daily basis. The participant athletes were asked not to use any kinds of medicine or ergogenic aids within 48 hours before competition-weighing in order to ensure standardization of the subjects and those who used medicines or ergogenic aids were excluded from the study. During the study period, no disease that could affect the blood values of the athletes was detected, but three athletes were excluded from the study because their CK levels were above 1,000 U/L (hyper-responder) and their values were considered as lost data. The study was completed with 69 elite wrestlers (22.51±2.49 years, 174.54±6.59 cm, 78.98±15.87 kg and BMI 25.73±3.77 kg/m^2).

The details of dehydration protocols (how long, between which time-periods, with what methods the elite wrestlers achieved weight-loss) were datails of dehydration protocols. Wrestlers reported that they lost weight 1–7 days before competitions through food and fluid restrictions, sauna and exhausting exercises. In the literature, euhydration is accepted to have a reference range of 280–290 mOsm/L. Thus, wrestlers with P_{Osm} ≤290 were assigned to the dehydrated group and those with P_{Osm} >290 to the not dehydrated group[25]. Dehydration was calculated using the formula below:

P_{Osm} = (2* NA)+(BUN/2.8)+(Glucose/18)[26].

Casa et al. determined 1% of dehydration as satisfactory dehydration, >1–3% of dehydration as mild dehydration, >3–5% of dehydration as high dehydration, and >5% of dehydration as severe dehydration[27]. The percentage of Body Weight-Loss (PBWL) calculation was performed using the formula below:

Body Weight Change=[(Pre-Body Weight − Post-Body Weight)/Pre-Body Weight] × 100.

With the help of specialists, 5 cc of blood was drawn from the forearm veins of the participant wrestlers into 8.5 mL tubes of a Vacuatiner blood collection system at the competition place and at the weighing time (one day before the competition, between 06:00 and 06:30 pm) and transported to the laboratory for centrifugation.

The blood samples were centrifuged with a Nüve NF-400 for 5 minutes at 4,000 RPM. For each athlete, serums extracted from blood was preserved in two different Eppendorf tubes under −20 °C until the time of analysis. On the day of the analysis, samples were stood at room temperature for 1 hour and dissolved. Biochemical analyses [hydration indicators (NA^+, BUN, Glucose) and analyses of Skeletal Muscle Damage indicators (AST, ALT, LDH, CK)] were performed using a Beckman Coulter AU2700 Plus biochemical auto-analyzer with Beckman Coulter kits, while hormone analyses were Roche Hitachi Cobas e601 auto-analyzer with Roche kits. C-RP analyses were performed using a Beckman Coulter IMMAGE 800 nephelometer autoanalyzer with Roche kits.

Data was tested for normality with the Kolmogorov Smirnov test. The independent Samples T Test was used to compare pairwise group variables that followed a normal distribution, and ANOVA was used for more than two groups. Following variance analyses; LSD multiple comparison test was employed in order to detect which measurement results caused the differences. Significance was accepted for values of $p<0.05$ with a 95% confidence interval.

RESULTS

The responses to the questionnaire show that 55.07% of the elite wrestlers underwent fast weight-loss just before the

competition (1–7 days) (4.55%±1.87). The wrestlers who underwent fast weight-loss had higher levels of P_{Osm} (296.05±3.14) above the upper limit of reference value (over 290) and suffered from dehydration. When intergroup hydration indicators were assessed, it was found that the Na^+, BUN and PBWL levels of the wrestlers who were dehydrated were higher than those of the wrestlers who were not dehydrated ($p<0.05$), but no differences existed between the groups in terms of glucose levels ($p>0.05$; Table 1).

When skeletal muscle damage and inflammation differences of the elite wrestlers were examined in relation to hydration status, differences in AST, LDH and CK levels ($p<0.05$) were found, whereas no differences existed between the groups in terms of ALT and C-RP levels ($p>0.05$). Although there were differences between the groups in terms of AST (upper limit: 50 U/L) and LDH (upper limit: 248 U/L) values, these values were within the reference ranges. However, CK levels (upper limit: 171 U/L) of both groups were higher than the reference range (Table 2).

According to the classification made by Casa et al. when investigating skeletal muscle damage and inflammation indicators of the athletes. There were differences between the groups in terms of AST, LDH, and CK levels ($p<0.05$), but there were no differences between the groups in terms of ALT and C-RP levels ($p>0.05$; Table 3).

DISCUSSION

Generally, many athletes perform fast weight-loss just before competitions (within 1–7 days) so that they can adapt themselves to different weight classes or compete against rivals who are less strong and weaker than them in order to gain advantage. Weight loss results in dehydration among the athletes by affecting their hydration levels negatively. Studies of dehydration report that dehydration can be detected with urine specific gravity (usg) as well as serum P_{Osm}[2, 28]. When the P_{Osm} value is ≤290, hydration is considered normal (euhydration), when it is >290, hydration is lower than the normal level (dehydration)[25]. In the present study, 55.07% of the elite wrestlers underwent fast weight-loss just before the competition

Table 1. Comparison of hydration indicators of wrestlers in terms of hydration status

	N	Hydration status	Reference range	$\overline{X} \pm \sigma$
Na^+ (mmol/L)	31	Dehydrated	136–146	142.5±1.6**
	38	Not dehydrated		137.5±2.7
BUN (mg/dl)	31	Dehydrated	8–20	16.4±3.4*
	38	Not dehydrated		14.3±3.6
Glucose (mg/dl)	31	Dehydrated	74–106	97.0±15.8
	38	Not dehydrated		97.1±12.5
P_{Osm} (mOsm/L)	31	Dehydrated	280–290	296.1±3.1**
	38	Not dehydrated		285.3±5.2
PBWL (%)	31	Dehydrated	-	4.6±1.9**
	38	Not dehydrated		1.0±1.3

*p<0.05, **p<0.01, $\overline{X}$: mean, σ: standard deviation, Na^+: sodium, BUN: blood urea nitrogen, P_{Osm}: plasma osmolarity, PBWL: percentage of body weight loss

Table 2. Comparison of skeletal muscle damage and inflammation indicators of the wrestlers in terms of P_{Osm} levels

	N	P_{Osm} (mOsm/L)	Reference range	$\overline{X} \pm \sigma$
AST (U/L)	31	Dehydrated	0–50	24.9±6.3*
	38	Not dehydrated		21.5±4.5
ALT (U/L)	31	Dehydrated	0–50	14.2±9.0
	38	Not dehydrated		14.0±7.3
LDH (U/L)	31	Dehydrated	0–248	207.2±37.2*
	38	Not dehydrated		185.8±27.6
CK (U/L)	31	Dehydrated	0–171	421.0±174.0**
	38	Not dehydrated		175.8±80.7
C-RP (mg/dl)	31	Dehydrated	0–0.6	0.3±0.3
	38	Not dehydrated		0.3±0.3

*p<0.05, **p<0.01, AST: aspartate aminotransferase, ALT: alanine aminotransferase, LDH: lactate dehydrogenase, CK: creatine kinase, C-RP: c-reactive protein, P_{Osm}: plasma osmolarity

(1–7 days) (Table 1). The level of P_{Osm} of the wrestlers who underwent fast weight-loss was above the reference range (upper limit: 290) (296.05±3.14) and they suffered dehydration of 4.55%. These results of P_{Osm} level of the wrestlers were similar to the results of usg[29, 30].

Serum Na^+ and BUN levels were higher among the dehydrated wrestlers due to the increase in P_{Osm}, but no differences were seen in their glucose values (Table 1). In the literature the Na^+ reference range is reported to be between 136–146 mmol/L. When the Na^+ concentration in a blood sample is ≤135 mmol/L it is defined as hyponatremia, and when it is ≥145, it is defined as hypernatremia[31]. It has been reported that the Na+ concentration generally remains high due to long-term physical activities and excessive sweating and deficiency in all body fluids, and that Na^+ gradually increases with time[32, 33]. It has been recommended that during exercises, athletes should keep serum Na^+ concentration within the reference range through a controlled diet[34], otherwise nervousness, over-reaction, lethargy, muscle contraction, spasticity, convulsions, coma and even mortality may occur.

It is our opinion that the differences in BUN values resulted from the fact that wrestlers did long-term exhausting exercises and/or adhered to food and fluid restriction programs for dehydration. Since BUN is closely associated with the metabolic functions of the liver, and the filtrating and excreting functions of the kidneys, dehydration may increase[35]. Indeed, the study of Mashiko et al. reported that according to measurements before and after a 20 day camp, rugby players lost weight and as a result their BUN levels decreased owing to weight loss[36].

The fact that there were no differences in the glucose values of the dehydrated wrestlers made us think that adrenaline increased by exercises converts glycogens stored in liver into glucose and glucose flows into blood with the help of glucagons and, as a result, regulates blood glucose levels. Differences in Na^+ and BUN values affect P_{Osm} values of the athletes and change their hydration status. It is stated that dehydration of 2–3% causes cognitive disorders, irregular body temperature, cardiovascular dysfunctions as well as reduced endurance and weakens muscle strength[37–39]. Besides, it is argued that dehydration may cause muscle damage among athletes.

There were significant differences in terms of the damage to skeletal muscles between the dehydrated wrestlers and not dehydrated wrestlers. This supports our study hypothesis. The differences between the hydration levels and the skeletal muscle damage was determined according to the classification of Casa et al., and in our study it was noted that there were significant differences in AST, LDH and CK, but no differences were found in ALT values (Tables 2 and 3) between the two groups. In the study of Nathwaniet et al., it was reported that serum levels of CK, LDH, AST, ALT increased following

Table 3. Comparison of skeletal muscle damage and inflammation indicators of the wrestlers in terms of PBWL classification

	N	PBWL (%) Classification	$\overline{X} \pm \sigma$
AST (U/L)	22	% 0–1	22.0±4.3[b]
	18	% >1–3	19.9±5.0[b]
	19	% >3–5	25.6±5.5[a]
	10	% >5	26.3±5.6[a]
ALT (U/L)	22	% 0–1	13.6±5.9
	18	% >1–3	14.1±7.6
	19	% >3–5	15.3±11.9
	10	% >5	13.1±3.2
LDH (U/L)	22	% 0–1	182.6±24.1[c]
	18	% >1–3	188.0±38.6[cb]
	19	% >3–5	203.2±25.8[ab]
	10	% >5	222.2±41.1[a]
CK (U/L)	22	% 0–1	191.6±89.6[b]
	18	% >1–3	214.4±125.1[b]
	19	% >3–5	364.5±170.8[a]
	10	% >5	472.9±226.3[a]
C-RP (mg/dl)	22	% 0–1	0.3±0.2
	18	% >1–3	0.4±0.3
	19	% >3–5	0.3±0.2
	10	% >5	0.4±0.3

[abc] Represents the differences among the groups. AST: aspartate aminotransferase, ALT: alanine aminotransferase, LDH: lactate dehydrogenase, CK: Creatine Kinase, C-RP: C-reactive protein, PBWL: percentage of body weight loss

muscle damage[13]. Under normal conditions, these elevated levels may be tolerated by the athletes with nutritional and relaxation programs, but among the dehydrated athletes, metabolism consumes low levels of carbohydrate due to food and fluid restrictions and uses an energy combination of fat and proteins; thus, glucose inhibition occurring with high plasma and free fat acids suggest that the damage to the muscles of the wrestlers would continue[40, 41].

In clinical practice, CK, LDH, AST, ALT were commonly used for the diagnosis of skeletal muscle diseases and skeletal muscle tissue damage[42]. The most important indicator of muscle tissue damage is the serum CK level[43]. The LDH level is accepted to be a specific indicator of fatigue[44, 45]. AST, being a cytoplasmic and mitochondrial enzyme, may increase in many clinical disorders, but ALT has been reported to be a specific indicator of liver damage[13]. In our study, serum CK and LDH levels, important damage indicators, were higher in the dehydrated group than in the not dehydrated group. Among the dehydrated wrestlers, the high level of serum CK would have affected their performance negatively as well as restricted their movements because of muscle pains. It is also possible that the high level of serum LDH may cause wrestlers to be reluctant and/or unwilling for the next exercise. When aminotransferases were investigated, levels of AST and ALT were increased. However, while there was a significant difference in AST levels, no significant difference was seen in ALT level, which demonstrates that AST exists in higher amounts in skeletal muscles than ALT. Serum levels of all these damage indicators reduced after exercises and correlated with relaxation and feeding after exercises[46]. All of the participant wrestlers reported that they did daily exercises and training. Therefore; it is our opinion that the high level of skeletal muscle damage among the dehydrated wrestlers was caused by food and fluid restriction following exercises.

C-RP is a major acute phase reactant that increases acutely and quickly in response to tissue damage and infection[47]. In a systematic study of C-RP, it was found that as an acute phase response, C-RP temporally increased after a single exercise protocol among trained athletes. However, in prospective studies, it was demonstrated that C-RP (pretest-posttest) levels of the exercise groups reduced. In other words: although physical activity increased C-RP levels, chronic physical exercises reduced C-RP levels[48].

C-RP levels of the participant athletes of both groups were low and no difference existed between the groups. Considering the fact that these athletes had a sportive experience of at least five years, it was expected that they would have increased tissue oxygenation because of having regularly exercised for years.

UWW (United World Wrestling) shortened the resting-time in competitions of the wrestling championships, aiming at muscle endurance among the wrestlers. In a wrestling tournament, wrestlers usually have five bouts. Considering that bouts continue until the qualifications, semi-finals and even finals, time between bouts will be short, and resting-time not be sufficient for full recovery, lowering the performance of wrestlers who lose weight. Therefore, losing weight is not a rational competition approach.

In summary, fast and/or higher levels of weight loss before a competition produced differences in wrestlers' hydration indicator levels. Damage in skeletal muscles of the dehydrated wrestlers was greater than in those hydrated, but no difference was found in the inflammation levels of the groups. If it is necessary to lose weight before a competition, athletes should do it in a way to achieve a gradual and extended weight loss over a period of time depending on the weight loss targeted. In addition, while athletes are losing weight, they should keep levels of hydration and skeletal muscle damage indicators within their reference ranges through ergogenic aids. Thus, ergogenic aids will play a mediator role for wrestlers wishing to demonstrate maximum performance and to lead a healthy life.

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