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The Effect of Acute Dehydration and Rehydration on Biomechanical Parameters of Elite Wrestling Techniques

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Abstract: The aim of this study was to investigate the effect of weight cutting and 18 hours rehydration in wrestlers' techniques performance. Methods: twenty-five men elite wrestlers participated in study, they randomly are divided into: group A (age of 18.38 ± 1.32 years, height 1.70 ± 0.04 m, weight 71.11 ± 11.80 kg) and group B (age of 21.00 ± 2.08 years, height 1.75 ± 0.04 m, weight 76.25 ± 12.55 kg). Body composition, biomechanical analysis were measure before dehydration, after weight cutting and after 18 hours rehydration. All subjects were dehydrated 3.5% of their body weight. Group A lost body weight in sauna and group B dehydrated according to active method. Single takedown technique's biomechanical parameters are measured in six points of body (both side). Three dimensional motion analysis and Skillspector software (version 1.3.2) is used to calculated right and left shoulder, pelvis, and knee linear velocity, left/right trunk, thigh segment angular velocity, and position. Reflective body markers attached all of the subjects' joints, and we used hero 3 camera @15fps/1440 p. Results with repeated measure and independent T-test showed that biomechanical characteristics decrease significantly after weight cutting ($P < 0.05$). Compare groups showed that dehydration by sauna have significantly more negative effect than active method. 18-hour rehydration period is not sufficient for recovery.

Key words: Three dimension, motion analysis, weight cutting, single takedown, kinetics, kinematics.

1. Introduction

Coaches and wrestlers believe that the best weight is below normal weight to obtain a competitive advantage [1, 2]. It is common knowledge that rapid weight reduction (weight cutting) is a wide spread practice among elite and amateur wrestlers around the world. This weight cutting involves exercise and heat disposal and passive dehydration and fluid and food restriction. This is despite the fact that there is short time to replace fluid, carbohydrate stores, electrolytes and minerals prior to competition. In that, several studies have looked at the effects of dehydration with different values and methods on bodyweight (dependent muscle performance), vertical jumping ability, sprint running, and any strength tests over the past decades. Now is the time to evaluate by the use of motion analysis methods and biomechanical methods to study effect of dehydration on Performance and implementation of the techniques [3, 4].

Biomechanics is the knowledge that studies the formation and function of biological systems using rules and procedures of mechanics in elite sports biomechanics quantifies and describes what exactly happens during a sports performance emphasizing on the technique of the athletic movement [5, 6]. Using two and three dimension motion analysis are common methods to describe kinetics and kinematics patterns between researchers. Some variables and parameters can be measured for example anthropometric parameters, segmental kinematics, external forces and moments, muscular electrical activity and metabolic energy. Although wrestling involve activities such as pulling, pushing, squatting, squeezing, twisting, etc, a successful outcome is more a result of technique and joints kinetics than of total body strength or speed, provided that a certain level of strength has been

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developed to allow the mastering of the technique Moreover, a wrestler's major purpose in competition is to disturb its opponents balance by mainly applying rotational forces in an optimal manner, i.e. using an optimal technique. This optimal technique is the product of the wrestler's physical capacities and mental skills and consists of several interrelated simple or more complex movements of his segments in all of his joints [7-9]. Proving the negative effects of weight cutting in the implementation techniques of sports is an important factor in athletic performance and injury prevention, especially in wrestling.

Kinetics and kinematics are effect by muscle strength, body mass, power and other physiological parameters. For example to compute linear momentum, the mass and velocity of an object must be known so if body mass changed, linear momentum will change [9]. Dehydration could be change body weight, body mass, fat mass, lean body mass, et al. Weight cutting have negative effect in body endurance, strength, muscle anaerobic power and muscle anaerobic capacity [9, 12-16] and psychomotor performance [16-18]. Food and fluid deficit during weight cutting seems to affect the psychological state of the athletes negatively as well, increasing tension, anger, fatigue, and confusion as well as decreasing vigor [18-20]. Dehydration has neurological impacts in central nervous system (CNS) and peripheral nervous system (PNS), control posture and locomotion of body done by cerebral cortex, and weight cutting have inhibitory effect on neurons, and they are unable to fire and trigger movement in the muscles [21]. Some studies have shown that acute dehydration and rehydration are not affected physical and mental characteristics of athletes [4, 12, 22-25].

For this reason, biomechanical ways should also examine the impact of weight cutting and give appropriate information to athletes, coaches and all sporting federations. By investigation, the effects of dehydration on the biomechanical parameters can be a deterrent to prevent dehydration among the wrestlers. A three-dimensional analysis has to be done for rotating or more complex movements, such as wrestling, judo, soccer, gymnastic etc. Therefore 3D motion analysis requires at least two cameras. Most movements require four or more cameras. This study used three cameras, calibration frames, and body markers to analyze single-leg takedown technique. Motion analysis methods are good technique to evaluate the effect of acute dehydration and rehydration on wrestling technique performance. In this study, we have evaluated the single takedown's biomechanical parameters (linear velocity, linear position, angular velocity and linear momentum) [23, 26, 27]. Single takedown technique is widely used in World Championships and Olympic games.. Until now, no research used a three dimensional motion analysis to calculate changes in biomechanical parameters relation to weight cutting [23].

2. Methods

2.1 Experimental Protocol

The wrestlers arrived at the gym at 12:00 PM and consumed a standardized breakfast and drank 500 ml of water before pre-test trial to ensure a normal hydration status [28-30]. Before, we put the three high-speed camera (hero three 15fps/1440 p) and calibration cube tasks was done. One hour later, subjects voided their bladder as completely as possible and a nude body weight and body composition data was measured on a precision scale (Tanita, TBF-300A Body Composition analyzer, Japan, weighing accuracy of ±10 g) [30, 31].

At 2:00 PM, the subjects in exercise group ran on a treadmill (Johnson T8000 USA) at a pre-test intensity of 65% VO_{2max} for 90 minutes in an environmental chamber (25 ± 0.1℃) to dehydrate by 3.5% body weight. One day ago, Balke treadmill test is used to determine maximum oxygen uptake (VO_{2max}) [30, 32]. After completing the dehydration exercise, a first post-test was taken. Passive group (Sauna 60-70℃) sat in the sauna three times for a period of 60 min. (3 × 20 min with 5 min rest interval) and submitted their weight variations and exercise groups and after

completing the dehydration, a first post-test was done.

Second post-test was performed 18 hours after weight cutting and rehydration step control by same foods and fluids during training camp. All subjects participated in a pre-test and post-tests and performed a single leg takedown technique 3 times, and all of the movements were done without a competitor. Implement the techniques without opponent is very common among wrestlers. Calibration cube, high-speed camera, and reflective markers were used for video analysis. The camera positions were: First camera was placed in front at 2.30 m, and the second and third cameras were placed sideways at 3 m from the calibrated place on the mat. We built calibration cube at university. Reflective joint markers were placed on both sides of the body at (right/left acromion, Lateral epicondyle of the humerus, wrist-ulna, ASIS, knee, ankle, toe must be parallel with heel marker). Video recording was done with high-speed digital camera hero three@15fps/1440 p; Skillspector (Version 1.3.2) software was used for 3D video analysis. Full body model with 6 points was used for calculating kinematic parameter of movements. The following measurements were taken: linear and angular kinematic (points velocity, position, angular velocity). Data smoothing was done with the help of frequency filter.

2.2 Subjects

Twenty-five male elite wrestlers were selected from Yol sport gym in Erzurum, Turkey, to participate in this study (the subjects were in the training camp). The subjects were divided randomly into two groups, a Sauna, and exercise. The mean age, height, and weight of Sauna group were 18.38 ± 1.32 yrs, 1.70 ± 0.04 m, and 71.11 ± 11.80 kg, respectively. Exercise group's mean age, height and weight were 21.00 ± 2.08 yrs, 1.75 ± 0.04 m, and 76.25 ± 12.55 kg and maximum oxygen uptake 52.50 ± 1.55 ml kg^{-1} min^{-1}. All participants were free of injury or illness, and they used their guard side of their body as their dominant side and the unguarded side as their non-dominant side. The experimental protocol was performed in accordance with the Declaration of Helsinki for human experimentation and was approved by the university of Ataturk ethical committee. The subjects from the gym read and signed the informed consent form.

2.3 Statistical Analyses

The data are reported as mean ± standard deviation. We have measured each factor three times, so the average of this information was used as evidence. The normal distribution of data was determined by k-s test. The parametric and non-parametric tests such as repeated measures and Friedman were performed to compare the variables between pre-test and post-tests. Compare the differences between the two groups through the independent t test was conducted. Statistical analysis was performed by IBM SPSS version 21.

3. Results

According to Table 1 in sauna group, the body composition specification was shown, body weight was 71.11 ± 11.80 in pre-test time and 68.03 ± 11.41 in post-test1 after dehydration and 70.20 ± 11.90 in post-test2 after rehydration. This represented a mean dehydration of 2.84 ± 0.34 kg. Water replacement during rehydration was 2.17 ± 1.25 kg. Fat percent and fat mass were not change significantly but fat free mass (FFM) and total body water (TBW) were changed strongly. Also in exercise group, weight in pre-test was (76.250 ± 12.554), post-test1 (73.018 ± 11.999) and in post-test2 (75.548 ± 12.562). In order, dehydration and rehydration mounts were 3.228 ± 0.641 and 2.529 ± 0.939. The body composition changes showed that body fat percent and fat mass did not change significantly during tests and FFM and TBW changes significantly during test.

The means and standard deviations for the sample of points and segments are shown in Tables 2-4. According to the tables in sauna group's post-tests, weight

Table 1 Body composition measurements during all tests.

		Pre-test	Post-test1	Post-test2	In group	Pre-test vs Post-test1	Pre-test vs Post-test2
Weight (kg)	Sauna	71.11 ±11.80	68.03 ±11.41	70.20 ±11.90	0.001*	0.001*	0.055
	Exercise	76.25 ±12.55	73.01 ±11.99	75.54 ±12.56	0.001*	0.001*	0.002*
	Between groups	0.606					
Fat%	Sauna	4.92 ±1.39	4.92 ±1.40	4.90 ±1.39	0.058	0.312	0.393
	Exercise	7.33 ±1.73	7.10 ±1.74	7.22 ±1.71	0.001*	0.002*	0.004*
	Between groups	0.001*					
Fat mass (kg)	Sauna	3.49 ±1.10	3.47 ±1.08	3.47 ±1.10	0.142	0.245	0.084
	Exercise	5.72 ±2.02	5.31 ±2.17	5.59 ±1.91	0.001*	0.001*	0.001*
	Between groups	0.001*					
Fat free mass (kg)	Sauna	64.19 ±8.52	60.04 ±9.26	60.73 ±9.38	0.010*	0.080	0.157
	Exercise	72.08 ±11.24	67.73 ±10.28	67.96 ±10.77	0.001*	0.001*	0.004*
	Between groups	0.919					
Total body water(kg)	Sauna	45.95 ±6.36	43.25 ±5.99	45.27 ±6.27	0.001*	0.001*	0.001*
	Exercise	52.98 ±8.82	49.87 ±8.31	52.20 ±8.69	0.001*	0.001*	0.001*
	Between groups	0.009*					

*$P < 0.05$.

Table 2 Shoulders, Pelvises' linear velocity and measurements of position during tests.

		Pre-test	Post-test1	Post-test2	In group	Pre-test vs Post-test1	Pre-test vs Post-test2
Right shoulder velocity (m/s)	Sauna	4.06 ±0.51	3.35 ±0.35	3.83 ±0.36	0.001*	0.001*	0.055
	Exercise	3.73 ±0.59	3.52 ±0.32	3.56 ±0.33	0.001*	0.001*	0.002*
	Between groups	0.378					
Left shoulder velocity (m/s)	Sauna	4.31 ±0.55	4.22 ±0.52	4.32 ±0.53	0.044*	0.624	0.008*
	Exercise	4.69 ±0.52	4.61 ±0.52	4.70 ±0.54	0.429	1.000	0.969
	Between groups	0.938					
Right shoulder Position (m)	Sauna	2.56 ±0.08	2.45 ±0.07	2.47 ±0.07	0.058	0.119	0.107
	Exercise	2.55 ±0.11	2.48 ±0.11	2.49 ±0.10	0.345	0.036*	1.000
	Between groups	0.057					
Left shoulder position (m)	Sauna	2.71 ±0.10	2.61 ±0.11	2.63 ±0.10	0.010*	0.080	0.157
	Exercise	2.74 ±0.15	2.65 ±0.15	2.66 ±0.13	0.001*	0.001*	0.004*
	Between groups	0.897					
Right pelvis Velocity (m/s)	Sauna	6.73 ±0.93	5.30 ±0.79	5.31 ±0.78	0.001*	0.001*	0.001*
	Exercise	7.05 ±0.52	6.76 ±0.61	6.83 ±0.65	0.001*	0.001*	0.001*
	Between groups	0.039					
Left pelvis Velocity (m/s)	Sauna	6.73 ±0.93	5.30 ±0.79	5.31 ±0.78	0.001*	0.001*	0.055
	Exercise	7.05 ±0.52	6.76 ±0.61	6.83 ±0.65	0.001*	0.001*	0.002*
	Between groups	0.001*					
Right pelvis position (m)	Sauna	2.44 ±0.05	2.37 ±0.05	2.39 ±0.05	0.044*	0.624	0.008*
	Exercise	2.47 ±0.03	2.42 ±0.04	2.42 ±0.04	0.429	1.000	0.969
	Between groups	0.130					
Left pelvis position (m)	Sauna	2.71 ±0.03	2.64 ±0.5	2.65 ±0.04	0.058	0.119	0.107
	Exercise	2.67 ±0.8	2.59 ±0.10	2.60 ±0.09	0.345	0.036*	1.000
	Between groups	0.888					

All values are mean ±SD, *$P < 0.05$.

Table 3 Knees linear velocity and position.

		Pre-test	Post-test1	Post-test2	In group	Pre-test vs Post-test1	Pre-test vs Post-test2
Right knee Velocity (m/s)	Sauna	6.73 ± 0.93	5.30 ± 0.79	5.31 ± 0.78	0.001*	0.001*	0.001*
	Exercise	7.05 ± 0.52	6.76 ± 0.61	6.83 ± 0.65	0.001*	0.001*	0.001*
	Between groups	0.152					
Left knee Velocity (m/s)	Sauna	6.73 ± 0.93	5.30 ± 0.79	5.31 ± 0.78	0.001*	0.001*	0.055
	Exercise	7.05 ± 0.52	6.76 ± 0.61	6.83 ± 0.65	0.001*	0.001*	0.002*
	Between groups	0.001*					
Right knee position (m)	Sauna	2.44 ± 0.05	2.37 ± 0.05	2.39 ± 0.05	0.044*	0.624	0.008*
	Exercise	2.47 ± 0.03	2.42 ± 0.04	2.42 ± 0.04	0.429	1.000	0.969
	Between groups	0.033*					
Left knee position (m)	Sauna	2.71 ± 0.03	2.64 ± 0.5	2.65 ± 0.04	0.058	0.119	0.107
	Exercise	2.67 ± 0.8	2.59 ± 0.10	2.60 ± 0.09	0.345	0.036*	1.000
	Between groups	0.173					

*$P < 0.05$.

Table 4 Trunks, thigh segments angular velocity measurements during tests.

		Pre-test	Post-test1	Post-test2	In group	Pre-test vs Post-test1	Pre-test vs Post-test2
Right trunk angular Velocity (deg/s)	Sauna	412.24 ± 6.13	361.05 ± 11.86	366.05 ± 13.89	0.001*	0.001*	0.001*
	Exercise	413.87 ± 4.92	406.68 ± 7.48	410.13 ± 6.33	0.001*	0.001*	0.001*
	Between groups	0.383					
Left trunk angular velocity (deg/s)	Sauna	440.69 ± 6.17	432.96 ± 7.98	433.86 ± 7.81	0.025*	0.056	0.099
	Exercise	440.26 ± 6.06	435.26 ± 5.65	429.90 ± 6.06	0.001	0.001*	0.019*
	Between groups	0.265					
Right thigh segment angular Velocity (deg/s)	Sauna	326.21 ± 7.64	276.49 ± 8.38	282.57 ± 9.34	0.001*	0.001*	0.001*
	Exercise	324.37 ± 7.13	276.97 ± 8.24	284.06 ± 10.86	0.001*	0.001*	0.001*
	Between groups	0.527					
Left thigh segment angular Velocity (deg/s)	Sauna	647.30 ± 24.14	555.16 ± 35.47	540.07 ± 17.45	0.010*	0.001*	0.001*
	Exercise	662.65 ± 14.72	632.48 ± 41.35	552.13 ± 21.85	0.001*	0.190	0.001*
	Between groups	0.001*					

All values are mean ± SD. *$P < 0.05$.

cutting and rehydration period resulted in significant decrease (M, SD) in the right and left shoulder, pelvis and knee, velocity and position, right/left trunk and thigh segment angular velocity (t, $P \leq 0.05$). In addition, in exercise group's post-tests, acute dehydration and rehydration resulted in significant decrease (M, SD) in the left shoulder velocity and right/left pelvis, knee velocity and position and right/left trunk and thigh angular velocity.

An independent sample t-test was conducted to compare effect of acute dehydration and 18-hour rehydration in sauna and exercise groups. Repeated measure test was conducted to compare pre t-test, post-test1 and post-test2. The results showed that in sauna group there is no significant decrease in left trunk angular velocity, left knee position, both pelvis position, both shoulder position.

Also, in exercise group, there is no significant decrease in left thigh segment angular velocity, both knees position, both pelvis position and right shoulder velocity. Comparisons of the groups and tests suggest that weight cutting by sauna methods really does have an effect on joints and segments biomechanical parameters more than exercise methods.

4. Discussion

The main aims of the study were determining the effect of dehydration by passive and active method in the ability of wrestler in performing a technique and determine the effects of acute dehydration on joints and body biomechanical characteristics. Literatures on the effects of dehydration and rehydration on the biomechanical parameters does not exist. Therefore, this is the first study to investigate the effects of dehydration on kinematic parameters, and this is the first on the biomechanical patterns among the wrestlers [6, 24].

The findings of this study showed that sauna and exercise groups' left and right shoulder, pelvis, knee linear and angular velocity significantly reduce after dehydration and after 18-hours rehydration period. Comparison changes between groups showed that weight loss through sauna have more negative impact than active method in joints and body biomechanical parameters. It can be stated when dehydration occurred, water, electrolytes, proteins, body fat and glycogen resources will decrease and rehydration period is not sufficient for electrolytes and water homeostasis [33]. These acute weight loss methods lead to, reduce muscle strength, decrease performance of muscle, decline blood volume and plasma, decrease cardiac capacity in submaximal condition (more heart rate, less stroke volume and cardiac output), decrease oxygen transfer and body temperature disorder. Decrease in joints linear velocity and angular velocity aligned with the above results.

A fluid deficit and acute dehydration can increase physiological, psychological impacts and reduce performance, and this effect has been reported in some study [10, 16, 34].

Rapid weight loss and increased again in individual sports are quite common and can be a cause of obesity after retirement [24, 35]. Hickner, Karila and Horswill, et al. [37-39] showed that dehydration has negative effect in physiological blood and substrate parameters. Kraft, Webster, Yoshida, et al. [4, 40-43] showed that power, maximum anaerobic power, vertical jump, vertical ground reaction impulse, body power and mean power have impacted during acute dehydration. The finding of this study disagree with previous studies [41, 44-46], which showed that there were no significant effect in peak power, mean power and vertical jump. Reasons of these differences in results were in level of dehydration, mode of testing and mode of measuring power.

Evans [24] reported components of reaction time, that is total reaction (TRT), central reaction (CNS) and peripheral reaction (PNS), held significant when looking at the total effect of weight cutting. Results showed there were positive significant effects on the total and central reaction time but a negative effect on the peripheral reaction time. Precision was also nearing with a negative effect. Buford et al. [46] reported that dehydration was damaging muscle performance. For this study, the authors calculated peak torque in at the knee midseason and postseason in wrestlers.

For this study, the authors calculated peak torque at the knee midseason and postseason in wrestlers. They reported in the postseason, when wrestlers were not attempting to weight cutting, peak torque 28% was a enhance but while they were lose weight their performance and peak toque were damaged. Kraemer et al. [47] measured, upper extremity isometric force production and torque wrestlers over the course of 5 matches. During competition, subject reduced 6% body mass via food and fluid limiting. Results showed significant reduce in isometric fore production of the upper torso and arms between pre-test measurements and after the first match. Significant elevation in testosterone, cortisol and lactate were showed after each match. Webster et al. [40] measured weight loss in wrestlers and isokinetic performance of the elbow and knee joints reported no effect of a 5% weight lose on peak torque at both fast and slow velocities. However, available information showed some sensitivity of similar isokinetic contraction measure to a 6% weight loss, as was seen with decline in knee flexion, fast knee

extension, and slow elbow extension torque value. Wrestling is an anaerobic sport, and all techniques have to be done in short time rapidly; power, speed, balance, coordination, and strength are the main components to the implementation of techniques in wrestling and other atrial sports. Decrease in joints position after dehydration and 18-hours rehydration periods expected above mentioned and aligned by anaerobic performance component. So decrease in reaction time and central reaction time in martial arts showed biomechanical parameters decreased by dehydration.

5. Conclusion

Coaches, wrestlers, and other athletes of weighing fields are recommended to avoid weight cutting methods (their physiological, psychological, and biomechanical disorders investigated in many studies) and use rehydration methods to replace water, electrolytes etc., is not sufficient to recover your preseason performance. Now biomechanical evidences through three dimensional motion analysis confirm disorders of acute dehydration on performance and technique accomplishment in wrestling and other combat sports. It is must be said, weight cutting by passive methods (sauna) have destructive effect on athlete's technique performance.

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