Impact of hydration on muscle contraction properties of elite competitive wrestlers

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A Study Design
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Abstract

Background & Study Aim: The wrestling events included in the Olympic Games have different weight classes. Most wrestlers reduce their body weight a few days before competition so they can enter the right weight category. Often they use irrational nutritional strategies to make the weight, sometimes even drastically reducing their water intake. The purpose of this study was the knowledge about influence of pre-competition level of hydration on muscle contractile properties in elite wrestlers.

Material & Methods: Sixty three wrestlers participated in the study (27 female and 36 male). We sampled data from the weigh-in for an international competition, recording each athlete's hydration level using bioelectrical impedance analysis and using tensiomyography to analyze the contractile properties of the vastus medialis (VM), vastus lateralis (VL), rectus femoris and biceps femoris (BF) muscles of both legs. Among wrestlers 16 were classified as "less-hydrated" (total body water $<60\%$) and 47 were classified as "more-hydrated" (total body water $\geq 60\%$).

Results: Less-hydrated wrestlers of both sexes had a greater ($p<0.05$) contraction time for all muscles and lower ($p<0.05$) maximal radial displacement of muscle belly for VL, VM and BF than those who were more-hydrated. Normalize response speed was significantly higher ($p<0.05$) in more-hydrated athletes of both sexes for both sides of VM and VL and for right side of BF.

Conclusion: Wrestlers who were less-hydrated at the weigh-in had poorer muscle contractile properties, due mainly to the additional contraction time and the lower radial muscular displacement. Years of reducing body weight by wrestlers based on irrational nutritional strategies may have negative effects on health in the future. Therefore, regular monitoring of the health of the wrestlers at the end of their sporting career is essential to develop recommendations for practice of training.

Key words: combat sport, irrational nutritional strategies, skeletal muscles, tensiomyography

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Tensiomyography – is a measuring method for detection of skeletal muscles' contractile properties. Tensiomyography assesses muscle mechanical response based on radial muscle belly displacement induced by a single electrical stimulus.

Wrestling – sport in which two contestants fight by gripping each other using special holds, each trying to force the other's shoulders onto a mat.

Freestyle wrestling – is a style of amateur wrestling that is practiced throughout the world. Along with Greco-Roman, it is one of the two styles of wrestling contested in the Olympic Games.

Introduction

Men's and women's Greco-Roman and freestyle wrestling are both part of the current Olympic program. Wrestling has spread throughout the world and is the oldest known sporting discipline. Different forms of wrestling are divided into weight classes, so many wrestlers have to restrict their food intake, and usually their liquid intake too, in the days leading up to a competition. This lower intake changes athletes' fluid balance, causing them to dehydrate.

The most harmful effects of rapid weight loss by dehydration have been documented since the 1970s [1]. The conclusions that were drawn from those studies were subsequently described in detail by other authors. One notable conclusion is that weight loss through dehydration poses a serious risk to the athlete's health and may cause acute cardiovascular disorders [2], immunosuppression [3], damage to cognitive function [4] hormonal imbalances [5] and major losses in athletic performance in high-intensity competition [6]. Despite these risks, most athletes still use dehydration to make the weight for competition, and they and their coaches ignore the damage that dehydration can cause to the athlete's health and performance.

One factor that makes dehydration remain a popular weight-loss method among wrestlers and coaches is perhaps the culture within the sport resulting from its confrontational origins. Knowledge from the sciences of sports training have left their mark on wrestling only in recent years [7]. The muscular system is affected by pre-competition dehydration [8], with a loss of muscular efficiency when it is required for high-intensity activity [9]. In sports such as wrestling, where success is measured not by a single, conditional factor, but by a multitude of variables used to judge performance, athletes usually use one of those variables as an excuse for defeat, but they hardly ever blame defeat on an erroneous pre-competition strategy involving measures to make the weight by dehydrating.

Tensiomyography (TMG) analyzes the contractile properties of muscles, providing us with a highly reliable non-invasive method to identify the state of the muscles [10]. This assessment method was developed in the early 1990s by Professor Valencic at the Faculty of Electrical Engineering at the University of Ljubljana (Slovenia), its initial main objective being to assess muscle tone in patients with neuromuscular diseases [11]. The technology was transferred to sports through the work carried out at the University of Ljubljana's Laboratory of Biomedical Visualization and Muscle Biomechanics and Laboratory for Computational Electromagnetics. The university's studies intensified and spilled over into sports when it began to work with the Slovenian Olympic team as it prepared for the 2000 Olympic Games in Sydney and the 2002 Winter Olympic Games in Salt Lake City [12]. The university began to develop a simple method to measure skeletal muscle response with implications for athletic performance [13].

TMG measures radial deformation (displacement) of the muscle belly caused by controlled-intensity external electrical stimulation under isometric conditions [10, 12]. These indicators, expressed as the displacement of the sensor against time, are used to measure muscular rigidity and the balance between muscular structures, muscle chains (flexor-extensor) or limbs (right and left) [12]. According to the inventors of TMG, displacement of the muscle belly is a result of displacement of the muscle surface, and appears to be proportional to the strength of the muscles [13, 14]. Dahmane et al. [15] show that the contraction times obtained using TMG could be useful for performing a non-invasive examination of the spatial distribution of muscle fiber types.

Pre-competition dehydration causes fatigue in the muscles, which mainly affects the duration of maximum strength [9]; muscle fatigue and potentiation are two important physiological processes that are being investigated using various assessment methods [16]. Pre-competition muscle fatigue, whether or not caused by dehydration, alters a wrestler's moves and technique and, by extension, their effectiveness in competition. By understanding the relationship between different levels of pre-competition dehydration and the different indicators identified when using TMG to evaluate the contractile properties of different muscles, we can produce a better schedule of tasks for the wrestler during the tapering microcycle.

The purpose of this study was the knowledge about influence of pre-competition level of hydration on muscle contractile properties in elite wrestlers.

Material and methods

Participants

This study evaluated 63 elite wrestlers (Greco-Roman and freestyle wrestling) of both sexes (female: n = 27, height = 1.63 ±0.06 m, body mass = 59.03 ±8.37 kg; male: n = 36, height = 1.74 ±0.09 m; body mass = 76.68 ±17.65 kg), aged 21 to 33 years old. The independent variable "hydration" had two categories: (1) "more-hydrated" if total body water (TBW) was equal or greater than 60% (15 female and 32 male) and (2) "less-hydrated" if TBW was lower than 60% (12 female and 4 male). All participants had competed at international level during the previous three years, had a minimum of 7 years of prior wrestling experience and had trained for at least 10 $h \cdot day^{-1}$ during the previous year.

Participants had no previous history of cardiopulmonary diseases and were not taking medications of sympathetic stimulants during the duration of the study. Before enrolling into the investigation, potential participants were fully informed of the risks and discomforts associated with the experiments and they gave their informed written consent to participate.

The study was approved by a local Research Ethics Committee (UCLM, Spain) in accordance with the latest version of the declaration of Helsinki.

Protocol

All measurements were taken during the International Cup of Spain held in Madrid in May 2014 and Grand Prix of Spain held in the same place in July 2014 just before the official weigh-ins took place. Height was measured according to the International Society for the Advancement of Kinanthropometry (ISAK) protocols [17], using a portable stadiometer (SECA 217, Hamburg, Germany).

Multi-frequency bioelectrical impedance analysis measurements were determined using an InBody 230 (Biospace, CA, USA). Body mass (in kg) and total body water (TBW) [18] were measured simultaneously when the subject's bare feet and palm and thumbs placed pressure on the electrodes and the digital scale. Participants were classified as: (1) "more-hydrated" if TBW was higher than or equal to the cutoff point (TBW ≥60%); or (2) "less-hydrated" if TBW was lower than the cutoff point (TBW <60%). Previous research on the validation of Multi-frequency bioelectrical impedance to estimate TBW and acute changes in TBW have demonstrated positive results [18, 19] and the cutoff point (TBW = 60%) were stablished taking into account the previous studies of Wang et al. [20] and García et al. [9].

Response contraction time and amplitude throughout maximal passive twitch contractions were recorded, on both sides (right and left lower extremity), from the rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM) and biceps femoris (BF) muscles, using tensiomyography (TMG) [21]. With this technique, oscillations of the muscle belly (generated in response to a percutaneous electrical stimulation), were recorded at the skin surface using a spring-loaded displacement sensor (digital-optical sensor, RLS Ltd, Slovenia) positioned perpendicularly directly above the center point of the muscle to enable sensitive recording of mechanical displacement of the underlying muscle tissue. This displacement was recorded by a host online computer at a sampling rate of 500 Hz. Two stimulating adhesive electrodes (3 cm × 3 cm) were placed symmetrically 5 cm distally and proximally from the position of the sensor. Passive twitch contractions were stimulated at a 100° knee angle. A single square wave monophasic maximal 1 ms pulse was applied to elicit a twitch response of the muscle that was recorded by the displacement sensor. To obtain maximal mechanical response the stimulation amplitude was adjusted (increased by 10 mA at a frequency of 10 s intervals to avoid the effects of fatigue and muscle potentiation) and selected in such a way that a maximal response (typically achieved between 40 mA and 70 mA) was obtained.

TMG gave information as to the mechanical characteristics and the contractile capacity of the muscles measured according to the indicators of: (1) Maximal Radial Displacement or deformation of muscle belly (Dm) in mm; (2) Contraction Time (Tc) in ms, was obtained by determining the time lag from the 10% to 90% of the Dm (Figure 1); (3) Contraction speed or response speed (Rs) in mm/s, was calculated by dividing Dm by the Tc in s; (4) normalized response speed (Nrs) in mm/s, was calculated by dividing 0.8 (Δ dr) by the Tc in ms [22].

Statistical analysis

Descriptive statistics were obtained using the mean and standard deviation. Several analyses of covariance (univariate ANCOVA) were conducted

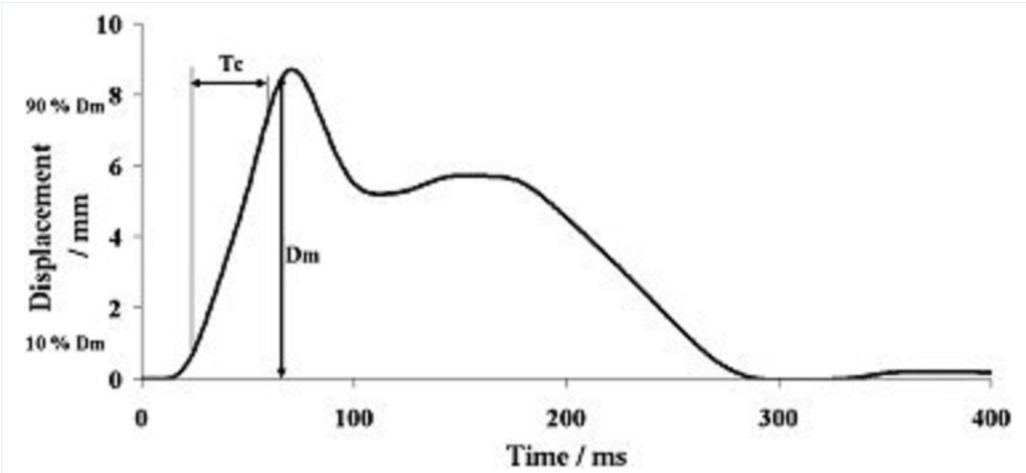

Figure 1. Typical displacement/time signal recorded as a result of an electrical stimulation. Tc = contraction time (ms) expressed as the response from 10% to 90% of peak contraction; Dm = total displacement (mm) of the muscle.

to evaluate the effect of TBW on Dm, Tc, Rs and Nrs of several muscles (BF, VM, VL, and RF, from both lower extremities), controlling for body mass. Preliminary transformations of measures in ranks were performed to ensure there was no violation of the ANCOVA assumptions. The statistical analyses were performed with the software IBM SPSS v.21 and the level of significance was set at $p<0.05$.

Results

Results showed that less-hydrated athletes had higher Tc than more-hydrated athletes (in both sexes and for all variables). For the Tc of VL (right and left), VM (right and left), and BF (right), significant differences were observed in female and male athletes. For the Tc of RF (right and left) and BF (left), significant differences were only observed in female athletes (Table 1).

Lower values in Dm were found for male less-hydrated ($p<0.05$) in BF (right and left). Moreover, for VL (right and left) and VM (right and left), less-hydrated wrestlers of both sexes had significantly lower Dm levels than more-hydrated athletes. No significant differences in Dm were observed in either sex for RF (right and left) between less-hydrated and more-hydrated athletes (Table 2).

There were no significant differences in the Rs of RF and BF (both sides) for either sex. However, for the Rs of VM and VL (both sides), both the male and female less-hydrated wrestlers had significantly ($p<0.05$) lower Rs values (Table 3).

Finally, the effect of hydration on the Nrs was similar to its effect on the Tc. Nrs was significantly higher ($p<0.05$) in more-hydrated male and female athletes for VM (both sides), VL (both sides), and BF (right). Less-hydrated female wrestlers had significantly lower Nrs values than more-hydrated female wrestlers for RF (both sides) and BF (left), but among male wrestlers there were no significant differences in this muscles (Table 4).

Discussion

This study sought to analyze the possible effects of pre-competition level of hydration in elite wrestlers in terms of the contractile properties of the muscles analyzed. Several studies confirm that dehydration significantly impairs traits such as athletes' performance and muscle function [23, 24], though some other authors make the contradictory claim that inducing dehydration of no more than 2% of body weight results in only a negligible loss of muscle strength [25]. Nevertheless, we analyzed the differences in the samples used in those studies (level of sporting excellence) and when the data was collected, and we believe that these differences could have affected the results. We believe that evaluating muscle force in dehydration among physical education majors at universities is not the same as doing so among elite athletes before a top-level competition. The way dehydration is induced is also a very important factor. Wrestlers usually reach dehydration after limiting food and liquid intake for more than a week, so they do not complete the tapering microcycle properly, which can affect their muscle contraction more severely.

Table 1. Summary statistics and ANCOVA results from evaluation of the effect of the two hydration groups (more-hydrated = total body water ≥60% and less-hydrated = total body water <60%) on the contraction time (ms), after controlling for body mass, for male and female competitive wrestlers.

Variable	Group	Male (n = 36)				Female (n = 27)			
		Summary statistics		Estimated marginal means		Summary statistics		Estimated marginal means	
		Mean	SD	Mean	SE	Mean	SD	Mean	SE
Rectus femoris, rigηt	More-ηydrated	27.31	2.81	17.69	1.83	27.07	2.15	10.01	1.75
	Less-ηydrated	30.00	3.37	24.95	5.38	32.33	4.75	18.99	1.96
		F(1.33) = 1.595, p = 0.215 (n.s.)				F(1.24) = 11.381, p = 0.003, $\eta_p^2 = 0.322$			
Rectus femoris, left	More-ηydrated	27.09	3.14	17.59	1.82	26.93	2.37	10.84	1.88
	Less-ηydrated	29.50	2.08	25.81	5.35	31.17	4.28	17.95	2.11
		F(1.33) = 2.080, p = 0.159 (n.s.)				F(1.24) = 6.159, p = 0.020, $\eta_p^2 = 0.204$			
Vastus medialis, rigηt	More-ηydrated	30.78	3.58	16.78	1.66	33.53	2.47	9.26	1.58
	Less-ηydrated	37.75	1.26	32.25	4.87	37.75	3.39	19.92	1.77
		F(1.33) = 8.866, p = 0.005, $\eta_p^2 = 0.212$				F(1.24) = 19.708, p < 0.001, $\eta_p^2 = 0.451$			
Vastus medialis, left	More-ηydrated	30.88	3.39	16.67	1.61	33.60	3.48	9.57	1.66
	Less-ηydrated	39.50	1.29	33.13	4.72	37.83	2.79	19.53	1.86
		F(1.33) = 10.703, p = 0.003, $\eta_p^2 = 0.245$				F(1.24) = 15.631, p = 0.001, $\eta_p^2 = 0.394$			
Vastus lateralis, rigηt	More-ηydrated	21.66	3.53	16.97	1.69	23.73	1.98	8.31	1.21
	Less-ηydrated	28.25	2.99	30.74	4.97	32.17	3.64	21.11	1.36
		F(1.33) = 6.745, p = 0.014, $\eta_p^2 = 0.170$				F(1.24) = 48.065, p < 0.001, $\eta_p^2 = 0.667$			
Vastus lateralis, left	More-ηydrated	21.53	3.61	17.13	1.68	23.87	2.64	8.57	1.27
	Less-ηydrated	27.75	3.20	29.42	4.94	32.42	3.73	20.79	1.42
		F(1.33) = 5.446, p = 0.026, $\eta_p^2 = 0.142$				F(1.24) = 40.028, p < 0.001, $\eta_p^2 = 0.625$			
Biceps femoris, rigηt	More-ηydrated	28.38	4.35	17.10	1.78	29.20	3.99	10.00	1.73
	Less-ηydrated	33.25	2.50	29.72	5.24	32.92	2.43	19.00	1.94
		F(1.33) = 5.109, p = 0.031, $\eta_p^2 = 0.134$				F(1.24) = 11.723, p = 0.002, $\eta_p^2 = 0.328$			
Biceps femoris, left	More-ηydrated	28.81	4.76	17.85	1.89	28.87	3.60	10.66	1.87
	Less-ηydrated	31.75	2.06	23.73	5.54	32.42	2.81	18.18	2.10
		F(1.33) = 0.991, p = 0.327 (n.s.)				F(1.24) = 7.003, p = 0.014, $\eta_p^2 = 0.226$			

Table 2. Summary statistics and ANCOVA results from evaluation of the effect of the two hydration groups (more-hydrated = total body water ≥60% and less-hydrated = total body water <60%) on the maximal radial displacement of muscle belly (mm), after controlling for body mass, for male and female competitive wrestlers.

Variable	Group	Male (n = 36)				Female (n = 27)			
		Summary statistics		Estimated marginal means		Summary statistics		Estimated marginal means	
		Mean	SD	Mean	SE	Mean	SD	Mean	SE
Rectus femoris, right	More-hydrated	5.41	0.79	29.35	2.77	6.40	1.69	38.53	5.58
	Less-hydrated	7.83	3.07	44.95	8.14	6.47	4.10	26.58	6.25
		$F(1.33) = 3.228, p = 0.082$ (n.s.)				$F(1.24) = 1.983, p = 0.172$ (n.s.)			
Rectus femoris, left	More-hydrated	5.56	0.88	28.97	2.96	6.54	1.50	38.71	5.26
	Less-hydrated	8.00	2.72	44.84	8.69	6.56	3.75	27.41	5.90
		$F(1.33) = 2.932, p = 0.096$ (n.s.)				$F(1.24) = 1.990, p = 0.171$ (n.s.)			
Vastus medialis, right	More-hydrated	8.17	0.73	44.70	2.13	7.09	0.75	25.86	2.62
	Less-hydrated	7.20	1.16	19.63	6.25	6.06	0.98	9.92	2.94
		$F(1.33) = 14.176, p = 0.001, \eta_p^2 = 0.300$				$F(1.24) = 15.994, p = 0.001, \eta_p^2 = 0.400$			
Vastus medialis, left	More-hydrated	8.21	0.69	45.43	1.91	7.05	0.64	24.37	2.53
	Less-hydrated	7.20	1.15	19.69	5.61	6.10	0.95	9.83	2.84
		$F(1.33) = 18.527, p < 0.001, \eta_p^2 = 0.360$				$F(1.24) = 14.204, p = 0.001, \eta_p^2 = 0.372$			
Vastus lateralis, right	More-hydrated	5.29	0.72	39.69	2.64	5.22	0.70	38.54	2.88
	Less-hydrated	3.15	1.39	14.60	7.76	3.28	0.69	9.12	3.23
		$F(1.33) = 9.203, p = 0.005, \eta_p^2 = 0.218$				$F(1.24) = 45.184, p < 0.001, \eta_p^2 = 0.653$			
Vastus lateralis, left	More-hydrated	5.37	0.64	40.07	2.53	5.23	0.56	37.00	2.87
	Less-hydrated	3.70	0.94	14.91	7.44	3.83	0.57	9.92	3.22
		$F(1.33) = 10.073, p = 0.003, \eta_p^2 = 0.234$				$F(1.24) = 38.455, p < 0.001, \eta_p^2 = 0.616$			
Biceps femoris, right	More-hydrated	5.22	0.97	26.68	2.82	5.95	1.16	35.54	5.30
	Less-hydrated	6.45	2.77	46.91	8.28	5.83	1.98	36.78	5.95
		$F(1.33) = 5.246, p = 0.029, \eta_p^2 = 0.137$				$F(1.24) = 0.024, p = 0.879$ (n.s.)			
Biceps femoris, left	More-hydrated	5.18	1.02	26.09	2.90	6.00	1.04	36.49	5.02
	Less-hydrated	6.45	2.23	46.14	8.51	5.85	1.80	37.43	5.63
		$F(1.33) = 4.890, p = 0.034, \eta_p^2 = 0.137$				$F(1.24) = 0.015, p = 0.902$ (n.s.)			

Table 3. Summary statistics and ANCOVA results from evaluation of the effect of the two hydration groups (more-hydrated = total body water ≥60% and less-hydrated = total body water <60%) on the contraction SPEED (mm/s), after controlling for body mass, for male and female competitive wrestlers.

Variable	Group	Male (n = 36)				Female (n = 27)			
		Summary statistics		Estimated marginal means		Summary statistics		Estimated marginal means	
		Mean	SD	Mean	SE	Mean	SD	Mean	SE
Rectus femoris, rigηt	More-ηydrated	20.05	3.65	29.46	2.82	23.66	5.86	38.72	5.49
	Less-ηydrated	26.25	9.98	45.69	8.27	19.84	10.63	25.81	6.15
		$F(1.33) = 3.385$, $p = 0.075$ (n.s.)				$F(1.24) = 2.391$, $p = 0.135$ (n.s.)			
Rectus femoris, left	More-ηydrated	20.77	3.92	29.28	2.86	24.41	5.55	39.64	5.36
	Less-ηydrated	27.02	8.61	45.10	8.39	20.90	10.19	25.33	6.00
		$F(1.33) = 3.122$, $p = 0.087$ (n.s.)				$F(1.24) = 3.083$, $p = 0.092$ (n.s.)			
Vastus medialis, rigηt	More-ηydrated	26.97	4.51	44.76	2.23	21.35	3.61	27.45	2.67
	Less-ηydrated	19.17	3.76	15.70	6.55	16.33	4.01	9.10	2.99
		$F(1.33) = 17.320$, $p < 0.001$, $\eta_p^2 = 0.344$				$F(1.24) = 20.447$, $p < 0.001$, $\eta_p^2 = 0.460$			
Vastus medialis, left	More-ηydrated	26.92	3.93	45.26	2.14	21.26	3.48	26.87	2.62
	Less-ηydrated	18.28	3.28	13.01	6.29	16.30	3.53	9.37	2.94
		$F(1.33) = 23.125$, $p < 0.001$, $\eta_p^2 = 0.412$				$F(1.24) = 19.213$, $p < 0.001$, $\eta_p^2 = 0.445$			
Vastus lateralis, rigηt	More-ηydrated	25.13	5.59	42.02	2.44	22.16	3.70	35.05	2.42
	Less-ηydrated	11.30	5.38	13.19	7.16	10.42	3.04	7.73	2.72
		$F(1.33) = 14.269$, $p = 0.001$, $\eta_p^2 = 0.302$				$F(1.24) = 54.903$, $p < 0.001$, $\eta_p^2 = 0.696$			
Vastus lateralis, left	More-ηydrated	25.70	5.69	42.06	2.42	22.16	3.47	34.12	2.25
	Less-ηydrated	13.57	4.14	14.03	7.12	12.05	2.82	8.52	2.52
		$F(1.33) = 13.655$, $p = 0.001$, $\eta_p^2 = 0.293$				$F(1.24) = 56.051$, $p < 0.001$, $\eta_p^2 = 0.700$			
Biceps femoris, rigηt	More-ηydrated	18.79	4.27	29.64	3.22	20.70	4.68	36.67	5.08
	Less-ηydrated	19.82	9.03	41.59	9.46	17.88	6.18	29.24	5.70
		$F(1.33) = 1.403$, $p = 0.245$ (n.s.)				$F(1.24) = 0.924$, $p = 0.346$ (n.s.)			
Biceps femoris, left	More-ηydrated	18.57	4.98	29.02	3.33	21.18	5.09	36.37	4.81
	Less-ηydrated	20.63	7.77	41.75	9.77	18.27	5.81	31.25	5.39
		$F(1.33) = 1.494$, $p = 0.230$ (n.s.)				$F(1.24) = 0.490$, $p = 0.491$ (n.s.)			

Table 4: Summary statistics and ANCOVA results from evaluation of the effect of the two hydration groups (more-hydrated = total body water ≥60% and less-hydrated = total body water <60%) on the normalized response speed (mm/s), after controlling for body mass, for male and female competitive wrestlers.

Variable	Group	Male (n = 36)				Female (n = 27)			
		Summary statistics		Estimated marginal means		Summary statistics		Estimated marginal means	
		Mean	SD	Mean	SE	Mean	SD	Mean	SE
Rectus femoris, rignt	More-ηydrated	2.96	0.30	36.54	3.21	2.97	0.25	36.98	3.88
	Less-ηydrated	2.70	.034	23.34	9.42	2.52	0.37	16.57	4.35
		F(1.33) = 1.727, p = 0.198 (n.s.)				F(1.24) = 11.954, p = 0.002, η_p^2 = 0.332			
Rectus femoris, left	More-ηydrated	2.99	0.33	36.15	3.27	2.99	0.29	35.96	4.09
	Less-ηydrated	2.72	0.19	21.07	9.61	2.61	0.35	19.64	4.58
		F(1.33) = 2.165, p = 0.151 (n.s.)				F(1.24) = 6.895, p = 0.015, η_p^2 = 0.323			
Vastus medialis, rignt	More-ηydrated	2.63	0.30	42.21	2.63	2.40	0.18	31.33	3.01
	Less-ηydrated	2.12	0.07	12.78	7.72	2.14	0.21	12.01	3.37
		F(1.33) = 12.789, p = 0.001, η_p^2 = 0.279				F(1.24) = 17.798, p < 0.001, η_p^2 = 0.426			
Vastus medialis, left	More-ηydrated	2.62	0.29	42.09	2.49	2.40	0.25	32.12	3.27
	Less-ηydrated	2.03	0.07	8.94	7.33	2.13	0.17	12.65	3.67
		F(1.33) = 17.994, p < 0.001, η_p^2 = 0.353				F(1.24) = 15.292, p = 0.001, η_p^2 = 0.389			
Vastus lateralis, rignt	More-ηydrated	3.79	0.59	42.20	2.64	3.39	0.31	33.19	2.27
	Less-ηydrated	2.86	0.30	18.14	7.76	2.52	0.30	7.92	2.55
		F(1.33) = 8.461, p = 0.006, η_p^2 = 0.204				F(1.24) = 53.490, p < 0.001, η_p^2 = 0.690			
Vastus lateralis, left	More-ηydrated	3.81	0.59	41.94	2.64	3.39	0.40	32.25	2.48
	Less-ηydrated	2.92	0.38	21.59	7.74	2.50	0.31	8.64	2.78
		F(1.33) = 6.077, p = 0.019, η_p^2 = 0.156				F(1.24) = 39.166, p < 0.001, η_p^2 = 0.620			
Biceps femoris, rignt	More-ηydrated	2.89	0.49	37.65	3.22	2.80	0.51	36.30	3.71
	Less-ηydrated	2.42	0.19	15.21	9.46	2.44	0.18	17.16	4.16
		F(1.33) = 4.950, p = 0.033, η_p^2 = 0.130				F(1.24) = 11.474, p = 0.002, η_p^2 = 0.323			
Biceps femoris, left	More-ηydrated	2.86	0.54	34.30[b]	3.56	2.83	0.49	38.27	3.73
	Less-ηydrated	2.53	0.17	23.22[b]	10.45	2.48	0.21	20.96	4.18
		F(1.33) = 0.989, p = 0.327 (n.s.)				F(1.24) = 9.311, p = 0.005, η_p^2 = 0.280			

Official weigh-ins for Greco-Roman and freestyle wrestling tournaments take place on the eve of the event, so the wrestlers have time to replace fluids once they have recorded their competition weight in the official weigh-in. This system should benefit the wrestlers, but it becomes a threat to the interests of some participants because they try to enter a lower weight class than their normal weight, since the night before the competition they can regain the weight they have lost.

Most studies on dehydration and muscle strength have involved an induced dehydration of subjects for one to three hours followed by an isometric [26, 27] or isotonic [23, 28] test to measure their strength. No known studies relate the states of dehydration with the various TMG indicators, except García et al. [9], which analyzes the relationship between dehydrated judokas, TMG and dynamic strength.

Our study shows a significant relationship between athletes who were less-hydrated at the weigh-in and poor Tc and Dm values in the muscles studied. Based on muscle response time and contraction time, an analysis of muscle contractility shows that muscles are much less explosive in wrestlers who are less-hydrated. These data are consistent with those found by Rodríguez-Matoso et al. [29] and García et al. [9].

More-hydrated athlete in the study has Tc indicators in the normal range for the RF and VL muscles (25-28 ms and 19-23 ms respectively); indicators for the BF muscle are also poorer among the less-hydrated athletes, but the results are less significant than for the RF and VL muscles. This finding could be related to the main type of muscle used by wrestlers. A slow RF can cause greater impairment of the hip flexors. When the RF muscles have high Tc values, the Dm values tend to be low (<3 mm), as confirmed by the less-hydrated wrestlers in our study, indicating a shortening of the muscle, which could cause pain in the lower back. Moreover, a slow RF muscle does not work properly when a wrestler presses forward, which would compromise wrestlers' attacking moves, especially in freestyle wrestling.

A slow Tc (e.g. >30 ms for the BF) indicates a slow muscle; if the Dm value is low too, as is the case in most less-hydrated athletes, the athlete suffers unwanted muscle fatigue, which can severely harm his or her performance if it occurs prior to competition. Most wrestlers who were less-hydrated at the weigh-in were in this situation, with female wrestlers particularly affected.

The muscles of athletes with a low Tc contract faster. Low Tc is correlated with athletes who have a muscle composition with a larger proportion of type II fibers [15, 30]. As we have discussed, dehydrated athletes, most of whom become dehydrated progressively rather than quickly over the course of a single day, have a Tc above the normal range. This abnormal Tc suggests that during the days prior to the competition the athletes changed their training routine to make the weight, thus harming the tapering effect on their muscle contractility, making the muscles unable to respond at optimum speed. A slow muscle response can of course, affect athletic performance.

TMG can be a very useful tool to manage the fatigue that sets in as the athlete becomes dehydrated. The Dm values of the muscles are related to the athlete's muscle strength [14]. In our study, more-hydrated wrestlers had higher Dm values (within the normal range) than less-hydrated wrestlers, so the weight and fluid loss by wrestlers who struggle to make their competition weight will affect their strength. Not only will their strength be diminished, but it will also be less explosive, as indicated by their higher Tc values.

Our results suggest that TMG can be an excellent tool to optimize training methods, especially in pre-competition periods or during intensive training, and to observe the effects that a training schedule or additional activity (i.e. hydration status) might have on the contractile properties of muscle activity. Moreover, wrestlers who frequently use pre-competition hydration to make the weight for competitions, can experience adverse effects of this practice among wrestlers are not widely studied.

On the negative health effects of the frequent weight reduction before the competition by combat sports pay attention (more or less directly), the researchers of this phenomenon in judo (in relation to the body composition, anthropometric indicators and maximal strength [31]) and taekwondo [32, 33]. With the frequent reduction in body weight before the competition can be explained by the conclusion of Drummond et al. [34] that taekwondo athletes had a negative caloric balance during the pre-competition period.

Conclusions

In conclusion, less-hydrated wrestlers had higher Tc values than more-hydrated wrestlers, indicating that the former had slower muscles. Less-hydrated wrestlers also had lower Dm values, suggesting they have greater muscle fatigue going into a competition. Furthermore, the combination of higher Tc and lower Dm values suggests that less-hydrated wrestlers will be less explosive. In other words, they will have a lower capacity to use their strength in a short space of time, which in a sport like competitive wrestling can result in a poorer competition performance.

Years of reducing body weight by wrestlers based on irrational nutritional strategies may have negative effects on health in the future. Therefore, regular monitoring of the health of the wrestlers at the end of their sporting career is essential to develop recommendations for practice of training.

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