




## Original Article

# Patterns of rapid weight loss and recovery of hydration/body composition in elite tug of war athletes

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## ABSTRACT

Rapid weight loss prior to official weigh-ins is a widespread practice in weight-class sports, but its application in tug of war (TOW) has received little attention. Given that team categories are determined by total Body mass (BM), athletes often resort to acute weight manipulation to gain a competitive advantage. The aim of this study was to examine day-to-day changes in body weight, body composition, and hydration status in elite TOW athletes before and after official weigh-ins, and to explore potential sex differences. Ninety-five elite TOW athletes (41 included in the analyses; 19 women, 22 men) were assessed during the 2019 European Outdoor and the 2020 World Indoor TOW Championships. Measurements were performed on the weigh-in day (Day 1) and on the two subsequent competition days (Days 2 and 3). BM, body composition, and hydration status were assessed using multifrequency bioelectrical impedance analysis. Repeated-measures ANOVA and regression analyses were applied to evaluate changes across days and associations between variables. Athletes showed significant increases in BM (~3.9 kg/5.6 %), total body water (TBW), extracellular (ECW) and intracellular water, fat-free mass (FFM), and BMI between the weigh-in and competition days (all  $p < 0.001$ ). However, changes in FFM should be interpreted with caution, as they are likely driven by hydration-related fluctuations rather than true alterations in lean tissue mass. The observed pattern suggests that elite TOW athletes likely undergo rapid pre-weigh-in weight reduction followed by aggressive rehydration and recovery. These patterns were similar between men and women, with trivial to small effect sizes across all variables. Findings highlight the need for safe and evidence-based weight management strategies to protect athlete health while maintaining performance.

## Introduction

Rapid weight loss before competitions is a common practice in weight class sports such as boxing, judo or mixed martial arts (MMA).<sup>1</sup> Athletes seek to compete in weight classes below their natural body mass (BM) to gain a competitive advantage, implementing methods such as fluid restriction, increased physical exercise, and sauna to induce rapid weight loss through dehydration prior to official weigh-ins.<sup>2</sup> These practices, although they may be associated with competitive success, can be detrimental to overall health and physical performance if not implemented correctly.<sup>3</sup> In this sense, several studies have analyzed the effects of these practices on sports performance indicating that rapid

weight loss can negatively affect athletes' kidney function,<sup>4</sup> neuromuscular function, decreasing their ability to perform during competition.<sup>5</sup> Rapid weight loss strategies involving a loss of 3 % to 6 % or more of BM negatively affected performance parameters, including strength, power production, and mood states.<sup>2</sup> It also has been observed that a 2-10 % reduction in BM in the week prior to the official weigh-in may be excessive and potentially detrimental to the athlete's health and performance.<sup>3</sup>

Dehydration is one of the most commonly used strategies to achieve the desired BM before competition.<sup>6</sup> However, strategies to achieve this weight loss should include nutritional protocols implemented several months prior to competition, but in several cases are performed just

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before the competition.<sup>7</sup> Accurate assessment of hydration status is crucial, but current methodologies, such as questionnaires, can be subjective and susceptible to falsification.<sup>8</sup> Therefore, the need for objective methodologies to accurately assess hydration level is postulated.<sup>9</sup>

Electrical bioimpedance analysis (BIA) is a non-invasive and validated method for estimating body composition and hydration status in normal populations, provided that appropriate protocols are followed.<sup>10</sup> This technique measures the opposition exerted by body tissues to the passage of an electrical current, allowing the estimation of total body water (TBW), intracellular water (ICW) and extracellular water (ECW), and therefore the state of hydration. Although some studies have shown mixed results in its application in athletes,<sup>11</sup> BIA can be useful for monitoring hydration status and fat-free mass (FFM), which are fundamental aspects of sports performance.<sup>12</sup> The estimation of FFM using BIA is inherently conditioned by the athlete's hydration status, as the method assumes that TBW represents a constant proportion (~73 %) of FFM.<sup>13</sup> However, when acute or cumulative variations occur in the intra- and extracellular compartments (as happens in rapid weight loss or dehydration protocols in weight-class athletes), this assumption is broken. For example, in states of dehydration, TBW decreases, which increases the resistance measured by BIA and leads to an underestimation of FFM and an overestimation of fat mass.<sup>14</sup>

The Tug of war (TOW) is a team sport in which two groups compete by pulling a rope in opposite directions, requiring a combination of maximum strength and endurance.<sup>15,16</sup> The TOW categories are determined by the total BM of the team, leading athletes to make adjustments to their body weight similar to those seen in sports such as boxing, judo and mixed martial arts.<sup>1</sup> However, in TOW, categories are defined not by the weight of each athlete but by the total weight of the team, allowing some athletes to compensate for the excessive weight of others.

Body weight significantly influences performance in TOW, especially in the rubber mode, where greater BM can provide an advantage in rope pull.<sup>16</sup> Therefore, teams seek to maximize their BM within allowable limits to increase their chances of victory. Rapid weight loss could compromise muscle mass and hydration, crucial factors for optimal performance in TOW.<sup>17</sup> In addition, it is important to consider that rapid weight loss not only affects physical performance but may also have consequences for the athlete's health.<sup>3</sup> Severe caloric restriction and dehydration can weaken the immune system, increase the risk of injury and negatively affect the athlete's overall well-being.<sup>18,19</sup> Furthermore, during the post-weighing recovery period, properly restoring not only body weight but also the ICW/ECW ratio (the normal range is 0.36-0.39) is essential to restore processes such as nutrient transport, protein synthesis, and cellular rehydration, and to avoid persistent adverse effects on physiological function and competitive performance.<sup>20</sup> Therefore, it is essential that TOW athletes and coaches are aware of these risks and seek weight management strategies that do not compromise health and athletic performance. Although the literature specific to weight loss in TOW is limited, it is reasonable to infer that rapid weight loss strategies could have adverse effects similar to those observed in other strength and endurance sports. To the authors' knowledge, there is no previous scientific evidence in TOW.

Given the above, this study aimed to examine day-to-day differences in body weight, body composition, and hydration status in athletes undergoing official weigh-ins prior to competition. Measurements were conducted on the day of the weigh-in and on the two subsequent competition days using bioelectrical impedance analysis. Additionally, we investigated whether these changes differed between male and female athletes.

## Material and methods

This study was designed as a retrospective observational analysis based on data collected from two TOW championships held in 2019 and 2020 under similar environmental conditions, depending on where the events took place.

## Participants

Forty-one TOW elite athletes ( $N = 41$ ), 22 men and 19 women were recruited for the study based on the following inclusion criteria: being between 18 and 60 years old, having no injuries or clinical conditions at the time of the study (such as pacemakers or cochlear implants), from any category, minimum 5 years of experience in international competitions, not being pregnant.<sup>3,9</sup> Athletes were recruited during the 2019 European Outdoor TOW Championships and the 2020 World Indoor TOW Championships.

In accordance with the Helsinki Declaration, participants received detailed information about the research procedures and provided written informed consent.<sup>21</sup> The study received ethical approval from the research ethics committees of the University of Deusto (M10\_2017\_108).

It must be noted that the obtained data were treated with the greatest confidentiality and scientific rigor, their use restricted by the guidelines for research projects following the scientific method required in each case, complying with the Organic Law 15/1999 of the 13<sup>th</sup> of December on the Protection of Personal Data (OLPPD); the proceedings used respected the ethic criteria of the Responsible Committee of Human Experimentation (established by law 14/2007, published in the Spanish Official State Gazette, n° 159).

This study is associated with the UN's Sustainable Development Goals, Agenda 2030, specifically with number 3, good health and well-being.

## Procedure

For this prospective observational study of repeated measurements, three measurements were taken: the first on the day of weighing, before the competitions; the second the following day (the first day of competition), leaving approximately 24 hours between the first and second measurements; and the third 24 hours after the second measurement (the second day of competition), leaving approximately 48 hours since the first measurement was taken. All participants were evaluated between 7:00 and 11:00 in the morning. All measurements were taken at the weighing site, in an auditorium, and the temperature (20-24°) and humidity conditions (40-60 %) did not change between the three weighing days.

Both the sociodemographic data collected to characterize the sample and height were measured only on the day of weighing. Height was measured without shoes using a SECA 220® measuring rod (Hamburg, Germany) with a precision to within 1 mm.<sup>22</sup>

Demographic data were collected using a short-printed questionnaire. BM was measured using an electronic scale (Epelsa electronic scale®, Challenger Z100), tested and calibrated accurately to weigh athletes individually.

Fluids and body composition were measured using the InBody S10® (Biospace, Seoul, Korea), which uses an eight-point tetrapolar electrode system method to assess impedance at six specific frequencies (1, 5, 50, 250, 500, and 1,000 kHz). Calibration was performed according to the manufacturer's instructions. The eight current-injecting electrodes were placed on the thumb and third finger of each hand and on the anterior aspect of the ankle, over the medial and lateral malleoli. The athletes wore shorts and stood with their limbs abducted to avoid current leakage. Before each measurement, the skin and electrodes were cleaned with alcohol. The athletes' height and age were entered manually into the system. All measurements were performed by trained personnel. The primary outcomes were changes in BM, body mass index (BMI), and the main MF-BIA fluid balance variables: TBW, ECW, ICW, ECW:ICW ratio and ECW:TBW ratio).<sup>23</sup>

Secondary outcomes included additional body composition parameters such as fat mass, FFM, body fat percentage, TBW: FFM ratio, mineral content, bone mineral content, and basal metabolic rate. In line with the ACSM statement, dehydration was operationally defined as a  $\geq 2$  % reduction in BM, which is known to impair exercise

performance.<sup>24,25</sup>

### Statistical analysis

Descriptive statistics are presented as mean  $\pm$  standard deviation (SD). The normality test was performed using the Kolmogorov-Smirnov test, and the homogeneity of variances was checked using Levene's test. Between-group comparisons (women vs. men) for participants' characteristics across days were conducted using one-way analysis of variance (ANOVA). Moreover, one-way ANOVA was used to assess between-group differences in the delta values (computed as Day 3 - Day 1, Day 2 - Day 1, and Day 3 - Day 2), while repeated measures ANOVA was used to examine within-subject changes across days (Day 1, Day 2, and Day 3). Bonferroni-adjusted post hoc tests were used for pairwise comparisons. Additionally, sex  $\times$  time interaction effects were also tested using repeated measures ANOVA with sex as the between-subjects factor. Associations between variables were examined using simple linear regression, with deltas ( $\Delta$ ) computed for each pairwise comparison between days. The strength of associations was interpreted based on the regression coefficients and their statistical significance. Finally, the ECW-to-TBW ratio distribution and cumulative percentage distributions across days was computed.

All statistical analyses were performed using IBM Statistical Package for Social Sciences (SPSS®; v.22.0 for Windows, IBM SPSS Statistics, IBM Corporation, Chicago, IL, USA) and GraphPad Prism (v.9 for Windows, San Diego, California, USA). The threshold for statistical significance was set at  $P < 0.05$ .

Effect sizes were calculated to complement statistical significance testing. Partial eta squared ( $\eta^2_p$ ) was used for repeated-measures ANOVA analyses, and Cohen's  $d$  was calculated for pairwise comparisons. Effect sizes were interpreted according to conventional thresholds, with values of 0.01, 0.06, and 0.14 representing small, moderate, and large effects for partial eta squared, and 0.2, 0.5, and 0.8 representing small, moderate, and large effects for Cohen's  $d$ , respectively.

### Results

The weight registered by the athletes on the day of weighing was  $70.1 \pm 8.5$  kg (Table 1). As can be seen in Table 1, men are heavier and taller than women, and there is no difference in BMI or age between the two groups. Table 2 presents the descriptive hydration and body composition variables of participants on Day 1. In brief, men yielded higher values for TBW, ICW, and ECW. Additionally, men presented greater fat mass and FFM compared to women (all  $P < 0.001$ ). Data for days 2 and 3 were similar (see Table S1). Notably, on both Day 2 and Day 3, women showed a lower ECW-to-TBW ratio values compared to men (both  $P = 0.01$ ).

Table 3 presents the between days differences, expressed as deltas, in body weight, body composition, and hydration status. One-way ANOVA analyses showed no significant between-group mean differences (all  $P > 0.13$ ; Table 3).

Detailed descriptive statistics and 95 % confidence intervals for these changes are presented in Table 4.

**Table 1**

Descriptive characteristics of participants on Day 1.

	All (N = 41)				Women (N = 19)				Men (N = 22)				P
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	
Age (years)	31.5	8.9	17.0	52.0	31.0	9.1	21.0	51.0	32.0	8.9	17.0	52.0	0.74
Height (cm)	175.8	9.5	159.0	199.0	169.1	3.8	159.0	175.0	181.6	9.1	168.0	199.0	<0.001
Body mass (kg)	70.1	8.5	54.9	86.9	64.6	4.8	54.9	76.5	74.8	8.1	61.8	86.9	<0.001
Body mass index (kg/m <sup>2</sup> )	22.6	1.6	19.5	27.1	22.6	1.5	20.5	27.1	22.7	1.8	19.5	26.2	0.87

Data are presented as minimum (Min), maximum (Max), mean and standard deviation (SD). P values from one-way ANOVA analyses.

Repeated-measures ANOVA analyses revealed significant changes across days for body weight, TBW, intracellular water, ECW, fat-free mass, and BMI (all  $P < 0.001$ ). Post hoc Bonferroni comparisons showed a similar pattern across these variables, with significant differences between Day 1 and Day 2 ( $P < 0.001$ ) and between Day 1 and Day 3 ( $P < 0.001$ ), whereas no significant differences were observed between Day 2 and Day 3 ( $P > 0.05$ ). Importantly, these patterns were consistent in both men and women, as no significant sex  $\times$  time interaction effects were detected for any of these variables. No mean difference was found between Day 2 and Day 3 ( $P = 0.19$ ). Similar to body weight, TBW, intracellular water, ECW, FFM, and BMI showed significant between-day differences ( $P < 0.001$ ). Bonferroni post hoc comparisons revealed similar between-day patterns to those observed for body mass. Finally, no significant between-day mean differences were observed for body fat mass ( $P = 0.134$ ) or the ECW-to-TBW ratio ( $P = 0.169$ ). Moreover, no significant interaction effects were observed, indicating that the day-to-day changes were similar between women and men. No sex  $\times$  time interaction was found for body weight ( $P = 0.860$ ), TBW ( $P = 0.641$ ), intracellular water ( $P = 0.499$ ), ECW ( $P = 0.698$ ), body fat mass ( $P = 0.536$ ), FFM ( $P = 0.612$ ), BMI ( $P = 0.385$ ), and the ECW-to-TBW ratio ( $P = 0.228$ ).

Simple linear regression analyses showed that Day 1 vs. Day 3 differences, expressed as deltas, in body weight were positively associated with changes in TBW, intracellular water, and ECW (Fig. 1 A-D). Moreover, similar associations were observed for changes in FFM with these hydration-related outcomes (Fig. 1 E-H). Similar associations were observed for Day 1 vs. Day 2 (Fig. S1). Concerning Day 2 vs. 3, weaker associations were observed for body weight and hydration-related parameters (Fig. S2A-D), whereas FFM showed a strong relationship (Fig. S2E-G). In addition, Fig. 2 shows positive associations between changes in body weight and FFM across days (Fig. 2 A and B), with a smaller magnitude of change observed between Day 2 and Day 3 (Fig. 2 C). Finally, Fig. S3 shows a similar distribution of ECW-to-TBW ratio values across days.

### Discussion

The aim of this study was to examine day-to-day differences in body weight, body composition, and hydration status in athletes undergoing official weigh-ins prior to competition. The main finding was that athletes experienced significant increases in body weight, TBW, ECW, FFM, and BMI between the day of weighing and competition days, with no significant differences between genders.

Additionally, effect sizes were trivial to small across all variables, further supporting the absence of meaningful differences between men and women.

Although effect sizes were generally small, the magnitude of body mass changes (~5–6 %) exceeds commonly accepted thresholds associated with impaired performance, suggesting that these changes may be physiologically and clinically relevant despite limited between-group differences.

These results suggest that pullers, as in other weight-category sports, likely undergo rapid weight reduction prior to weigh-ins, followed by

**Table 2**  
Hydration and body composition variables of participants on Day 1.

	All (N = 41)				Women (N = 19)				Men (N = 22)				P
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	
TBW (L)	42.3	7.3	31.0	54.9	35.9	2.7	31.0	40.9	47.8	5.2	39.7	54.9	<0.001
ICW (L)	26.5	4.6	19.2	34.7	22.5(62.6 %)	1.7	19.2	26.0	30.0(62.7 %)	3.3	24.7	34.7	<0.001
ECW (L)	15.8	2.7	11.8	20.3	13.4(37.4 %)	1.0	11.8	15.6	17.8(37.2 %)	1.9	14.8	20.3	<0.001
Body fat mass (kg)	12.4	4.5	4.7	29.3	15.5(24.0 %)	4.1	11.4	29.3	9.6(12.8 %)	2.7	4.7	14.0	<0.001
Fat-free mass (kg)	57.7	10.0	42.3	75.0	49.1(65.6 %)	3.6	42.3	55.9	65.2(87.2 %)	7.1	53.8	75.0	<0.001
ECW-to-TBW ratio	0.37	0.01	0.37	0.39	0.37	0.01	0.37	0.39	0.37	0.01	0.37	0.38	0.14

Data are presented as minimum (Min), maximum (Max), mean and standard deviation (SD). P values from one-way ANOVA analyses. ECW: extracellular water. ICW: Intracellular water. TBW: total body water.

**Table 3**  
Changes (Δ) in body weight, body composition, and hydration status across days.

	Women (n = 19)		Men (n = 22)		P	η <sup>2</sup> partial
	Mean	SD	Mean	SD		
Δ Body weight (Day 1 to Day 3)	3.9(6.0 %)	1.9	4.0	2.3	0.88	0.001
Δ Body weight (Day 1 to Day 2)	3.7(5.5 %)	1.3	3.0	1.8	0.92	0.002
Δ Body weight (Day 2 to Day 3)	0.2(0.4 %)	0.7	1.9	1.0	0.83	0.002
Δ TBW (Day 1 to Day 3)	3.0(8.5 %)	0.6	1.1	0.8	0.64	0.001
Δ TBW (Day 1 to Day 2)	2.6(6.9 %)	1.0	-0.2	1.3	0.66	0.008
Δ TBW (Day 2 to Day 3)	0.4(1.5 %)	1.8	4.2	2.4	0.93	0.04
Δ ICW (Day 1 to Day 3)	1.9(8.1 %)	0.6	1.1	0.7	0.33	0.001
Δ ICW (Day 1 to Day 2)	1.6(6.5 %)	0.01	0.01	0.01	0.26	0.02
Δ ICW (Day 2 to Day 3)	0.3(1.6 %)	1.2	3.8	2.2	0.74	0.03
Δ ECW (Day 1 to Day 3)	1.2(9.2 %)	1.2	2.8	1.8	0.56	0.005
Δ ECW (Day 1 to Day 2)	1.1(7.7 %)	0.7	1.7	1.0	0.34	0.001
Δ ECW (Day 2 to Day 3)	0.1(1.4 %)	0.5	1.1	0.8	0.92	0.03
Δ Body fat mass (Day 1 to Day 3)	-0.3(2.8 %)	0.9	-0.1	1.3	0.52	0.005
Δ Body fat mass (Day 1 to Day 2)	0.01(0.9 %)	1.6	3.9	2.5	0.53	0.01
Δ Body fat mass (Day 2 to Day 3)	-0.3(2.9 %)	0.4	1.1	0.7	0.37	0.03
Δ Fat-free mass (Day 1 to Day 3)	4.3(8.7 %)	0.01	0.01	0.01	0.14	0.001
Δ Fat-free mass (Day 1 to Day 2)	3.7(7.1 %)	0.9	0.2	0.8	0.75	0.01
Δ Fat-free mass (Day 2 to Day 3)	0.6(1.3 %)	0.8	0.2	0.9	0.21	0.04
Δ Body mass index (Day 1 to Day 3)	1.2(6.0 %)	0.5	0.2	0.5	0.22	0.02
Δ Body mass index (Day 1 to Day 2)	1.2(5.5 %)	0.3	0.1	0.4	0.24	0.02
Δ Body mass index (Day 2 to Day 3)	0.1(0.4 %)	1.1	-0.1	1.1	0.25	0.007
Δ ECW-to-TBW ratio (Day 1 to Day 3)	0.01(0.5 %)	1.0	0.3	1.2	0.19	0.03
Δ ECW-to-TBW ratio (Day 1 to Day 2)	0.01(0.7 %)	0.3	0.1	0.2	0.59	0.05
Δ ECW-to-TBW ratio (Day 2 to Day 3)	0.01(0.2 %)	0.01	0.01	0.01	0.78	0.002

Values are presented as mean and standard deviation (SD). Δ were calculated as Day 3 minus Day 1, Day 2 minus Day 1, and Day 3 minus Day 2, respectively. P values correspond to between-group comparisons. SD: Standard deviation. ECW: extracellular water. ICW: Intracellular water. TBW: total body water.

rapid recovery afterwards.. The 5.7 % increase in body weight observed after weigh-in (almost 4 kg on average) suggests aggressive recovery, probably through rehydration and caloric rein take, which is consistent with what has been described in other sports such as judo or wrestling.<sup>26,27</sup> This rapid recovery may have consequences for competition performance, as well as compromising short- and long-term health.<sup>28</sup>

Although the average body mass increase between Day 1 and Day 3 was ~5.6 % (6.0 % in women and 5.2 % in men), these relative changes were comparable between sexes. This suggests that, despite differences in absolute body mass, both men and women followed similar patterns of weight loss and subsequent recovery. However, the most significant weight differences have been observed in men. In contrast, in other sports such as judo or MMA, the differences recorded in men are greater than those recorded in women.<sup>29</sup> This could be due to the lower level of professionalization among TOW athletes, which may be a cause of the greater standard deviation in weight differences between the day of weigh-in and other days.

The mean body mass fluctuation observed in the present study (~3.9 kg) represents approximately 5–6 % of the athletes' initial body mass, a magnitude that exceeds the thresholds commonly associated with impaired physical performance in weight-category and endurance-strength sports. Based on the observed magnitude of body mass recovery following the weigh-in, 97.5 % of the athletes exhibited changes exceeding the 2 % threshold commonly used to define dehydration, while 82.9 % exceeded a 3 % change. Previous studies have demonstrated that acute body mass reductions greater than 2 % of baseline values can significantly compromise aerobic capacity, muscular strength, and power output, particularly when achieved through dehydration.<sup>27,30,31</sup> Reductions between 3 % and 5 % have been linked to decrements in repeated-sprint performance, thermoregulatory efficiency, and cognitive function during competition.<sup>32,33</sup> These findings suggest that the magnitude of pre-competition weight manipulation observed in elite TOW athletes may already be sufficient to induce transient performance impairments, reinforcing the need for controlled and evidence-based rehydration protocols prior to competition. The significant increase in TBW and ECW after weighing confirms that the previous weight loss was largely achieved through dehydration. This pattern has already been identified in combat sports, where weight is primarily manipulated through fluid loss.<sup>31,34</sup> Although no significant changes in the ECW:TBW ratio or sex differences were observed in this variable, the fact that women presented higher values for this ratio over the three days could suggest greater extracellular fluid retention or physiological differences related to water distribution. In this regard, the menstrual cycle is a variable that can greatly influence the fluid retention that women may suffer.<sup>35</sup>

Although the present study quantified changes in TBW, ICW, and ECW, the interpretation of these compartments should be made with caution. Estimates obtained through bioelectrical impedance analysis are based on prediction algorithms that assume relatively stable hydration conditions and constant relationships between body water compartments. In situations involving acute dehydration followed by rapid rehydration, such as those commonly observed in pre-competition

**Table 4**  
Descriptive statistics (mean ± SD and 95 % CI) for day-to-day changes by sex.

	N (22 Men/ 19Women)	Mean (SD)	CI 95 %	
			Min	Max
Δ BW (Day 1 to Day 3))	22	3,98 ± 2,27	2,97	4,99
	19	3,88 ± 1,88	2,97	4,78
Δ BW (Day 1 to Day 2)	22	3,78 ± 2,23	2,79	4,77
	19	3,59 ± 1,18	3,02	4,16
Δ BW (Day 2 to Day 3)	22	0,2 ± 0,76	-0,13	0,54
	19	0,29 ± 0,9	-0,14	0,72
Δ TBW (Day 1 to Day 3)	22	3,01 ± 1,81	2,21	3,81
	19	3,06 ± 1,29	2,44	3,68
Δ TBW (Day 1 to Day 2)	22	2,77 ± 1,82	1,97	3,58
	19	2,48 ± 1,19	1,91	3,06
Δ TBW (Day 2 to Day 3)	22	0,24 ± 0,89	-0,16	0,63
	19	0,57 ± 0,77	0,20	0,94
Δ ICW (Day 1 to Day 3)	22	1,88 ± 1,01	1,43	2,33
	19	1,82 ± 0,71	1,48	2,17
Δ ICW (Day 1 to Day 2)	22	1,71 ± 1,03	1,26	2,17
	19	1,45 ± 0,69	1,11	1,78
Δ ICW (Day 2 to Day 3)	22	0,17 ± 0,55	-0,07	0,41
	19	0,37 ± 0,5	0,13	0,62
Δ ECW (Day 1 to Day 3)	22	1,13 ± 0,84	0,75	1,50
	19	1,24 ± 0,62	0,94	1,54
Δ ECW (Day 1 to Day 2)	22	1,06 ± 0,83	0,69	1,43
	19	1,04 ± 0,53	0,78	1,29
Δ ECW (Day 2 to Day 3)	22	0,07 ± 0,39	-0,11	0,24
	19	0,2 ± 0,31	0,05	0,35
Δ BFM (Day 1 to Day 3)	22	-0,24 ± 1,3	-0,81	0,34
	19	-0,4 ± 1,01	-0,89	0,09
Δ BFM (Day 1 to Day 2)	22	-0,11 ± 1,32	-0,70	0,48
	19	0,13 ± 0,92	-0,32	0,57
Δ BFM (Day 2 to Day 3)	22	-0,13 ± 1,12	-0,62	0,37
	19	-0,53 ± 1,06	-1,04	-0,02
Δ FFM (Day 1 to Day 3)	22	4,22 ± 2,44	3,14	5,30
	19	4,28 ± 1,76	3,43	5,13
Δ FFM (Day 1 to Day 2)	22	3,89 ± 2,48	2,79	4,98
	19	3,46 ± 1,62	2,68	4,24
Δ FFM (Day 2 to Day 3)	22	0,33 ± 1,23	-0,21	0,88
	19	0,82 ± 1,05	0,31	1,32
Δ BMI (Day 1 to Day 3)	22	1,14 ± 0,68	0,84	1,44
	19	1,35 ± 0,64	1,04	1,66

**Table 4 (continued)**

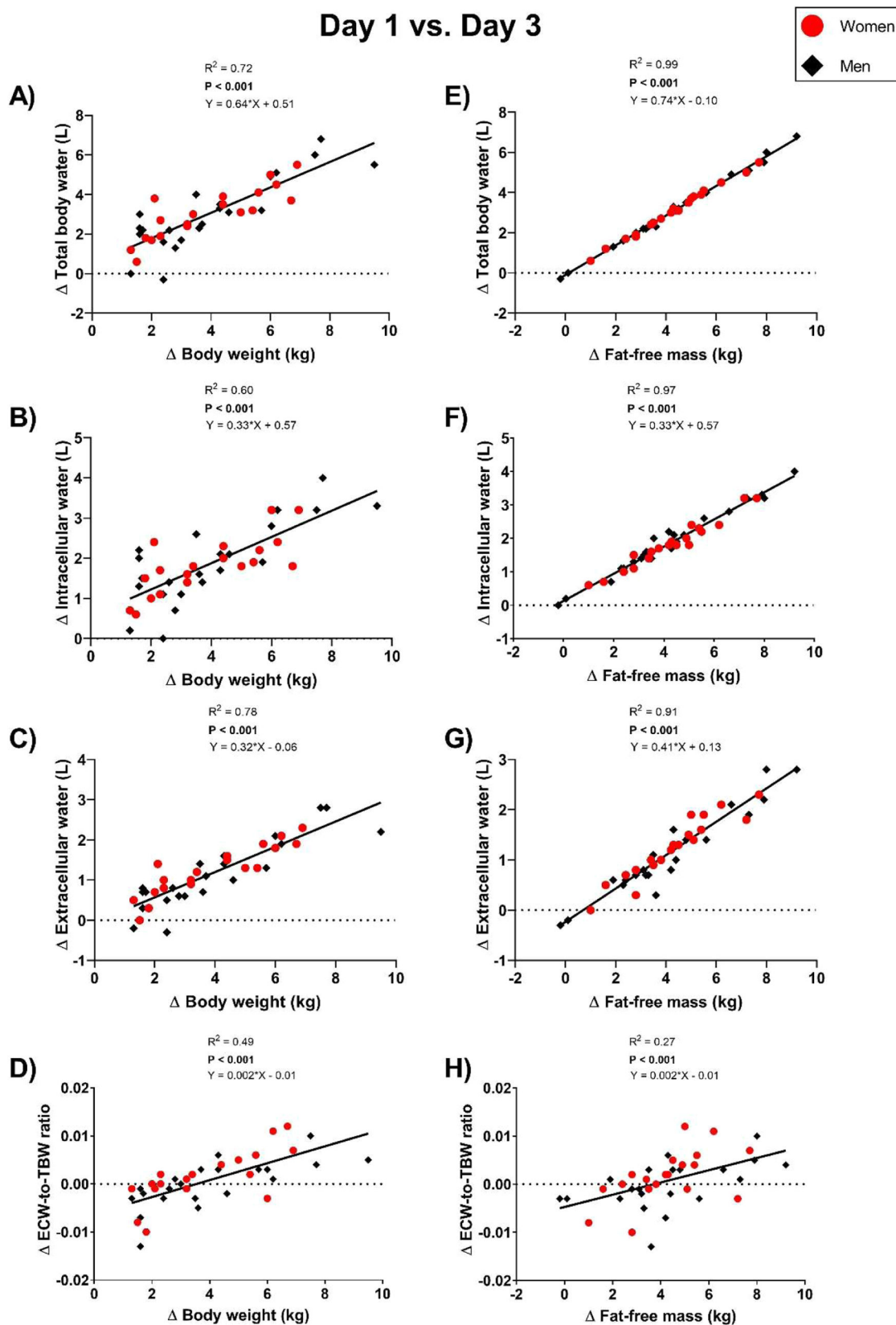
	N (22 Men/ 19Women)	Mean (SD)	CI 95 %	
			Min	Max
Δ BMI (Day 1 to Day 2)	22	1,08 ± 0,67	0,78	1,38
	19	1,24 ± 0,4	1,05	1,44
Δ BMI (Day 2 to Day 3)	22	0,06 ± 0,22	-0,04	0,16
	19	0,11 ± 0,32	-0,05	0,26
Δ ECW to TBW ratio (Day 1 to Day 3)	22	0 ± 0	0,00	0,00
	19	0 ± 0,01	0,00	0,00
Δ ECW to TBW ratio (Day 1 to Day 2)	22	0 ± 0	0,00	0,00
	19	0 ± 0	0,00	0,00
Δ ECW to TBW ratio (Day 2 to Day 3)	22	0 ± 0	0,00	0,00
	19	0 ± 0	0,00	0,00

Values are presented as mean and standard deviation (SD). Δ were calculated as Day 3 minus Day 1, Day 2 minus Day 1, and Day 3 minus Day 2, respectively. SD: Standard deviation. BFM: Body Fat Mass. BMI: Body Mass Index. BW: Body Weight. ECW: extracellular water. FFM: Fat Free Mass. ICW: Intracellular water. TBW: total body water.

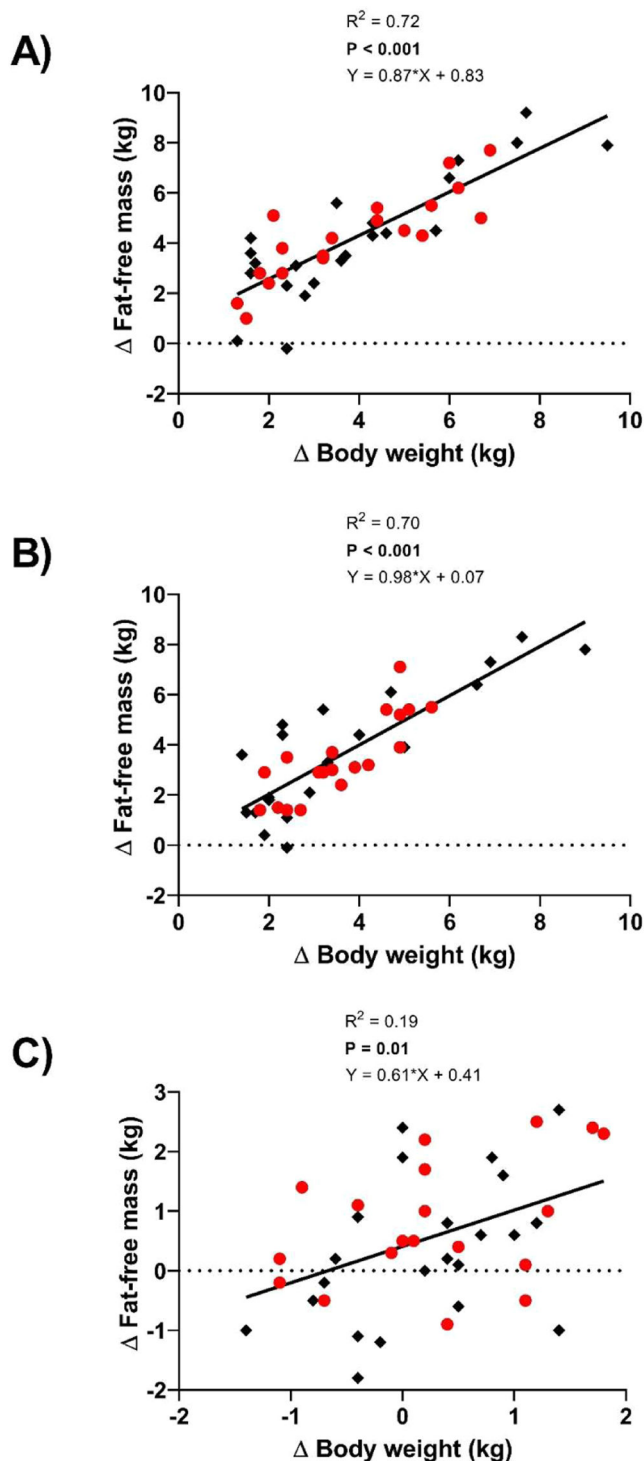
weight manipulation in weight-class sports, these assumptions may be partially violated, potentially affecting the accuracy of ICW and ECW estimations.<sup>25,36</sup> Consequently, although the observed increases in TBW and ECW suggest that dehydration was a primary mechanism for achieving the required body mass before the weigh-in, the precise redistribution between intracellular and extracellular compartments cannot be interpreted with complete physiological certainty in this context. Furthermore, acute changes in hydration status have been shown to significantly influence body composition estimates obtained through BIA, reinforcing the need to interpret these results with caution when rapid fluid shifts occur.<sup>36,37</sup>

The FFM also showed a significant increase between the weigh-in and competition days. Since FFM includes hydratable body components (intracellular water, proteins, and minerals), this increase most likely reflects a recovery in hydration status rather than an actual gain in lean tissue over such a short period.<sup>38</sup> This interpretation aligns with the concurrent rises in TBW, ICW, and ECW observed after the weigh-in, suggesting that the apparent recovery of FFM is predominantly driven by fluid replenishment. Importantly, under conditions of acute dehydration and rapid rehydration, BIA-derived estimates of fat mass and fat-free mass should not be interpreted as accurate reflections of true body composition. Instead, these variables should be understood as indirect markers that are strongly influenced by shifts in body water compartments.<sup>37,38</sup> Therefore, the observed changes in fat-free mass in the present study are likely driven by hydration-related fluctuations rather than actual changes in lean tissue mass. Because FFM estimation in BIA devices is mathematically derived from total body water under the assumption of a constant hydration fraction (~73 %), the method is inherently sensitive to acute fluctuations in body water.<sup>36</sup> Accordingly, the observed increase in FFM may represent a methodological artefact related to rehydration rather than a physiological adaptation. This limitation underscores the need for caution when interpreting BIA-derived FFM changes in contexts of rapid dehydration and rehydration, where body water redistribution can confound true variations in lean tissue mass. In this regard, body mass BM may constitute a more objective indicator of acute hydration recovery, as it is independent of conductivity-based estimations and less affected by transient water shifts.<sup>39</sup>

Regarding sex differences, no significant differences were found between men and women in the daily variations of any of the variables analyzed. This suggests that both sexes follow similar patterns of weight and hydration loss and recovery in the competitive context of TOW.



**Fig. 1.** Associations between changes ( $\Delta$ ) in body weight and fat-free mass with hydration-related variables from Day 1 to Day 3. Panels A–D show the relationships between changes in body weight ( $\Delta$  Day 3 – Day 1) and changes in total body water (A), intracellular water (B), extracellular water (C), and the ECW-to-TBW ratio (D). Panels E–H display the same hydration-related variables plotted against changes in fat-free mass ( $\Delta$  Day 3 – Day 1). Each data point represents a participant, with women shown in red and men in black. Regression lines, equations, and  $R^2$  values from linear regression analyses are presented in each panel. ECW: extracellular water. TBW: total body water.



**Fig. 2.** Associations between changes ( $\Delta$ ) in body weight and fat-free mass across days. Panels A–C show the relationships between changes in body weight and fat-free mass from Day 1 to Day 3 (A), Day 1 to Day 2 (B), and Day 2 to Day 3 (C). Each data point represents a participant, with women shown in red and men in black. Regression lines, equations, and  $R^2$  values from linear regression analyses are presented in each panel.

Nevertheless, physiological sex differences could manifest in aspects not measured in this study, such as hormonal responses to fluid stress or the subjective perception of thirst.<sup>39</sup>

Although the correlations between changes in body weight and hydration-related variables were consistently lower than those observed with FFM, body weight may actually represent a more unbiased

indicator in this context. Unlike FFM, which is estimated with BIA and is therefore directly influenced by fluctuations in hydration status, body weight is measured independently of tissue conductivity or water distribution. Unlike FFM, which is estimated by BIA algorithms that are directly influenced by body water compartments, BM is measured independently of tissue conductivity. Therefore, the lower  $R^2$  values observed for BM may reflect the fact that it is not mathematically derived from hydration-related variables, unlike BIA-derived parameters such as FFM. Despite the significant findings, this study is not without limitations. First, hormonal responses to fluid stress and subjective perceptions of thirst were not measured, which may have provided additional insights into individual variability in hydration status. Nevertheless, validated BIA-derived hydration markers and repeated objective measurements across consecutive days were used to partially compensate for the absence of these physiological and perceptual data. Second, the menstrual cycle phase of the female participants was not recorded, which could have influenced fluid retention and body water distribution. Third, due to the real-world competitive context in which the data were collected, it was not possible to record the specific nutritional or rehydration strategies implemented by each athlete following the weigh-in. Similarly, the exact time interval between the official weigh-in and the first competition bout, as well as competitive performance outcomes, were not documented. These factors may contribute to individual variability in hydration recovery and body mass fluctuations and should therefore be considered when interpreting the present findings. Future studies conducted under more controlled conditions could help clarify the influence of these variables on weight manipulation and recovery dynamics in TOW athletes. This study shows that elite TOW athletes undergo rapid weight loss prior to official weigh-ins, followed by a marked recovery of BM and hydration during the competition days. These changes occurred similarly in men and women, indicating comparable strategies of acute weight manipulation across sexes. The observed increases in TBW and FFM after the weigh-in suggest that dehydration and subsequent rehydration are key drivers of body mass fluctuations. However, the increase in FFM likely reflects hydration-related changes rather than true recovery of lean tissue mass. While these practices are common in weight-category sports, they may pose risks to athlete health and performance if not adequately controlled. Therefore, the present findings highlight the need for evidence-based weight management strategies in TOW that minimize health risks while preserving competitive performance.

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#### Institutional review board statement

The study was conducted by the Declaration of Helsinki and approved by the Ethics Committee of the University of Deusto code M10\_2017\_108.

#### Informed consent statement

Informed consent was obtained from all subjects involved in the study.

#### Data availability statement

The data of the research is available on the tables of the manuscript or on request from the corresponding author.

#### CRediT authorship contribution statement

**Arkaitz Castañeda-Babarro:** Conceptualization, Data curation,

Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Aitor Martínez Aguirre-Betolaza:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft. **Saioa Agirre-Elordui:** Formal analysis, Software, Visualization, Writing – review & editing. **Julio Calleja-González:** Methodology, Supervision, Visualization, Writing – review & editing. **Ruth Cayero:** Methodology, Supervision, Visualization, Writing – review & editing.

## Conflicts of interest

The authors declare no conflicts of interest.

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To the International Tug of War Federation.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.apunsm.2026.100518](https://doi.org/10.1016/j.apunsm.2026.100518).

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