Body Composition and Power Changes in Elite Judo Athletes

Abstract

The purpose of this study was to analyse the association between body composition changes, from a weight stable period to prior competition, on upper-body power in judo athletes. 27 top-level male athletes were evaluated at baseline (weight stable period) and 1–3 days before competition, with a time difference of approximately 1 month. Total body and extracellular water were estimated by dilution techniques (deuterium and bromide, respectively) and intracellular water was calculated as the difference. Body composition was assessed by DXA. A power-load spectrum was used to assess upper-body power output in a bench-press position. Comparison of means, bivariate, and partial correlations were used. Results indicate that though no significant mean changes were found in body composition and upper-body power, individual variability was large. Among all body composition changes, only total-body water ($r=0.672; p<0.001$) and intracellular water ($r=0.596; p=0.001$) were related to upper-body power variation. These associations remained significant after controlling for weight and arm lean soft tissue changes ($r=0.594, p=0.002$ for total-body water; $r=0.524, p=0.007$ for intracellular water). These findings highlight the need for tracking total-body water, specifically the intracellular compartment in elite judo athletes in order to avoid reductions in upper-body power when a target body weight is desired prior to competition.

Introduction

Water consumption, hydration status, and the effects of dehydration on exercise and work performance, health, and well-being have been the topic of much public and scientific debate in recent years [6]. The effect of body water balance on aspects of exercise performance has been extensively researched and, in recent years, reviewed comprehensively [14, 20]. Judelson and colleagues [14] indicated dehydration limits strength, power, high intensity endurance and, therefore, is an important factor to consider when attempting to maximize muscular performance in athletes.

Water is the most abundant component of body mass at the molecular level in healthy adults [24]. Water is distributed into 2 main compartments: intracellular (ICW) and extracellular (ECW). The reference methods for total body water (TBW) and ECW assessment are based on dilution techniques, such as deuterium and bromide, while ICW can be accurately assessed as the difference between TBW and ECW [21]. However, few studies have been conducted with athletes using these reference techniques [2, 18, 22]. Hence, the use of less valid techniques for assessing athletes has limited our understanding of the effects of hydration changes on performance [4, 19].

Body water loss in humans results in fluid losses from both the intracellular and extracellular fluid compartments [7]. However, fluid losses from these 2 compartments can cause different effects on the remaining body water pools [13, 17]. When body water loss has occurred, various effects on neuromuscular function and short-term power have been reported [14]. The published evidence suggests that there is a likelihood of a reduction in strength if dehydration is induced as a result of prolonged food and fluid restriction [3, 14]. However, to our knowledge no literature has identified which of the main compartments of TBW (ECW and ICW) are decreased after fluid restriction and what are the respective consequences of these changes on physical performance, especially in power sports.
The purpose of the current study was to analyse the relationship between body composition changes and upper-body power output in male judo athletes.

Material and Methods

Subjects

27 male judo athletes were eligible to participate in the study. The inclusion criteria were: 1) age ≥18 years, 2) voluntarily practiced rapid weight loss at least 3 times within the past year, 3) practiced judo for ≥5 years, 4) trains ≥15 h a week, 5) a level of >1° degree black belt, 6) tested negative for performance enhancing drugs, and 7) not taking any medications or dietary supplements. Medical screening indicated no health limitation for study participation. All subjects were informed about the possible risks of the investigation before giving their written informed consent to participate. All procedures were approved by the Ethic Committee of the Faculty of Human Movement, Technical University of Lisbon. The present study was performed in accordance with the ethical standards of the International Journal of Sports Medicine [10].

Experimental design

A sample of national top-level judo athletes, engaged in the sport for more than 7 years enrolled into the study. Data collection was performed between September (1 month after the beginning of the in-season) and December. Body composition assessment was made during a period of weight stability and again 1–3 days prior to competition, with a time difference of approximately 1 month. The period of weight stability was considered the baseline phase with athletes performing their regular regimen of judo training which typically last 2–2 h in the morning and 2–2 h in the evening. 2 of the morning sessions were used for improving cardiorespiratory fitness and strength while the other sessions consisted of judo specific skills and drills and randori (fighting practice) with varying intensity above and below 90–95% of VO2max. Prior to competition some athletes lost body weight voluntarily restricting both fluid and food while others remained or increased their body weight.

Body composition measurements

Subjects came to the laboratory at baseline and prior to competition, after a 12-h fast, while refraining from exercise, alcohol, or stimulant beverages for at least 15 h. All measurements were carried out on the same morning.

Anthropometry

Subjects were weighed to the nearest 0.01 kg wearing a bathing suit without shoes on an electronic scale connected to the plethysmograph computer (BOD POD®, Life Measurement, Inc., Concord, CA, USA). Height was measured to the nearest 0.1 cm using a scale (Seca Hamburg, Germany) according to standardized procedures described elsewhere [16].

Fat mass (FM), Fat-free mass (FFM), Lean soft-tissue (LST), and Appendicular LST

Whole body composition using dual energy X-ray absorptiometry (QDR-4500, Hologic, Waltham, USA) was used to estimate FM, FFM, LST, and appendicular LST using 8.21 software. Scan positioning, acquisition, and analysis were standardized. Based on test-retest using 10 subjects, the coefficient of variation (CV) for FM and LST was 2.9% and 1.7%, respectively.

Total body water (TBW)

TBW was assessed by deuterium dilution using a stable hydrogen isotope ratio mass spectrometer (PDZ, Europa Scientific, UK). After a 12 h fast, an initial urine sample was collected followed by the administration of a deuterium oxide solution (D2O) of 0.1 g/kg of body weight. After a 4 h equilibration period, a second urine sample was collected. TBW was estimated including a 4% correction due to TBW exchanging with non-aqueous compartments [21]. Based on test-retest using 10 subjects, the CV was 0.4%.

Extracellular water (ECW)

ECW was also calculated using sodium bromide dilution. The subject was asked to drink 0.300 g/kg of body weight of NaBr. The NaBr concentration in plasma was measured by high-performance liquid chromatography (Dionex Corporation, Sunnyvale, CA) before and 3 h after tracer administration. The volume of ECW was calculated as: ECW(L) = [dose / (post-plasma bromide ([Br]PLASMA) – pre([Br]PLASMA))] × 0.90 × 0.95 where 0.90 is a correction factor for intracellular bromide (Br–), found mainly in red blood cells, and 0.95 is the Donnan equilibrium factor [21]. Based on test-retest using 7 subjects, the CV was 0.5%.

Intracellular water (ICW)

ICW was also calculated as the difference between TBW and ECW using the dilution techniques mentioned above (deuterium and sodium bromide, respectively).

Hydration status

To assure all athletes were in a neutral hydration state at baseline (weight stability period) we used the combined information of athletes’ post-voiding first-morning body weights in the 3 days prior to the first visit and the observation of urine colour, as proposed by Casa et al. [4]. If body weight changed by less than 1% and pale yellow urine (the color of lemonade, 1–3 on the Urine Colour Chart) was observed, strong evidence existed that athletes were in a euhydrated condition [4].

Physical performance test – upper-body power output

After body composition was assessed a physical test representing strength capacities needed to powerfully push the opponent during successive short intensive bouts was performed. Therefore, upper-body power output (UBPO) was determined in a bench press machine interfaced to a computer for data analysis both at baseline and prior to the competition. During upper extremity test actions, bar displacement, average velocity (meters per second) and mean power (watts) were recorded by linking a rotary encoder to the end part of the bar. The rotary encoder recorded the position and direction of the bar. The rotary encoder recorded the position and direction of the bar within an accuracy of 0.0002 m. Customized software (JLML I+D, Madrid, Spain) was used to calculate the output of each repetition performed throughout the whole range of motion. Subjects performed the test lying in a supine position on a bench. Legs were positioned at the sides of the bench with feet flat on the floor. The bar was gripped with hands a shoulder width apart. The subjects started the test placing the bar close to the chest with forarms perpendicular to the floor in line with the shoulders. As fast as possible, the bar was pressed upwards...
extending the arms completely and immediately returning the bar back to the chest.
At baseline, a power-load spectrum (5 kg increment) was used to assess UBPO. Subjects performed 3 repetitions at each workload and the mean power output was recorded. A rest interval of 3 min was used between each workload. Before the competition, and after a standardized warm-up, only the individual load where the peak power output value was attained at baseline was used to assess power output changes. This option was made to avoid affecting the energy demands of the competition.

| Table 1 | Mean and standard deviation values for body composition, energy intake, and upper-body power output assessed at baseline, prior competition, and the respective changes. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                | Baseline Mean ± SD | Prior Competition Mean ± SD | Changes * Mean ± SD |
| age (yrs)       | 23.2 ± 2.8       | 23.4 ± 2.2       | −0.2 ± 0.6      |
| stature (m)     | 1.76 ± 0.05      | 1.76 ± 0.05      | 0.0 ± 0.0       |
| weight (kg)     | 72.8 ± 7.1       | 72.0 ± 6.9       | −0.8 ± 0.8      |
| BMI (kg/m²)     | 23.6 ± 2.3       | 23.4 ± 2.2       | −0.2 ± 0.2      |
| %FM             | 12.1 ± 3.1       | 11.7 ± 2.8       | −0.4 ± 0.3      |
| FM (kg)         | 8.8 ± 2.8        | 8.4 ± 2.5        | −0.4 ± 0.3      |
| FFM (kg)        | 63.4 ± 5.7       | 62.9 ± 5.8       | −0.5 ± 0.5      |
| LST (kg)        | 60.3 ± 5.4       | 59.9 ± 5.5       | −0.4 ± 0.5      |
| arms LST (kg)   | 7.4 ± 1.1        | 7.2 ± 1.0        | −0.2 ± 0.1      |
| legs LST (kg)   | 20.5 ± 1.8       | 20.3 ± 1.7       | −0.2 ± 0.1      |
| TBW (kg)        | 47.4 ± 4.8       | 47.1 ± 4.8       | −0.3 ± 0.3      |
| ECW (kg)        | 19.8 ± 2.2       | 19.6 ± 2.3       | −0.2 ± 0.1      |
| ICW (kg)        | 27.6 ± 3.2       | 27.5 ± 3.2       | −0.1 ± 0.1      |
| energy intake   | 2486.3 ± 154.0   | 2340.0 ± 764.2   | −576.3 ± 114.3  |
| UBPO (watts)    | 467.0 ± 104.7    | 472.7 ± 83.6     | 5.7 ± 12.1      |

Abbreviations: BMI, body mass index; % FM, percent fat mass; FFM, absolute fat mass; FFM, fat-free mass; LST, lean soft-tissue; TBW, total-body water; ICW, intracellular water; ECW, extracellular water; UBPO, upper-body power output.

* Changes are expressed as a percentage of the baseline value; ≠ significantly different from 0, p < 0.05.

Energy intake
Energy intake was assessed during a period of 7 days using a 24-h diet record both at baseline and prior to competition. Subjects were instructed regarding portion sizes, supplements, food preparation, and others aspects pertaining to an accurate recording of their energy intake. Records were turned in and reviewed at the time of laboratory testing for macro and micro nutrient composition and total energy expenditure (kilocalories). Diet records were analysed using 2 software packages (Food Processor SQL and PIABAD).

Statistical Methods
Data was analysed with SPSS for Windows version 17.0 (SPSS Inc, Chicago). Descriptive statistics included means ± SD and were calculated for all outcome measurements. Using 27 subjects, this study was 80% powered to detect a correlation coefficient higher than 0.51 and as low as ~0.51. Comparison of mean changes was performed using paired samples T-Test while independent samples T-Tests were used for comparisons between groups. Changes were expressed as a percentage of the baseline value (variation). The relationship between body composition changes and physical performance was conducted by bivariate correlations. Partial correlations were used to adjust those relations for the changes in potential confounding variables. For all tests, statistical significance was set at p < 0.05.

Results
Subject characteristics are presented in Table 1. A significant reduction (p < 0.05) of 1.1 kg in body weight was observed, ranging from −6.2 to 5.8%, while no significant changes were found in FM, FFM, LST, arms and legs LST, TBW, ECW, ICW, energy intake.
intake and UBPO. Considering a cut-off point for UBPO of \(-2\%\), athletes were divided in 2 groups: those who lost more than \(-2\%\) (10 athletes) and those who changed less (loss or gain) than \(-2\\%\) UBPO (17 athletes). Fig. 1 indicates the mean changes in body weight, FM, FFM, LST, arms and legs LST, TBW, ECW, and ICW. Significant reductions were found in TBW and ICW \((p<0.05)\) in those who lost upper-body power by more than \(-2\%\) though no differences were found in the other body composition variables \((p>0.05)\) when compared to those who lost upper-body power by less than \(-2\%\) (or gained).

The association between alterations in UBPO and body composition is displayed in Table 2. Changes in UBPO were only related to changes in TBW and ICW. As observed in Fig. 2, those athletes who lost TBW and ICW were those that had a reduced UBPO. These associations remained after controlling for weight and arms LST changes \((r=0.594, p=0.002\) and \(r=0.524, p=0.007,\) respectively).

### Discussion

The primary goal of this study was to examine the association between alterations in body composition and upper-body power.

#### Table 2

<table>
<thead>
<tr>
<th>Body Composition Variation</th>
<th>Upper-Body Power Output Changes (%)</th>
<th>Coefficient of correlation ((r))</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>body weight changes (%)</td>
<td>0.255</td>
<td>0.200</td>
<td></td>
</tr>
<tr>
<td>FM changes (%)</td>
<td>0.232</td>
<td>0.244</td>
<td></td>
</tr>
<tr>
<td>FFM changes (%)</td>
<td>0.232</td>
<td>0.244</td>
<td></td>
</tr>
<tr>
<td>LST changes (%)</td>
<td>0.271</td>
<td>0.171</td>
<td></td>
</tr>
<tr>
<td>arms LST changes (%)</td>
<td>0.271</td>
<td>0.171</td>
<td></td>
</tr>
<tr>
<td>legs LST changes (%)</td>
<td>0.251</td>
<td>0.207</td>
<td></td>
</tr>
<tr>
<td>TBW changes (%)</td>
<td>0.672#</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>ECW changes (%)</td>
<td>0.277</td>
<td>0.162</td>
<td></td>
</tr>
<tr>
<td>ICW changes (%)</td>
<td>0.596#</td>
<td>0.001</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: FM, fat mass; FFM, fat-free mass; LST, lean soft-tissue; TBW, total-body water; ICW, intracellular water; ECW, extracellular water; UBPO.  
* Changes are expressed as a percentage of the baseline value;  
\# Significant association \((p<0.01)\)

From a weight stability period to prior competition in elite judo athletes, with approximately 1 month apart between evaluations. Dilution techniques were uniquely used to assess TBW, ECW and ICW, thus offering more accurate estimates than provided by other commonly used methods to estimate body water and its compartments \([9]\). An important finding in our study was that those athletes with a more decreased upper-body power were those who had a greater reduction in TBW, even controlling for changes observed in body weight and arms lean soft-tissue. A recent review by Judelson et al. \([14]\) indicated that decreases in TBW were related to decreases in muscular performance, specifically a 3–4% reduction in hydration results in a 2% reduction in muscular power \([5, 23]\). However, these studies induced acute dehydration and hyperthermia which was not the case in our study, as subjects came to the laboratory approximately 1 month after the baseline evaluation, in a fasted state \((12\ h)\) with no exercise for at least 15 h. Additionally earlier studies did not use gold standard techniques to evaluate TBW nor did they assess the effect of ECW and ICW on muscular power.

The effect of changes in ECW and ICW on performance in athletes \([8]\) is not reported in the literature. Our results indicated a clear relationship between changes in ICW and power output. A possible mechanism may be the cell swelling theory introduced by Haussinger in the 1990s \([11, 12, 15]\). This concept postulates that cellular volume is a key signal for the metabolic orientation of cell metabolism, namely cellular swelling leads to anabolism whereas cellular shrinkage promotes catabolism. The cell swelling theory is therefore very attractive as a possible mechanism for explaining why those athletes who increased the cellular water compartment increased muscular power, as cellular enlargement acts as an anabolic proliferative signal. Moreover, malnutrition induces extracellular expansion and intracellular water shrinkage \([1]\). In our findings, it is possible that a shift may have occurred between water compartments due to the fact that some of our athletes restricted their diet (energy intake changes ranged from \(-54\%\) to \(76\%\)).

Unfortunately, in a clinical setting, the assessment of the intracellular space is largely ignored and no reference values are available to compare ICW measurements, specifically in athletes. Therefore, athletes do not know whether their ICW is in a healthy or unhealthy range and a medical practitioner cannot use an evidence-based target value for a rehydration strategy in a dehydrated person.

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Fig. 2 Associations between changes in total-body water, extracellular water, and intracellular water with upper-body power output.
In conclusion, we observed that reductions in body water, particularly within the cells, are related with decreased upper-body power output in elite judo athletes. Moreover, measures of TBW and ICW should be performed in athletes that need to achieve a target body weight prior to competition and further studies should be employed to establish reference values for total and intracellular water in an athletic population.

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References