Changes in body composition due to weight reduction by elite youth judo athletes in short period pre-competition

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Abstract

Background & Study Aim: The majority of judo athletes do not maintain their body weight by elimination of fat mass; rather, they reduce body weight shortly before competition. The aim of the study is effect of weight reduction by elite youth judo athletes in short period pre-competition.

Material & Methods: Study participants included 10 elite youth judo athletes (age 22.1 ±2.8 years, weight 80.03 ±11.8 kg, height 183.0 ±4.2 cm) whose body composition was measured using bioelectrical impedance before and after pre-competitive weight loss (6 days on average, using dehydration). We used the BIA 2000M bio-impedance method in two periods (pre- and post-reduction period) 6 days apart.

Results: The results showed significant changes in directly measurable indicators of body composition (resistance, reactance, phase angle) due to intentional body weight reduction in judo athletes. Resistance after weight reduction increased by 22.26% ($M_{pre\text{-}test}$: 373.60 ±34.94 Ω, $M_{post\text{-}test}$: 480.60 ±47.17 Ω, $t_9 = -8.44$, $p<0.01$, $d = 0.96$). We also detected significantly higher reactance ($M_{pre\text{-}test}$: 50.90 ±6.52 Ω, $M_{post\text{-}test}$: 59.60 ± 6.33 Ω, $t_9 = -9.11$, $p<0.01$, $d = 1.05$). Due to a higher increase in resistance (22.26%) in comparison to reactance (14.60%), the phase angle decreased significantly ($M_{pre\text{-}test}$: 7.54 ±0.91 °, $M_{post\text{-}test}$: 7.24 ±1.05 ° $t_9 = 5.031$, $p<0.01$, $d = 1.26$). A significant proportion of body weight loss was represented by a decrease in total body water ($M_{pr\ ECWe\text{-}test}$: 52.87 ± 5.59 l, $M_{post\text{-}test}$: 47.73 ±6.17 l, $t_9 = 8.20$, $p<0.01$, $d = 1.37$).

Conclusions: Alternating resistances and the associated phase angle can be considered an option to eliminate a possible source of errors (condition of constant hydration, usage of a specific prediction equation when calculating fat-free mass, body cell mass and fat mass).

Keywords: bio-impedance analysis • body weight loss • phase angle • reactance • resistance

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Body weight loss – reduction of total body mass. In combat sports, it is used for preparation to start in a lower weight category.

Bio-impedance analysis – the method of measuring body composition quality.

Phase angle – an indicator of cellular health and integrity.

Resistance – conductor resistance in bio-impedance measurements. A material with low resistance conducts well, while a material with high resistance conducts poorly.

Reactance – resistance in bio-impedance measurements. It is a measure of body cell mass.

Randori – sparring in judo in which both participants practice attacking and defending [42].

Ippon – one point. Achieved through the execution of a valid technique on the opponent [42].

Timing – the choice, judgement, or control of when something should be done (e.g. the moment of the attack in judo).

Dan (dan'i) – a term used to denote one's technical level or grade [42].

Training load – "A simple mathematical model of training load can be defined as the product of qualitative and quantitative factor. This reasoning may became unclear whenever the quantitative factor is called 'workload volume' or 'training volume' interchangeably with 'volume of physical activity'. Various units have been adopted as measures i.e. the number of repetitions, kilometres, tons, kilocalories, etc. as well as various units of time (seconds, minutes, hours) (…) As in the real world nothing happens beyond the time, the basic procedure of improvement of workload measurement should logically start with separation of the time factor from the set of phenomena so far classified together as '*workload volume*'. (…) Due to the fact that the heart rate (HR) is commonly accepted as the universal measure of workload intensity, the product of effort duration and HR seems to be the general indicator of *training load* defined as the amount of workload. It is useful in analyses with a high level of generality. (…)In current research and training practice the product of effort duration and HR was referred to as conventional units' or further calculations have been made to convert it into points." [41, p. 238].

Introduction

The nature of judo athletes' physical load is intermittent when, during *randori*, there are irregular and alternating anaerobic-aerobic periods; moreover, it also requires a high level of power, coordination, stability, reaction time and mental preparedness on the part of the athlete. Optimal judo performance depends on appropriate timing of the optimal level of technical, tactical, psychological and physiological characteristics and their mutual symbiosis at the moment of execution of the technique up to the *ippon*. One of the factors influencing in judo performance in terms of optimal predisposition is body composition [1]. A judo athlete is characterised as having a high proportion of lean body mass and muscle mass [2] and a low proportion of inactive fat mass [3]. Undesired fat mass acts as inactive mass that does not take part in active movements or reactions to the opponent and is not involved in techniques or throws. On the contrary, lean body mass and its components, intracellular mass and muscle mass, strongly contributes to strength and power performance [4]. An optimal proportion of lean body mass is required due to movement coordination during the execution of the throwing technique [5].

Body weight loss with the aim of competing in the tactically most advantageous category is typical for judo [3, 6-9] and other combat sports [10, 11]. It means, achieving favourable relationship with respect to weight of potential opponents before reduction. The majority of judo athletes do not maintain their body weight by elimination of fat mass; rather, they reduce body weight shortly before competition [3].

Methods of pre-competitive weight reduction may include increased training load, training in rooms with higher temperatures, fluid restriction, reduction diet or training in special plastic clothing in order to sweat more [3, 12]. Intensive and, in the long term, harmful methods include using weight loss drugs in the form of diuretics or laxatives. Some methods of radical weight reduction may negatively influence both the physical and mental state of an athlete, and thus, it is better to avoid this type of weight reduction [8, 11]. Risks associated with this process are reflected in the judo athlete's performance in terms of insufficient amount of water essential for optimal thermoregulation and metabolic processes. According to Heaps et al. [13], hydrated athletes have better indicators in muscle strength manifestations, and any type of imbalance in hydration among judo athletes could be harmful to their performance and health [14]. Dehydration in athletes causes decreased work capacity, reduced muscle strength and their cognitive abilities also deteriorate [15]. The most affected indicators in dehydrated athletes most often include muscle strength, muscle power and muscle strength production on average [16]. Furthermore, it is generally accepted that victory over individual opponents is conditioned by a similar level of strength abilities [17].

Body composition, in terms of factors enabling optimal predisposition for muscle work and execution of the throwing technique to the level of *ippon*, is disrupted by an imbalance in the internal environment and dehydration incurred by reducing body weight over a short time period. Radical body weight loss and its effect on body composition and performance in combat sports have been the subjects of several studies [3, 10, 16 18, 19] . However, the results of these studies suggest that these factors usually involve indirectly estimated indicators that are recalculated once or twice using prediction equations (intracellular mass, extracellular mass, lean body mass, fat mass). The assumption of constant hydration and the necessity to use prediction regression equations carry a relevant source of eventual error, which is not further interpreted by research teams [9].

The aim of the study is effect of weight reduction by elite youth judo athletes in short period pre-competition.

Material and methods

Participants

National youth level Czech judo athletes (n = 10, age 22.1 ±2.8 years, weight 80.03 ±11.8 kg, height 183.0 ±4.2 cm, BMI 25.22 ±2.2) from five weight categories (excluding weight categories up to 100 kg and over 100 kg) took part in the research. All participants have practised judo for at least 10 years and have attained a level of competency between 1st and 3rd dan. Their volume of load[1] was 720 to 1200 min (preparatory period, or 60 to 80 tournaments in the competitive period).

The research was approved by the ethical committee of the Faculty of Physical Education and Sport, Charles University in Prague (Czech Republic).

1. See in glossary the term "training load" and concerning it recommendation of the paper which is raising a lot of controversies concerning the terminology, the measurement and documenting of training load.

Procedures

The judo athletes underwent field measurement using the BIA 2000M bio-impedance method in two periods (pre- and post-reduction period) 6 days apart. The athletes reported their weight reduction methods as reduction diet, fluid restriction, greater training load and sweating. All participants usually reduce their body weight in this way 5-7 days on average before a tournament. Both measurements were taken in the morning at the same hour, and all judo athletes underwent basic anthropometric measurements and body composition measurements before and after body weight reduction. The athletes were instructed to consume no fluids or food for two hours before the measurement, to abstain from alcohol and caffeine for 24 hours before the measurement and to reduce exercise for 12 hours before the measurement in order to meet the standardised conditions of bio-impedance measurement [20].

Body height was measured using a digital stadiometer (SECA 242, Hamburg, Germany), and body weight was measured using a digital scale (SECA 769, Hamburg, Germany). To determine the whole-body bioimpedance, we used a BIA 2000M multi-frequency bioimpedance analyser (Data Input GmbH, Germany). We observed resistance (measurement at 50 KHz), reactance (measurement at 50 KHz), phase angle, absolute and relative amount of lean body mass (LBM and LBMr), body cell mass (BCM), the ratio of extracellular and intracellular mass (ECM/BCM), the percentage of fat mass (FM) and total body water and its components (intra- and extracellular water). When indirectly calculating the measured indicators the quality of body composition, we used software with the appropriate prediction equations (Data Input GmbH, Germany).

Statistical analysis

For statistical processing of the research data, we used the method of descriptive statistics. The measure of location was expressed using the arithmetic mean, and the measure of variability was expressed using standard deviation. To determine significant changes in body composition indicators due to body weight loss, we used a paired t-test for comparison of means of two independent samples. The parametric procedure was chosen after verification of normality of data distribution using the Shapiro-Wilk test.

Moreover, the effect size between the compared means (pre-test, post-test) at the beginning and end of weight reduction was assessed using *Cohen's* "*d*" coefficient of effect size. It was calculated as the difference of the means of the compared indicators and divided by a "pooled" standard deviation [21]. The coefficient was assessed as follows: $d = 0.20$ – small effect, $d = 0.50$ – medium effect and $d = 0.80$ – large effect [22].

The probability of type I error (alpha) was set at 0.05 in all statistical analyses. Statistical analysis was carried out using IBM® SPSS® v21 (Statistical Package for Social Science, Inc., Chicago, IL, 2012).

Results

The results showed significant changes in directly measurable indicators of body composition (resistance, reactance, phase angle) due to intentional body weight reduction in judo athletes (Table 1, Figure 1). Resistance after weight reduction increased by 22.26% ($M_{pre\text{-}test}$: 373.60 ±34.94 Ω, $M_{post\text{-}test}$: 480.60 ±47.17 Ω, $t_9 = -8.44$, $p<0.01$, $d = 0.96$). We also detected significantly higher reactance ($M_{pre\text{-}test}$: 50.90 ± 6.52 Ω, $M_{post\text{-}test}$: 59.60 ± 6.33 Ω, $t_9 = -9.11$, $p<0.01$, $d = 1.05$). This increase amounts to 14.60%, while the variability of the parameter was not changed (Table 1). Due to a higher increase in resistance (22.26%) in comparison to reactance (14.60%), the phase angle decreased significantly ($M_{pre\text{-}test}$: 7.54 ±0.91, $M_{post\text{-}test}$: 7.24 ±1.05 ° $t_9 = 5.031$, $p<0.01$, $d = 1.26$).

Intentional body weight reduction in judo athletes caused a decrease in weight by 8.84%; however, a higher absolute loss was found in lean body mass (LBM) in comparison to fat mass (Table 1). A significant proportion of body weight loss was represented by a decrease in total body water ($M_{pr\ ECWe\text{-}test}$: 52.87 ±5.59 l, $M_{post\text{-}test}$: 47.73 ±6.17 l, $t_9 = 8.20$, $p<0.01$, $d = 1.37$). A significant loss of total body water was caused by loss of both ICW (6.14 %) and ECW (14.51%).

Discussion

Individual indicators defining the quality of body composition in the tested judo athletes are, in all participants, at the level of elite combative athletes [3, 5, 6, 23, 24] . All our tested judo athletes reported, in accordance with available sources, a high proportion of lean body mass, intracellular mass, and muscle mass with high phase angle and a low value of ECM/BCM and a low proportion of undesired fat mass.

Our participants achieved the required representation of proportion of total body water to body weight both before and after intentional body weight reduction

Table 1. Differences between pre- and post-test indicators values (all indicators high effect size).

Indicator	Pre-test		Post-test		Difference	t	d
	mean	SD	mean	SD			
Resistance (Ω)	**373.60**	34.94	**480.60**	47.17	**107****	−8.44	0.96
Phase angle (°)	**7.54**	0.91	**7.24**	1.05	**0.3****	5.03	1.26
Reactance (Ω)	**50.90**	6.52	**59.60**	6.33	**8.7****	−9.11	1.05
CQ (%)	**57.55**	3.61	**63.42**	7.56	**5.87****	−3.28	1.11
BW (kg)	**80.03**	11.80	**73.20**	10.99	**6.83****	8.19	1.32
FM (%)	**12.35**	4.25	**10.68**	3.02	**1 .67**	1.59	1.15
LBM (kg)	**72.00**	8.06	**66.76**	9.92	**5.24****	3.69	1.31
LBMr	**0.91**	0.06	**0.92**	0.09	**0.01**	−0.52	1.25
ECM (kg)	**31.80**	5.35	**26.73**	4.71	**5.07****	3.78	1.41
BCM (kg)	**40.67**	8.40	**42.04**	5.75	**1.37**	−0.70	1.15
TBW (l)	**52.87**	5.59	**47.73**	6.17	**5.14****	8.20	1.37
ICW (l)	**31.09**	1.83	**29.18**	2.28	**1.91****	6.30	1.39
ECW (l)	**21.71**	3.89	**18.56**	4.02	**3.15****	6.02	0.80
ECM/BCM	**0.73**	0.12	**0.64**	0.08	**0.09***	3.12	1.43
BMR (kcal)	**1959.00**	150.37	**1945.00**	183.86	**14**	0.65	1.29
BMI (kg.m^{-2})	**25.22**	2.22	**23.17**	1.53	**2.05***	2.97	1.44

*p<0.05 ** p<0.01

Legend: **CQ** cell quote; **BW** body weight; **FM** fat mass; **LBM** lean body mass, **LBM** relative lean body mass: **ECM** extracellular mass; **BCM** body cell mass; **TBW** total body water; **ICW** intracellular water; **ECW** extracellular water; **ECM**/**BCM** extracellular-intracellular mass ratio; **BMR** basal metabolic rate; **BMI** body mass index

(65% of body weight). When tracking changes in total body water before and after body weight reduction, we recorded an average decrease of approximately 10% (mild to moderate dehydration) at the expense of both components, with a predominance of reduction in extracellular water. Moreover, not only total body water but also intracellular water was significantly changed (Table 1); however, in a state of dehydration, intracellular water achieved an optimal proportion (62% on average). A weight decrease by more than 2% lowers the level of a judo athlete's muscle strength [25], coordination [26], cardiorespiratory endurance and muscular function [27], which subsequently negatively influences performance in judo [28].

The assessment of body water representation, without taking into account its components – intracellular and extracellular water – is a limitation factor in understanding the effects of hydration changes on athletes' performance [29]. Silva et al. [18] present a clear relationship between changes in ICW and upper-body power output in 27 elite male judo athletes (23.2 ±2.8 years). According to the authors, athletes with decreased upper-body power were those who had a greater reduction in TBW, even monitoring for changes observed in body weight and lean soft arm tissue. The authors built on Häussinger's theory [30] that cellular volume is a key signal for the metabolic orientation of cell metabolism, meaning that cellular swelling leads to anabolism whereas cellular shrinkage promotes catabolism. According to this theory, our recorded changes in components of total body water, especially a significant change in intracellular water proportion (Table 1), would probably mean decreased muscle strength in judo athletes and, eventually, a negative impact on performance in *randori*. However, this statement should be supported using other methods related to the performance of participants with a certain state of dehydration (diagnostics of plasma volume or other supplementary

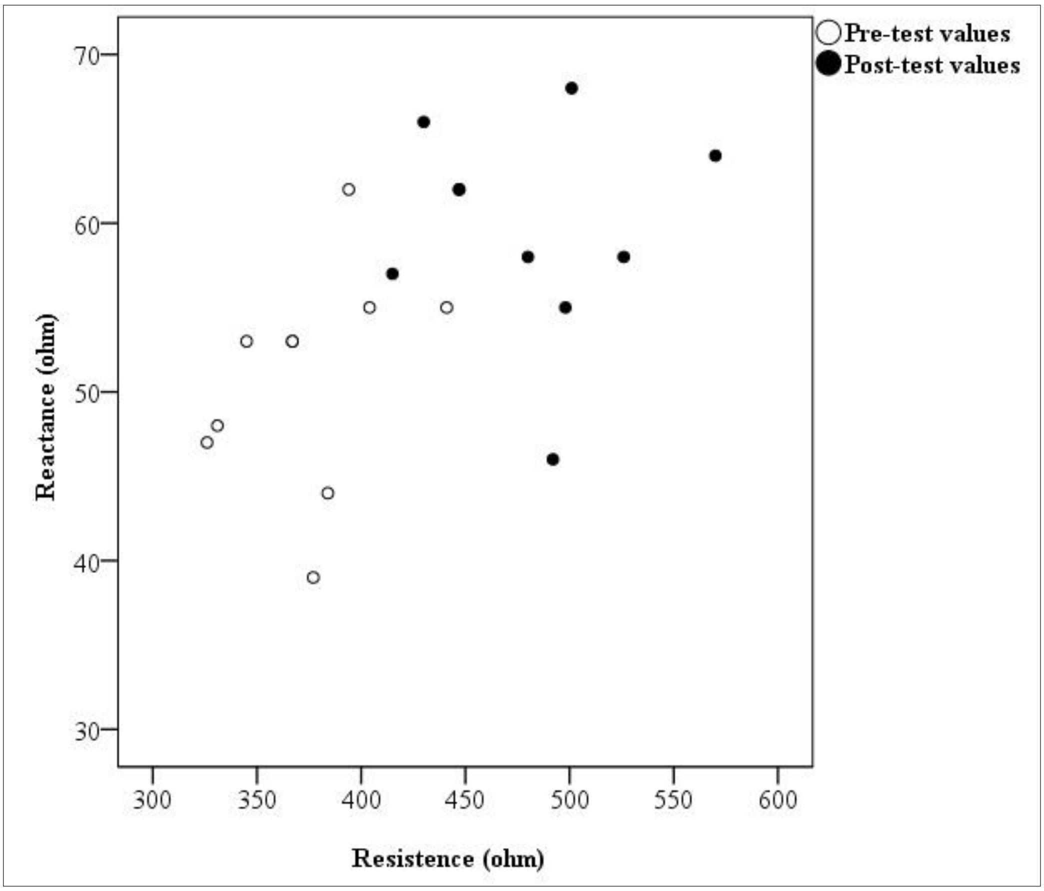

Figure 1. Changes in resistance and reactance values between pre- and post-test measurement.

examination of inner balance in the participants' bodies along with methods identifying performance in judo). However, it has been proved that improvement in cellular hydration may affect protein anabolism [29] and that ICW is related to decreased muscle power and strength in elite judo athletes [18, 19].

When assessing other directly measurable indicators we took into account resistances obtained using bio-impedance measurement (resistance, reactance and associated phase angle). Resistance, in terms of physics, is the pure ohmic resistance of a conductor to alternating current, and therefore, it is in contrast to the representation of total body water. A high proportion of total body water and electrolytes is a good conductor of electricity in muscle water. A material with low resistance conducts well, while a material with high resistance conducts poorly [32]. Fluctuation in total body water proportion influences the value of resistance. The value of resistance increased with dehydration of soft tissue in our tested judo athletes, and this change was significant (Table 1). Reactance as a measure of cell mass decreased as a result of changes in dehydration in our participants. However, it showed normal values (8-14 % of the value of resistance) before and after dehydration.

Changes in indirectly estimated indicators have been presented in several studies. Reljic et al. [10] reported that after 5 days of dehydration, no relationship between APV (−8% on average) and boxing-related tasks was observed in collegiate boxers who had reduced their body mass by 3% to 4% within a few hours through excessive sweat loss. Calvo et al. [16] reported a reduction of muscle mass after dehydration in judo athletes. The authors tested athletes with dehydration (n = 40) from senior and junior categories of the Portuguese national team and reported a significant difference in muscle strength average, muscle power average and muscle strength production ($p<0.05$).

Silva et al. [18, 19] showed in a sample of judo athletes that reductions in TBW and particularly in ICW were observed in athletes who lost more than 2% of their upper body power and forearm maximal strength, thus indicating that small changes in the ICW component may interfere with performance. Coufalová et al. [9] presented significant changes in the proportion of lean body mass and total body water ($p<0.01$) and, on the contrary, insignificant changes in the proportion of fat mass due to precompetitive body weight loss in elite Czech judo athletes.

Regarding changes in lean body mass in our participants, we must take into account the fact that changes occurred as a result of radical reduction and dehydration, i.e., mostly due to changes in total body water and its components. The values of cell quote and ECM/BCM index are influenced by changes in resistance, reactance and phase angle in terms of recalculation of indirectly measurable indicators. A real change (undesired loss) in body cell mass after body weight reduction in our participants has to be accompanied by changes in phase angle, cell quote and reactance in one direction in the bio-impedance measurement (loss of body cell mass and simultaneous decrease of phase angle, reactance and cell quote). In our participants, we found changes in total body water and its components, not a loss of body cell mass (insignificant change). Similarly, absolute values of lean body mass and their significant changes are influenced by a significant change in body weight and BMI (Table 1), which is confirmed by an insignificant difference in relative values. The calculation of fat mass is affected by differences in body weight and the amount of active mass.

Assessment of directly measurable indicators (resistance, reactance, phase angle) together with the proportion of total body water and recording changes in its components was used because according to O'Brien et al. [33], the multi-frequency bio-impedance method is not sufficiently accurate to assess TBW under conditions of hydration change. The reason is the difficulty in assessing alterations in electrolytes and the ratio of intracellular and extracellular water, which subsequently affects conversion (possible error) of estimated indicators identifying body composition. In patients with large alterations of body geometry or hydration status, the application of standard BIA is not appropriate to assess BCM.

Further, Battistini et al. [34], De Lorenzo [35] and Pirlich et al. [36] state that BIA does not allow accurate assessment of total body water and extracellular water, when body water components are undergoing acute changes. Similarly, conversion of lean body mass and its other components depends on constant hydration (lean body mass = total body water / 0.73) [37, 38]. In athletes, we must consider not only gender, ethnicity, physical maturation or ageing [39] but also the state of hydration, the ratio of protein and minerals and bone mineral density [40].

Resistance and reactance together with phase angle appear to be suitable indicators for monitoring short-term changes after radical loss of body water and could be an eventual replacement for indirectly calculated indicators dependent on the above-mentioned conditions (Figure 1).

Phase angle reflects the relationship between reactance and resistance and indicates changes in the quality of soft tissue. It depends on the resistance of tissue hydration. Phase angle is an indicator of cellular health and integrity; the relationship between phase angle and cellular health is increasing and is nearly linear [32]. A low phase angle is consistent with the inability of cells to store energy and an indication of a breakdown in the selective permeability of cellular membranes. A high phase angle is consistent with large quantities of intact cell membranes and body cell mass. Significantly lower values of phase angle in our participants (Table 1) indicate worse cellular integrity, worse state of membranes and worse distribution of liquids after a radical reduction of body weight.

An interval of three to six hours between weigh-in and competition is typical [7]. This time is sufficient for rehydration in order to eliminate the effect of dehydration on a judo athlete's abilities and performance in *randori*. To eliminate the eventual negative effects of radical body weight loss before competitions, it would be optimal to maintain body weight close to a targeted weight category; however, most judo athletes do not apply this option in practice.

A limitation of our study is the small sample size due to selection of elite athletes at the national level, as well as the absence of a linkage between the obtained data and judo performance, i.e., components taking part in judo performance (muscular strength, speed, coordination and stability). The bio-impedance method with an interpretation of tissue resistances and directly measurable indicators characterising alterations during precompetitive body weight reduction appears to be a suitable, cheap, fast, portable and non-invasive method for recording eventual changes.

Conclusions

Alternating resistances and associated phase angle can be considered an option to eliminate a possible source of errors (condition of constant hydration, usage of a specific prediction equation when calculating fat-free mass, body cell mass and fat mass). Limitations of our study include the low number of participants and the absence of methods directly associated with judo performance, i.e., with components that take part in judo performance that would support the negative impact of short-term body weight reduction on judo (identification of strength, monitoring plasma volume). We recommend tracking directly measurable indicators using bio-impedance measurements as a possible non-invasive method when monitoring short-term changes for precompetitive weight reduction in judo athletes.

Competing interest

The authors declare that they have no competing interests.

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