ORIGINAL ARTICLE

Changes in body composition, anthropometric indicators and maximal strength due to weight reduction in judo

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B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background & Study Aim: The pre-competitive weight reduction is very common in combat sports and it can have negative impact not only on performance but also on health. The purpose of this study was the knowledge about the impact weight reduction pre-competitive judo on indicators of body composition, anthropometric variables and maximum isometric strength. The purpose of this study was to know about the effects of weight reduction pre-competitive judo on indicators of body composition, anthropometric variables and maximum isometric strength.

Material & Methods: Nine national level Czech judoists (mean age 22.3 ± 2.4 years) from five weight categories (except category -100 and +100) took part in this study. Body composition was measured by bioelectrical impedance and anthropometrical indicators from skinfold thickness and body circumferences. Maximal isometric strength was assessed in upper and lower extremities, trunk and handgrip. All participants were assessed before reduction and then in the last day of body weight reduction. These two occasions were 5 days apart.

Results: A reduction of body weight of 4.6% (an average 3.4 kg) was observed with the greatest changes were detected in the fat free mass (FFM) and total body water (TBW). No significant change in body fat was detected. Weight reduction was also reflected in changes of skinfold thickness and body circumferences. A significant decrease in maximal trunk strength was observed, but the weight reduction did not affect the maximal isometric strength of upper or lower extremities.

Conclusions: Ideally, athletes should reduce body fat without decreasing skeletal musculature. Although we didn't find any significant decrease of maximal isometric strength, we suppose that strength endurance can be greatly influenced.

Keywords: body weight loss, combat sports, bioimpedance analysis, skinfold thickness

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Introduction

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

Bioimpedance analysis – the method for estimating body composition.

Skinfold thickness – the measurement of subcutaneous fat.

Isometric strength – the capacity to produce force with a voluntary isometric contraction.

Judo is an Olympic sport with a competitive weight class system. It is a martial art where two individuals compete in hand-to-hand combat, using a grip that incorporates complex technical and tactical actions to leverage the power of the opponent, all of which requires a great deal of both physical and psychological skill [1]. Judo is an intermittent sport, which on average takes 3.30 ± 0.17 minutes to complete [2].

In grip combat constant dynamic changes occur, which requires a combination of strength and endurance to control the distance between the opponents [3-5]. In all official competitions, judo athletes are paired with opponents of similar body weight from a weight class system. This ensures fairness and promotes even-handed combats in terms of strength, leverage and agility [6].

To gain an advantage over opponents, many judoists try to achieve a weight category that is below their usual body weight and will undertake cycles of weight loss before competition and weight gain post-competition. The reduction of body weight prior to competition typically involves fluid and food restriction, increased exercise, and exercise in warmer conditions such as saunas [7-9].

It is common practice in many judoists to undertake weight reduction strategies. Horswill [10] reported that 70-80% of judoists reduce their weight for inclusion in a lower weight category. However, the effects of weight cycling can have a negative impact of energy metabolism, endocrine, immune function [11] and performance. Fogelholm et al. [12] observed that a decrease of over 5% in body weight over 3 weeks cause a deterioration of physical performance in judoists.

It has been well documented that pre-competitive body weight reductions decrease total body water, body fat and lean body mass [13]. A decrease of fat free mass (FFM) can reflect a reduction of muscle strength, which can affect the athlete's ability to train at the required intensity. Body weight reduction has serious consequences on an athlete's health and performance, where negative effects of rapid weight loss can have detrimental effects on physiological aspects such as increased heart rate, decreased circulatory and respiratory functions, impaired thermoregulatory processes, decreased renal blood flow, and salt imbalance. Further, a reduction in circulating blood can decrease cardiac output and lead to a reduction in muscle strength and decreases the length of intense performances [14].

Furthermore, the body structure can play a determining role in the achievement of top judo performance [8,15]. During gradual reduction of body weight, the anaerobic efficiency does not decrease, but decelerated re-syntheses of glycogen and loss of protein from muscles may influence sports performance [16]. It has been reported that a sudden reduction of 5% of body weight decreases physical efficiency to 30%, irrespective of the body weight reduction method applied [16].

Muscle strength is important in judo, and its decrease due to weight loss is disadvantageous [17], especially the ability to develop a strong grip and maintain it during a judo match has become an important element for judo athletes [18]. Dynamic grip strength endurance seems to be an important attribute between judo athletes, probably because judo combat involves many elbow extensions and flexions in order to avoid the opponent's grip and to subdue them [18]. Also other authors consider strength as potential predictor of judo performance [15,19,20]. Rankin et al. [21] have shown that a 3 to 4% reduction in body weight reduces high-intensity intermittent arm power performance. Generally we can say, that body weight loss has a negative impact on the amount of body cellular mass and it can decrease the muscle strength. These components are also part of health oriented fitness and are closely related to health [22].

It had been well documented about changes in body composition due to weight reduction [23-25], however, little research has been conducted on competitive judo athletes that have examined changes in body composition, anthropometry indicators and muscle strength concurrently. The purpose of this study was the knowledge about the impact weight reduction pre-competitive judo on indicators of body composition, anthropometric variables and maximum isometric strength. It was hypothesised that the pre-competitive body weight reduction decreases total body water and muscle mass and these changes negatively affect the muscle strength.

Material and Methods

Nine national level Czech judo athletes (age 22.3 ± 2.4 years, weight 79.1 ± 9.0 kg, height 181.0 ± 6.2 cm) from five weight categories (except category - 100 and + 100) volunteered for the study and gave their written consent where ethical approval was granted by the University Human Ethics. The athletes had been involved in judo for 15.5 ± 2.3 years, were currently training 7.0 ± 2.0 trainings/week and

had participated in 11 competitions during the calendar year where they had reduced their body weight in seven competitions.

Study Design

The national top-level judo athletes attended the laboratory on two different occasions (pre- and post-reduction period) 5 days apart. Athletes reported their weight reduction method as exercise-induced sweating and concurrently decreased energy intake or changed their diet. Athletes stated that their usual reduction period lasts on average 5.7 ± 2.8 days. Both testing sessions were made at the same time of the day where each athlete underwent body composition and anthropometric evaluation. Following this maximal isometric strength of upper, lower extremities and trunk was assessed. Athletes were asked not to eat for two hours and drink two hours before the measurement. They were also instructed to abstain from alcohol and caffeine in the 24 h and exercise in the 12 h preceding their assessments.

Body Composition

Body composition was evaluated using the multi-frequency, whole-body bioimpedance (Inbody 720, Biospace Co Ltd., Korea) device. The calculation of body fat percentage was determined from prediction equation supplied by manufacturer (Biospace Co., Ltd., Korea). The device provided fluid distribution of five body segments (left and right arm, trunk, left and right leg). Previous research [25,26] supports the validity of using BIA to determine % BF in the wrestling population.

The following anthropometric measurements were carried out: body weight, body height, skinfold thickness (cheek, neck, pectoral, triceps, subscapula, midaxilla, abdomen, suprailiac, front thigh and medial calf), circumferences (upper arm, waist, hips, thigh and medial calf). For skinfold measurements a calliper (Best II K-501, Trystom, Czech Republic) (constant pressure 28.5 $g \cdot mm^{-1}$) was used and to ensure inter-reliability the main investigator performed all anthropometric measurements.

Maximal isometric strength

Isometric strength of arm, leg and trunk flexion and extension was measured as the peak forced produced by the maximal voluntary isometric contraction at defined positions. Isometric strength of hands was determined by a hand grip dynamometer (Takey Kogi, Japan) that assessed static grip strength of the right and left hand. Athletes stood upright with arms down the side of the body. Always 3 maximal trials were performed and the best score used for data analysis.

Data analysis

Data are presented as mean ± standard deviation (M ± SD). The Wilcoxon sign rank test was used to the differences of observed parameters. Rejection of the null hypothesis was assessed at the level of $p < 0.05$, or $p < 0.01$. Cohen's coefficient of effect size "d". It was calculated as the difference of the means of the compared parameters and divided by a „pooled" standard deviation (1) [27]. The coefficient was assessed as follows: d = 0.20 – a small effect, d = 0.50 – medium effect and d = 0.80 – large effect [28].

$$s_p = \sqrt{\frac{s_1^2(n_1 - 1) + s_2^2(n_2 - 1)}{n_1 + n_2 - 2}} \quad (1)$$

Statistical analysis was performed using SPSS (version 20.0, IBM, New York, USA).

Results

The pre-competitive reduction was in average 4.6% of initial body weight. The analysis of the results showed significant changes in all indicators of body composition except fat mass and edema exam (Table 1).

In segmental fluid distribution we observed significant decrease in all measured indicators ($p < 0.05$) (Table 2).

Furthermore, it was found significant changes in several skinfold thickness (subscapular, abdomen, midaxilla, suprailiac and front thigh) and in circumferences of waist, hips, thigh and medial calf (Table 3).

In contrast, there were no significant differences in isometric strength except trunk flexion (Table 4).

Discussion

The main finding of this study reported a weight loss of 4.6% (an average approximately 3.6 kg). This finding was similar to the study of Umeda et al. [29] who measured 22 Japanese judoists and the average decrease of body weight was 3.7 ± 2.2 kg what accounted 4.7%. Slightly lower was result of Boguszewski and Kwapisz [9], who observed the body weight reduction about 3.19 kg (4.07%). In previous study [30] it was found that top Czech athletes in combat sports

Table 1. Changes in body composition from weight reduction (M ± SD) (n = 9)

	Pre		Post		Sig	d	Effect Size
	M	SD	M	SD			
Body weight (kg)	79.14	8.97	75.74	9.51	p <0.01	0.37	small
Body Mass Index (kg.m-2)	24.16	1.85	22.99	1.87	p <0.01	0.63	medium
Fat Free Mass (kg)	71.10	8.38	68.66	8.58	p <0.05	0.29	small
Fat Mass (kg)	8.07	3.29	7.09	2.40	N.S.	0.34	small
Fat Mass (%)	10.16	3.99	9.29	2.90	N.S.	0.25	small
Protein mass (kg)	14.14	1.64	13.72	1.65	p <0.05	0.26	small
Total Body Water (l)	52.20	6.17	50.38	6.32	p <0.05	0.29	small
Intracellular Water (l)	32.70	3.79	31.77	3.85	p <0.05	0.24	small
Extracellular Water (l)	19.49	2.52	18.62	2.63	p <0.05	0.34	small
one mass (kg)	3.89	0.48	3.75	0.50	p <0.01	0.28	small
Body Cell Mass (kg)	46.83	5.44	45.47	5.51	p <0.05	0.25	small
Muscle mass (kg)	40.64	4.93	39.40	5.04	p <0.05	0.25	small
Basal Metabolic Rate (kcal)	1904.78	180.93	1853.03	185.25	p <0.05	0.28	small
Edema exam	0.327	0.002	0.323	0.004	N.S.	1.08	high

Table 2. Changes in segmental fluid distribution from weight reduction (M ± SD) (n = 9)

	Pre		Post		Sig	d	Effect Size
	M	SD	M	SD			
Right arm (l)	4.27	0.65	4.07	0.61	p <0.05	0.31	small
Left arm (l)	4.25	0.63	4.05	0.66	p <0.05	0.32	small
Trunk (l)	31.47	3.63	30.48	3.55	p <0.05	0.28	small
Right leg (l)	10.97	1.38	10.64	1.48	p <0.05	0.23	small
Left leg (l)	10.79	1.34	10.54	1.35	p <0.05	0.19	small

Table 3. Changes in skinfold thickness and circumferences from weight reduction (M ± SD) (n = 9)

	Pre		Post		Sig	d	Effect Size
	M	SD	M	SD			
Cheek (mm)	3.44	0.83	2.89	0.74	N.S.	0.71	high
Neck (mm)	1.11	0.31	1.00	0.00	N.S.	0.50	medium
Pectoral (mm)	2.22	1.13	1.78	0.63	N.S.	0.49	medium
Triceps (mm)	3.11	0.99	2.78	0.92	N.S.	0.35	small
Subscapula (mm)	7.56	2.83	6.56	2.36	p <0.05	0.38	small
Abdomen (mm)	8.11	4.79	6.44	3.92	p <0.05	0.38	small
Midaxilla (mm)	4.78	1.55	3.78	1.31	p <0.01	0.70	high
Suprailiac (mm)	3.67	1.15	2.89	1.29	p <0.05	0.64	medium
Front thigh (mm)	6.78	2.57	5.22	2.30	p <0.05	0.64	medium
Medial calf (mm)	4.11	1.29	3.67	1.33	N.S.	0.34	small
Upper arm (cm)	31.80	2.05	31.33	2.24	N.S.	0.22	small
Waist (cm)	81.11	4.21	78.11	3.95	p <0.01	0.74	high
Hips (cm)	100.00	5.47	97.56	5.33	p <0.01	0.45	medium
Thigh (cm)	54.78	2.91	53.22	2.63	p <0.05	0.56	medium
Medial calf (cm)	38.33	2.54	37.39	2.60	p <0.01	0.37	small

(n=53) regularly decrease their body weight about 5.4% (average body loss was 3.9 ± 2.3 kg, range from 1 kg to 10 kg). According to Fogelholm [31] if the time between weigh in and starting the competition is shorter than 5 hours, as in judo, it is not recommended to reduce body weight by more than 4%; where a 3 to 4% reduction in body weight reduces high-intensity intermittent arm power performance [21].

It was hypothesised that the pre-competitive body weight reduction decreases total body water and muscle mass and these changes negatively affect the muscle strength. Presented results show that decrease of total body water and muscle mass was confirmed against muscle mass, where it was not found any significant changes except trunk flexion.

Significant changes were observed in the current in all body composition parameters except body fat; however, a decrease of almost one kilogram of fat mass (i.e. almost 1% of body fat) was noted. Contrary, Umeda et al. [29] found a significant decrease of body fat (from 9.1 ± 4.7 kg to 7.9 ± 4.1 kg) what meant a decrease of relative body fat from 11.1 ± 4.5% to 10.1 ± 4.5%. This discrepancy can be explained by shorter time of reduction of our file, when our contestants reduced body weight for 5 days compared to weight reduction lasting 20 days in Umeda's study. A significant difference was evident in fat free mass (FFM), where participants lost on average 2.44 kg of active mass (1.36 kg of body cell mass, 1.24 kg of muscle mass and 0.42 kg in protein mass). This decrease can negatively influence sport performance, as muscle mass is positively related to anaerobic performance [32]. According to other research [23,33,34] acute weight reduction induces proteolysis of muscle tissue, resulting in a decrease in fat-free mass and physical strength. The loss of fat free mass observed in the present study was similar to that found

Table 4. Changes in maximal isometric strength from weight reduction (M ± SD) (n = 9)

	Pre		Post		Sig	d	Effect Size
	M	SD	M	SD			
Hand R (kg)	48.30	7.50	49.89	7.60	N.S.	0.21	small
Hand L (kg)	48.78	7.11	49.19	7.70	N.S.	0.06	small
Arm Flexion R (kg)	31.42	3.72	31.70	6.09	N.S.	0.06	small
Arm Flexion L (kg)	29.26	3.44	30.60	5.86	N.S.	0.28	small
Arm Extension R (kg)	28.21	5.05	27.07	3.83	N.S.	0.26	small
Arm Extension L (kg)	29.19	5.43	26.51	3.77	N.S.	0.57	medium
Trunk Flexion (kg)	78.06	16.60	68.89	17.14	$p < 0.05$	0.54	medium
Trunk Extension (kg)	79.49	20.21	70.42	19.13	N.S.	0.46	medium
Knee Flexion R (kg)	27.13	5.63	29.31	6.39	N.S.	0.36	small
Knee Flexion L (kg)	26.68	6.06	28.60	8.38	N.S.	0.26	small
Knee Extension R (kg)	60.10	12.19	64.61	11.97	N.S.	0.37	small
Knee Extension L (kg)	57.87	9.61	59.24	13.79	N.S.	0.12	small

R = right, L = left

in other studies. Umeda et al. [24] observed a significant decrease of fat free mass (~ 1.7 kg) after reduction of 2.8 kg of body weight and reported an average body mass reduction of 4.9 kg from pre-season to mid-season in college wrestlers. Similarly, Yoshioka et al. [35] observed reduction of 2.0 kg fat free mass, (relative body fat ~ 2.9%), while the total body weight reduction was 2.8 kg.

From the significant changes in total body water (TBW), it was able to confirm that judo athletes commonly use dehydration techniques to achieve a target body weight. It was observed significant ($p < 0.05$) decrease of fluid in all body segments due to body weight reduction. Loss of body water occurred in extracellular (ECW), which was similar to intracellular water (ICW). However, from our previous study [36] of 11 elite judo athletes, body weight was reduced by 4.7 % (~ 3.8 kg), which is a larger than the current extracellular water (ECW), where we observed a loss of 3.7 l, but on the other side we observed an increase of intracellular water (ICW) of 0.4 l.

In the present study a significant loss of bone mass was reported however, it is difficult to postulate a valid reason for this after weight regain. Proteau et al. [13] found that weight loss negatively affected bone metabolic status and a net increase in bone resorption relative to formation. This phenomenon was reversed with subsequent weight regain. Furthermore, weight loss has been shown to induce acute as well as chronic increases in bone resorption [37], but the exact mechanisms by which bone resorption increases have yet to be clarified. Elevated bone formation pertaining to judo athletes lent protection from alterations in bone metabolic balance with weight cycling. This observation suggests that high osteogenic stimuli provided by judo's unique biomechanical environment may help prevent bone loss associated with weight loss interventions.

Houston et al. [38] reported a gradual decrease in muscle strength during and after 4 days of weight loss in college wrestlers. However, the present findings suggest that pre-competition body weight reduction does not affect maximal isometric muscle strength of upper or lower limbs despite significant lower

circumferences and muscle mass reduction. Contrary, Kurakake et al. [17] reported a decrease in handgrip, which was significantly lower on the right side 4 days before the competition in judo in the marked weight reduction group (≥6% of body weight). However, we observed a significant decrease in maximal muscle strength of trunk. Currently, to our knowledge no study has observed muscle strength of these main body segments.

Conclusions

Reduction of body weight is an integral part of disciplines, in which competition is performed with division into weight categories. According to our results pre-competitive weight reduction is reflected in varying degrees in all parameters of body composition and anthropometric indicators, what can greatly affect sports performance and athletes' health.

There appears to be a lack of knowledge on how to lose weight successfully without it negating an athlete's performance. Optimally, the judoists should be able to lose the necessary amount of weight without reducing performance. As rapid weight loss is not free of risk to health, rule changes should be implemented to prevent serious adverse occurrences. The official weighing of competitors is now one day before competition and is not in morning the same day as competition, what allows for a longer time to regenerate. Notwithstanding, we believe that shortening the duration between the weighing and competition, could possibly reduce the radical weight loss. Judo rule changes should be implemented to prevent serious adverse occurrences. In parallel, educational programs should aim at increasing athletes', coaches' and parents' awareness about the risks of aggressive nutritional strategies as well as healthier ways to properly manage body weight.

Competing Interests

Authors declare that we do not have any financial or personal relationships with other people or organisations that could inappropriately influence our paper.

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