Body composition and motor potential of judo athletes in selected weight categories

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
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Abstract

Background and Study Aim: Judo is a speed-strength discipline and requires a high level of motor preparation from competitors. Judo-related effort is general and activates more than 30% of the athlete's body mass, both in the upper and lower body, but the flexor muscles of the arm and elbow are the most involved. The aim of the study was knowledge about the body composition of judo athletes and the level of tissue components. Taking into account the previous research and the characteristics of the effort in judo, a research hypothesis was adopted: the body composition of judo athletes has a significant impact on their motor potential.

Material and Methods: Fifty four judo athletes (training 6+ years) participated in the research. Body composition analysis was performed using a Tanita BC-418MA analyzer. Motor potential was determined by the International Physical Fitness Test IPFT.

Results: The higher level of lean body mass of the examined players was accompanied by an increase in the level of adipose tissue. Among the group of championship class udo athletes was the associated with clearly noticeable significant differences in body composition compared to the other classes. The higher level of lean body mass of the tested judokas was accompanied by an increase in the level of adipose tissue. The championship class athletes were better prepared in terms of strength and speed abilities. Higher lean body mass generated higher levels of strength in athletes, but it was accompanied by a lower level of endurance.

Conclusions: The championship class judo athletes were better prepared in terms of strength and speed abilities. This may indicate a precise match to a given weight category of these judokas. Higher lean body mass generated higher levels of strength in judokas, but it was accompanied by a lower level of endurance. Therefore, in the training of all tested levels, attention should be paid to the development of this motor ability. Muscular hypertrophy and the related increase in body weight of the tested athletes with a decrease in the level of adipose tissue were a desired factor influencing the increase in motor potential.

Keywords: adipose tissue • competition • dietetics • motor potential • training loads

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Athlete – *noun* 1. someone who has the abilities necessary for participating in physical exercise, especially in competitive games and races **2.** a competitor in track or field events [86].

Player – ***noun*** someone taking part in a sport or game [86].

Adipose tissue – ***noun*** tissue in which the cells contain fat [86].

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." [87, p. 238].

Kurash (also **kuresh**, **koresh**, **kulesh**, and similar variants) – refers to a number of folk wrestling styles practiced in Central Asia. Kurash wrestlers use towels to hold their opponents, and their goal is to throw their opponents off the feet. The wrestling is the main competition at the folk festival Sabantuy [88].

INTRODUCTION

Judo is a speed-strength discipline and requires a high level of motor preparation from competitors [1, 2]. Judo-related effort is general and activates more than 30% of the athlete's body mass, both in the upper and lower body, but the flexor muscles of the arm and elbow are the most involved.

Fighting is characterized by alternating periods of high and low intensity exercise. Competitive activities consist of three sequences: fight for a grip, main fight (with an attack, defence, grabbing) and a break [3]. The average duration of a single sequence in combat is from 7 s to 35 s. In a stand-up, the duration of a single sequence is 18.9 s, and on the ground it is 15.79 s) [4]. During one fight, the attack is usually carried out every 15-20 s. The frequency of attacks and a large number of fights for the grip generate high intensity of exercise and result in an increase in the activation of key glycolytic enzymes, i.e. phosphoofructokinase, glyceraldehyde-3 dehydrogenase [5]. The average value of the maximum oxygen consumption is 55-60 ml/kg/min [6]. Aerobic capacity is very important in sport judo, because during the tournament the competitor takes up several fights.

The training process can be managed when information on the factors having a key impact on the sports performance is available [7]. In martial arts, one of these factors is body weight, which resulted in the creation of a body weight classification, the so-called weight categories. Both women and men are divided into seven weight categories, for men: up to 60 kg, up to 66 kg, up to 73 kg, up to 81 kg, up to 90 kg, up to 100 kg and over 100 kg, and in women: up to 48 kg, up to 52 kg, up to 57 kg, up to 63 kg, up to 70 kg, up to 78 kg and over 78 kg. Body weight is measured on the day before the competition, and on the day of the start, the weight of the competitor must not exceed the 5% weight limit. The competition is taking place on one day, usually in a knockout system with possible repechage.

The body weight of judo competitors is the subject of numerous discussions among training staff [8]. However, there is still little research that would convince both coaches and competitors to pay more attention not only to body weight but also to the composition of tissue components. The body composition depends on genetic factors, age, sex, ethnic group, health condition and energy balance, which is the result of diet and physical activity. The average level of adipose tissue in men is 10-20%, and in professional athletes 6-13% [9]. In the literature, studies on the somatotype of judo athletes dominate the number of studies related to the composition of body weight. Research was conducted on the morphological characteristics of judo athletes, which is a consequence of endogenous and exogenous factors in the period of progressive development. Judo athletes were considered to be quite a diverse group with a tendency to an endomorphic mesomorph body type [10]. In some studies, judo athletes physique was assessed only on the basis of body weight and height using the body mass index (BMI), which is not a good method of assessing body weight, especially in athletes, because it does not take into account the ratio of body fat to lean body mass. In studies assessing the thickness of the skin and fat folds, it was found that representatives of high weight categories are characterized by an increased content of adipose tissue [11, 12].

In studies on the relationship between the body composition of judo athletes and the motor potential, it was proved that the VO2max decreased with increasing body weight [13]. Other studies confirmed that with increasing weight distribution, the relative oxygen uptake decreased and the level of adipose tissue (%) increased [14]. It has also been proven that the anaerobic power of judo athletes is influenced by an increase in lean body mass while maintaining the initial level of adipose tissue [15, 16]. The highest VO2max and respiratory threshold were observed in athletes with the lowest mass of adipose tissue [17]. It has been suggested that the factors responsible for success may be specific for each weight range [18]. Analyses of medallists' fights during the Polish championship prove that the greatest impact on the winners' victory was their activity during the fight [19]. The specific training of judokas develops the anaerobic fitness of the body, while not significantly affecting the level of aerobic fitness [20]. Another study noted that weight gain, regardless of the component composition, may reduce aerobic capacity [21]. At the same time, the speed of reaction is a factor that translates into the achievements during the competition [22]. Previous studies confirm that when assessing the body structure of judo athletes, not only weight, but also its components should be taken into account [23]. Taking into account some limitations in the possibilities of shaping motor skills, such as genetic control [24-27] and character [28-32] and taking into account the periods of sensitive phases of the development of motor skills, it should be stated that the research relationship between body composition and motor potential may be important for the development of sport judo. Optimization of tissue components can be an important element influencing sports performance, especially when there are limitations in increasing the time (also increasing the types and repetitions of exercises etc.) or intensity of training loads. Currently, even athletes of higher sports classes do not treat body composition recomposition as a tool to achieve the highest level of sports preparation. Such practices often require excessively abrupt weight-control techniques just prior to a competition. Many studies confirm the negative impact of weight loss just before the official weigh-in [33], emphasizing that it is the result of water loss. Dehydration increases the risk of loss of strength [34]. Moreover, excessive dietary restrictions forced by an excessive desire to reduce body weight directly before the tournament have a negative effect on the motor skills and mental condition of the athletes [35]. In studies on the differences in fighting techniques between women and men, the importance of factors such as levels of physical and mental preparation, athlete's age, but also body composition indicators was emphasized [36]. Research confirms that in order to improve effectiveness during combat, a competitor should increase muscle mass and use natural physical predispositions [37]. Currently, it is common that along with an increase in the weight category, the strength of athletes increases, but it also causes an increase in body fat [38]. Along with the increase in the level of adipose tissue, some adipocytokines may be secreted in too large amounts [39]. As a result of disturbances in systemic homeostasis, inflammatory processes, disturbances in insulin secretion and decreased sensitivity of tissues to its effects may be intensified [40]. Some studies show that the increase in the level of adipose tissue negatively affects the availability of amino acids in the bloodstream for myocytes [41], which in practice may hinder the development of the player's (athletes) muscle mass. Based on the data of the Evidence Analysis Library (EAL), the Academy of Nutrition and Dietetics (AND), Dietitians of Canada (DC) and the American College of Sports Medicine (ACSM), in 2016, issued a document related to the subject of nutrition and exercise capacity of athletes. It contains the information that the composition of the tissue components of body mass should not be recommended to any groups of athletes or apply to any sporting event [42]. This emphasizes that the composition of the body mass is a factor that should be individualized, then it can be a tool supporting the motor potential of the player (athlete). As the information gathered so far does not meet the needs of targeting the optimization of the tissue components of judo athletes, it was decided to undertake research in this field.

The aim of the study was knowledge about the body composition of judo athletes and the level of tissue component.

Taking into account the previous research and the characteristics of the effort in judo, a research hypothesis was adopted: the body composition of judo athletes has a significant impact on their motor potential.

MATERIAL AND METHODS

Researched persons

Fifty four judo athletes (judokas) participated in the research, with a minimum training period of 6 years. The most numerous group (n = 28) was represented by class I judokas (Table 1). Athletes who were: in the period of intense weight loss were excluded from the study; within 2 weeks before the planned start in the competition; declaring to start in the highest weight categories. The above factors have a direct impact on the water content in the body, thus influencing all the components of the analysis of the tissue components of body mass.

Table 1. Characteristics of the examined judokas in terms of their sports class.

Sport class	Number of judokas
Champion class	10
Class I	28
Class II	16

The competitors from the highest weight categories constituted a very small group (Table 2) and taking them into account would lead to an unreasonable increase in the average body weight and tissue components of the studied group. The number of examined judokas from each weight category is proportional to the number of competitors starting in 2018 at the Polish championship in each category, and at the same time reflects the trend.

Table 2. Characteristics of the examined judokas (n = 54) in terms of the weight category.

Weight category	Number of judokas in the weight category: according to the declaration				by body weight on the day of the test			
	Total	Champion	Class I	Class II	Total	Champion	Class I	Class II
up to 60 kg	**8**	0	4	4	**2**	0	1	1
to 66 kg	**6**	2	3	1	**9**	0	6	3
to 73 kg	**17**	1	11	5	**11**	2	7	2
to 81 kg	**16**	4	7	5	**15**	2	7	6
to 90 kg	**7**	3	3	1	**13**	4	6	3
to 100 kg	**0**	0	0	0	**4**	2	1	1
Total	**54**	10	28	16	**54**	10	28	16

Design and research methods

The research was conducted from October 2017 to March 2018 at the University School of Physical Education in Wrocław and the University School of Physical Education in Warsaw. The project was approved by the Senate Committee for Ethics of Scientific Research at the University School of Physical Education in Wrocław (No. 25/2018).

Body composition analysis was performed using a Tanita BC-418MA analyser. The analyser is certified and confirmed for clinical use. It is certified in 93/42 EEC, NAWI Certification, MDD III and CE Approval. Tanita is a beneficiary of quality management certificates, incl. ISO 9001, JIS (Japanese Industrial Standards), CE (EU Declaration of Conformity), NAWI, FDA and Good Housekeeping Seal standards.

Total body weight, body fat mass, water mass, and lean body mass were measured prior to the performance of the International Physical Fitness Test (IPFT). The subjects were wearing sportswear, they were at least 60 minutes after consuming food and liquids. The competitors did not perform intense physical exercise 12 hours before the test and showed no symptoms of infectious diseases that could affect the content of electrolytes and fluids. The body height measurement was entered into the analyser with an accuracy of 1 cm. Due to the fact that people with a high level of physical activity have a different body type than people who do not engage in physical activity, the analysis was performed in the "athlete" mode. Body composition analysis in a different mode in active people may result in underestimation of the water content, and this affects other elements of the analysis, including overstating the mass of adipose tissue.

The motor potential was determined by the level of individual motor skills of the examined judo athletes on the basis of eight fitness tests of the IPFT [43]. The test is standardized, it uses the T scale, which covers 100 units, assuming as one unit the tenth of the standard deviation. In addition, it is outside the normal range of the study population, ranging from −5 to +5 standard deviations, and scaling the raw scores of individual tests normalizes their distribution to a Gaussian curve. The T scale is wide enough, with each normal distribution of scores falling between 25 and 27 points, i.e. every 5 standard deviations, and the arithmetic mean is 50. The IPFT was chosen because it is used to assess the motor potential of voivodeship team players in various sports disciplines, it is recommended by the Polish Judo Association. All competitors were tested under the same conditions. According to the guidelines of the IPFT, the tests of each group of competitors were divided into two days. On the first day, five fitness tests were carried out: 1. standing long jump; 2. hand strength measurement (using a Takei dynamometer); 3. pull-ups on the bar; 4. sit-ups from lying down within 30 s; 5. torso bend. On the second day of the research, three fitness tests were performed: 1. 50 m run; 2. run in alternate directions (4 × 10 m); 3. 1000 m run.

All tests were performed after warming up and in accordance with the instructions.

Statistics

Statistical analyses were performed using IBM SPSS Statistics version 25. The basic descriptive statistics were analysed, such as: arithmetic mean (M) and standard deviation (± or SD), minimum (Min) and maximum (Max), skewness (Skew) and kurtosis (Kurt) and the median (Me). The Shapiro-Wilk test was used to check the normality of distributions. A series of one-way analyses of variance and a series of Pearson's r correlation analyses were performed. The test results at the level of p<0.05 were considered significant. We also monitor the correlation of p<0.10 as a trend towards a statistically significant relationship.

In the analysers of the correlation between the mass and the composition of tissue components, the judokas were not divided into weight categories, because the category is only a reformatted value of the body mass, without adding any additional variables. Correlations between the individual body mass components for all tested athletes were made in order to test the strength of the relationship between mass and individual body composition components. Because with some exceptions, percentages are not the best predictors of fitness test scores, the correlations were made in order to check whether there is a basis for MANOVA for the percentages. It is assumed that correlation between variables (the indicators of variables) they should not be higher than 0.80 to 0.85.

RESULTS

From the output obtained we cannot assume normality of distribution the following variables (for all judo athletes): pull-ups on the bar; torso bend; 1000 m run; 50 m run; run in alternate directions; sit-ups from lying down in 30 s. The p-value of the remaining variables is smaller than 0.05 (Table 3). In the judo champions group we cannot assume normality of distribution of variables: torso bend; 1000 m run; 50 m run (Table 4). In the judo athletes class I we cannot assume normality of distribution of variables: pull-ups on the bar; 1000 m run; 50 m run; long jump from place; sit-ups from lying down in 30 s (Table 5). In the judo athletes group class II the distribution of the given data is not different from normal distribution significantly (Table 6).

There is a average positive correlation between the mass of adipose tissue (kg) and the body mass (kg) of the examined judo athletes, and a very strong positive correlation (almost complete correlation) between the body mass (kg) and lean body mass (kg), and skeletal muscle mass (kg) and the water content (kg) (Table 7).

Table 3. Basic descriptive statistics with the Shapiro-Wilk test for all judo competitors (n = 54).

Variables	M	Me	SD	Skew	Kurt	Min	Max	S-W	p
Body mass [kg]	75.03	75.15	9.42	–0.18	–0.46	52.80	92.90	0.98	0.475
Height [cm]	178.56	180.00	6.27	–0.05	–0.70	167.00	192.00	0.98	0.340
Fat tissue [%]	9.71	9.30	3.44	0.11	–0.99	4.10	16.10	0.96	0.101
Fat tissue [kg]	7.36	7.25	2.83	0.09	–0.86	2.60	13.30	0.97	0.228
Lean tissue mass [kg]	67.56	68.30	8.70	–0.28	0.77	41.90	86.00	0.98	0.468
Skeletal muscle mass [%]	50.95	51.15	2.16	–0.25	–0.49	45.60	55.00	0.98	0.534
Skeletal muscle mass [kg]	38.39	38.39	4.87	<0.01	–0.16	27.80	48.70	0.99	0.769
Water content [%]	65.95	66.15	2.71	–0.34	–0.42	58.60	70.20	0.97	0.181
Water content [kg]	49.74	50.00	6.76	0.27	0.05	35.90	66.60	0.98	0.486
Hand strength [kg]	52.94	53.00	6.99	0.06	–0.32	40.00	70.00	0.98	0.439
Pull-ups on the bar [n]	14.83	13.50	5.52	0.93	0.16	7.00	29.00	0.91	**0.001**
Torso bend [cm]	39.96	40.00	7.36	0.46	3.10	22.00	67.00	0.93	**0.003**
1000 m run [s]	210.30	213.00	16.81	0.47	–0.60	186.00	252.00	0.94	**0.013**
50 m run [s]	7.33	7.24	0.29	0.36	–0.04	6.58	8.02	0.94	**0.013**
Run in alternate directions [s]	12.28	12.21	0.46	1.05	1.48	11.63	13.83	0.92	**0.002**
Long jump from place [cm]	242.67	242.50	12.87	0.65	0.43	219.00	280.00	0.96	0.085
Sit-ups from lying down in 30 s [n]	32.72	32.00	2.80	–0.53	3.27	22.00	39.00	0.92	**0.001**

Table 4. Basic descriptive statistics with the Shapiro-Wilk test for the champion class of the examined judokas (n = 10).

Variable	M	Me	SD	Skew	Kurt	Min	Max	S-W	P
Body mass [kg]	81.76	83.15	8.30	−0.34	−1.01	68.8	92.9	0.95	0.682
Height [cm]	178.60	180.50	4.20	−0.44	−1.50	172.00	184.00	0.89	0.178
Fat tissue [%]	10.57	10.00	2.52	0.37	−1.45	7.40	14.60	0.91	0.304
Fat tissue [kg]	8.59	8.40	2.04	0.41	−0.67	5.90	12.00	0.95	0.704
Lean tissue mass [kg]	72.78	72.30	7.96	0.14	−0.06	59.50	86.00	0.97	0.908
Skeletal muscle mass [%]	50.65	50.95	1.44	−0.34	−1.56	48.40	52.40	0.91	0.271
Skeletal muscle mass [kg]	41.44	40.90	4.60	0.06	−0.42	33.70	48.70	0.98	0.906
Water content [%]	64.67	64.95	2.80	−1.08	1.26	58.60	67.80	0.91	0.275
Water content [kg]	55.16	53.30	7.50	0.07	−1.15	43.60	66.60	0.95	0.717
Hand strength [kg]	61.40	61.00	4.62	0.33	0.16	54.00	70.00	0.99	0.993
Pull-ups on the bar [n]	17.90	16.00	5.95	0.64	−0.49	11.00	29.00	0.93	0.454
Torso bend [cm]	41.40	39.50	10.77	1.26	4.13	24.00	67.00	0.84	**0.049**
1000 m run [s]	197.10	193	15.26	1.99	3.62	186.00	234.00	0.71	**0.001**
50 m run [s]	7.08	7.13	0.20	−1.95	4.64	6.58	7.27	0.79	**0.011**
Run in alternate directions [s]	12.59	12.61	0.68	0.61	−0.17	11.71	13.83	0.93	0.468
Long jump from place [cm]	252.90	251.50	11.29	0.83	−0.31	240.00	273.00	0.90	0.206
Sit-ups from lying down in 30 s [n]	32.60	32.50	1.65	−0.13	−1.26	30.00	35.00	0.94	0.532

Table 5. Basic descriptive statistics with the Shapiro-Wilk test for the I sport class of the examined judokas (N = 28).

Variables	M	Me	SD	Skew	Kurt	Min	Max	S-W	P
Body mass [kg]	73.60	73.70	8.53	−0.08	−0.46	55.60	90.20	0.98	0.886
Height [cm]	178.85	179.00	6.98	0.04	−0.72	167.00	192.00	0.96	0.436
Fat tissue [%]	9.79	9.90	3.95	0.07	−1.19	4.10	16.10	0.93	0.084
Fat tissue [kg]	7.30	7.20	3.27	0.15	−1.14	2.7	13.3	0.94	0.116
Lean tissue mass [kg]	66.23	65.70	7.53	0.09	0.81	49.60	83.50	0.96	0.357
Skeletal muscle mass [%]	50.74	50.60	2.60	−0.11	−0.88	45.60	55.00	0.96	0.445
Skeletal muscle mass [kg]	37.53	37.20	4.48	0.15	0.26	28.10	47.30	0.98	0.758
Water content [%]	66.04	66.00	2.89	−0.07	−1.17	61.40	70.20	0.93	0.077
Water content [kg]	48.17	47.70	5.68	0.19	0.45	36.30	61.10	0.97	0.618
Hand strength [kg]	52.52	53.00	5.31	−0.06	0.49	41.00	64.00	0.96	0.405
Pull-ups on the bar [n]	15.70	15.00	5.64	0.84	−0.32	9.00	29.00	0.89	**0.008**
Torso bend [cm]	41.85	42.00	4.96	0.75	0.86	33.00	55.00	0.95	0.180
1000 m run [s]	207.63	212.00	13.31	0.39	−0.57	189.00	240.00	0.92	**0.033**
50 m run [s]	7.39	7.25	0.25	0.58	−0.87	7.00	7.78	0.92	**0.031**
Run in alternate directions [s]	12.15	12.04	0.33	0.42	−0.81	11.63	12.84	0.95	0.247
Long jump from place [cm]	238.44	234.00	13.00	1.52	2.75	223.00	280.00	0.86	**0.002**
Sit-ups from lying down in 30 s [n]	33.15	33.00	3.12	−1.33	5.62	22.00	39.00	0.83	**0.001**

Table 6. Basic descriptive statistics with the Shapiro-Wilk test for the II sport class of the examined judokas (n = 16).

Variable	M	Me	SD	Skew	Kurt	Min	Max	S-W	p
Body mass [kg]	73.99	75.20	10.05	−0.44	0.03	52.80	92.30	0.96	0.568
Height [cm]	178.06	180.00	6.60	−0.24	−1.40	167.00	187.00	0.92	0.174
Fat tissue [%]	9.39	8.65	2.86	0.41	−1.45	5.70	13.80	0.89	0.062
Fat tissue [kg]	6.98	6.70	2.16	0.16	−1.40	3.80	10.20	0.93	0.212
Lean tissue mass [kg]	66.98	69.20	10.28	−0.86	1.25	41.90	84.40	0.95	0.461
Skeletal muscle mass [%]	51.28	51.65	1.61	−0.38	−1.45	48.80	53.40	0.90	0.075
Skeletal muscle mass [kg]	38.19	39.20	5.24	−0.38	−0.04	27.80	47.80	0.97	0.819
Water content [%]	66.34	66.90	2.09	−0.40	−1.42	63.20	69.10	0.89	0.065
Water content [kg]	49.36	50.65	6.75	−0.38	−0.01	35.90	61.80	0.97	0.829
Hand strength [kg]	49.00	50.00	6.31	0.04	−1.20	40.00	59.00	0.94	0.292
Pull-ups on the bar [n]	11.50	11.00	3.45	0.74	−0.02	7.00	19.00	0.93	0.285
Torso bend [cm]	35.63	37.00	7.09	−0.33	−0.95	22.00	45.00	0.94	0.371
1000 m run [s]	222.88	220.00	15.94	0.18	−1.11	201.00	252.00	0.94	0.930
50 m run [s]	7.50	7.53	0.30	0.21	−1.32	7.11	8.02	0.93	0.206
Run in alternate directions [s]	12.30	12.18	0.44	0.26	−1.25	11.67	12.99	0.93	0.249
Long jump from place [cm]	244.19	244.50	10.06	−0.83	1.07	219.00	257.00	0.91	0.111
Sit-ups from lying down in 30 s [n]	32.13	32.00	2.92	0.91	0.32	28.00	38.00	0.90	0.095

There is a very strong positive correlation between body mass and lean tissue mass (kg), and skeletal muscle mass in all sports classes. In sports class I and II, there is a very strong positive correlation between the body mass (kg) and the water content (kg) (Table 8).

There are no statistically significant correlations between fat tissue (kg) and other individual components of body mass, measured in kg. The others are very strongly correlated (almost complete correlation) with each other (Table 9). The correlations between skeletal muscle mass (%) and water content is too high – see explanation in section of statistical analysis (Table 10).

Results of a one-way analysis of variance (for differences between sports classes in their composition of body mass components) was statistically significant $F(2.51) = 3.46$ ($p = 0.039$) and the effect size was $\eta^2 = 0.12$, which means that about 12% of the variability in body weight scores can be explained by the differences between the tested sport classes. The results of Tukey's post-hoc tests showed significant differences between the championship class (M = 81.76 ±8.30) and class I (M = 73.21 ±8.61) and class II (M = 73.99 ±10.05) and no significant differences between class I and class II (Table 11).

Table 7. Analysis of Pearson's r correlation between the body mass of the examined judokas (n = 54) and its individual components.

Variable						
Fat tissue		Lean tissue mass [kg]	Skeletal muscle mass		Water content	
[%]	[kg]		[%]	[kg]	[%]	[kg]
0.19	**0.47*****	**0.95*****	−0.14	**0.94*****	−0.25^	**0.93*****

****p*<0.001; ^*p*<0.10

Table 8. Analysis of the correlation between body mass and its individual components.

Variable	Body mass [kg]		
	Champion class (n = 10)	Class I (n = 28)	Class II (n = 16)
Fat tissue [%]	–0.22	0.35^	–0.09
Fat tissue [kg]	0.18	**0.56****	0.31
Lean tissue mass [kg]	**0.96*****	**0.92*****	**0.96*****
Skeletal muscle mass [%]	0.20	–0.28	0.08
Skeletal muscle mass [kg]	**0.97*****	**0.90*****	**0.96*****
Water content [%]	–0.10	–0.36*	0.10
Water content [kg]	**0.87****	**0.93*****	**0.96*****

**p*<0.05; ***p*<0.1; ****p*<0,001; ^*p*<0.10

Table 9. Analysis of Pearson's r correlation between the individual components of body mass of the examined judo athletes (n = 54), measured in kg.

Variables	1	2	3
Fat tissue [kg]	----		
Lean tissue mass [kg]	0.20	----	
Skeletal muscle mass [kg]	0.17	**0.98*****	----
Water content [kg]	0.25^	**0.94*****	**0.95*****

****p*<0,001; ^*p*<0.10

Table 10. Analysis of Pearson's r correlation between the individual components of the body weight of the examined judo players measured in% (n = 54).

Variable	1	2
Fat tissue [%]	----	
Skeletal muscle mass [%]	**–0.89*****	----
Water content [%]	**–0.92*****	**0.82*****

****p*<0.001

Table 11. Analysis of differences between sports classes (ordinal variable from the most numerous group) in the composition of body weight of the studied judo athletes. A series of one-way analyses of variance.

Variable	Class I (n = 28)		Class II (n = 16)		Champion class (n = 10)		Statistical indicator		
	M	SD	M	SD	M	SD	F	P	η^2
Body mass [kg]	73.21	8.61	73.99	10.05	81.76	8.30	3.46	0.039	0.12
Fat tissue [%]	9.59	4.02	9.39	2.86	10.57	2.52	0.39	0.679	0.02
Skeletal muscle mass [%]	50.87	2.64	51.28	1.61	50.65	1.44	0.30	0.745	0.01
Water content [%]	66.18	2.94	66.34	2.09	64.67	2.80	1.41	0.255	0.05

Table 12. Analysis of the correlation between the body mass components and the results of fitness tests for all judo competitors (n = 54).

Variable	Hand strength	Pull-ups	Bend	1000 m run	50 m run	Alternate run	Long jump	Sit-ups
Fat tissue [%]	0.09	–0.16	0.13	–0.11	0.07	0.01	–0.01	0.18
Fat tissue [kg]	0.24^	–0.21	0.12	0.02	–0.01	0.21	0.10	0.16
Lean tissue mass [kg]	**0.53*****	–0.08	–0.05	**0.47*****	–0.15	**0.67*****	**0.27***	–0.10
Skeletal muscle mass [%]	–0.11	0.19	–0.09	0.14	–0.13	–0.02	–0.03	0.08
Skeletal muscle mass [kg]	**0.52*****	–0.11	–0.04	**0.48*****	–0.19	**0.67*****	**0.30***	–0.06
Water content [%]	–0.16	0.13	–0.11	0.16	<0.01	–0.06	–0.13	–0.17
Water content [kg]	**0.54*****	–0.08	–0.06	**0.38****	–0.20	**0.66*****	**0.34***	–0.08
Body mass [kg]	**0.54*****	–0.12	<0.01	**0.43****	–0.16	**0.69*****	**0.30***	–0.05

**p*<0.05; ***p*< 0.01; ****p*<0.001; ^*p*<0.10

There is a strong positive correlation: between lean tissue mass (kg) and hand strength, and alternate run; between skeletal muscle mass (kg) and alternate run; between water content (kg) and hand strength, and alternate run; between body mass (kg) and hand strength, and alternate run. Average correlation: between lean tissue mass (kg) and 1000 m run; between skeletal muscle mass (kg) and 1000 m run; between water content (kg) and long jump; between body mass (kg) and 1000 m run. Weak correlation: between lean tissue mass (kg) and long jump; between skeletal muscle mass (kg) and long jump; between body mass (kg) and long jump (Table 12).

In the II sports class of the surveyed judo athletes there is a very strong positive correlation: between fat tissue (%) and 1000 m run; between skeletal muscle mass (kg) and 1000 m run, and alternate run; between water content (kg) and 1000 m run, and alternate run; between water content (kg) and 1000 m run; between body mass (kg) and 1000 m run, and alternate run. A strong correlation: between fat tissue (%) and 50 m run, and long jump; between fat tissue (kg) and 50 m run; between lean tissue mass (kg) and hand strength, and alternate run; between skeletal muscle mass (%) and 50 m run, and long jump; between skeletal muscle mass (kg) and hand

Table 13. Analysis of the correlation between the body mass components and the results of fitness tests for the judo competitors of the II sport class (n = 16).

Variables	Hand strength	Pull-ups	Bend	1000 m run	50 m run	Alternate run	Long jump	Sit-ups
Fat tissue [%]	–0.31	0.15	0.20	–0.12	**0.58***	–0.03	**–0.59***	0.05
Fat tissue [kg]	–0.12	0.07	0.03	0.21	**0.58***	0.27	–0.42	–0.03
Lean tissue mass [kg]	**0.51***	–0.02	–0.41	**0.74****	–0.07	**0.66****	0.26	–0.19
Skeletal muscle mass [%]	0.29	–0.14	–0.20	0.11	**–0.57***	0.02	**0.59***	–0.05
Skeletal muscle mass [kg]	**0.51***	–0.06	–0.41	**0.76****	–0.12	**0.71****	0.35	–0.21
Water content [%]	0.31	–0.15	–0.19	0.14	**–0.57***	0.03	**0.59***	–0.06
Water content [kg]	**0.50***	–0.06	–0.42	**0.76****	–0.11	**0.70****	0.35	–0.21
Body mass [kg]	0.43^	<0.01	–0.35	**0.79*****	0.06	**0.75****	0.22	–0.24

**p*<0.05; ***p*< 0.01; ****p*<0.001; ^*p*<0.10

Table 14. Analysis of the correlation between the body mass components and the results of fitness tests of the surveyed judo athletes with I sports class (n = 28).

Variable	Hand strength	Pull-ups	Bend	1000 m run	50 m run	Alternate run	Long jump	Sit-ups
Fat tissue [%]	0.24	–0.23	0.11	0.02	–0.01	0.12	0.19	0.23
Fat tissue [kg]	0.34^	–0.35^	0.11	0.17	–0.01	0.26	0.20	0.24
Lean tissue mass [kg]	**0.46***	**–0.44***	–0.07	**0.65*****	–0.01	**0.55****	0.10	0.03
Skeletal muscle mass [%]	–0.28	0.29	0.01	0.05	–0.14	–0.18	–0.26	0.17
Skeletal muscle mass [kg]	**0.43***	**–0.45***	–0.02	**0.68*****	–0.07	**0.50****	0.08	0.08
Water content [%]	–0.25	0.24	–0.12	–0.03	–0.01	–0.12	–0.19	–0.22
Water content [kg]	**0.46***	**–0.44***	–0.03	**0.63*****	–0.05	**0.57****	0.09	0.01
Body mass [kg]	**0.50***	**–0.49***	–0.02	**0.63*****	–0.05	**0.57****	0.16	0.10

*$p<0.05$; **$p<0.01$; ***$p<0.001$; ^$p<0.10$

strength; between water content (%) and 50 m run, and long jump. Average correlation between water content (kg) and hand strength (Table 13).

In the I sports class of the surveyed competitors in a strong positive correlation: between lean tissue mass (kg) and 1000 m run time, and alternate run; between skeletal muscle mass (kg) and 1000 m run; between water content (kg) and 1000 m run; and alternate run; between body mass (kg) and 1000 m run time, and alternate run time. Average correlation: between lean tissue mass (kg) and hand strength, and pull-ups; between skeletal muscle mass (%) and hand strength, and pull-ups, and alternate run; between water content (kg) and hand strength, and pull-ups; between body mass (kg) and hand strength, and pull-ups (Table 14).

The championship sports class of the surveyed competitors there is a very strong positive correlation: between lean tissue mass (kg) and 1000 m running time, and alternate run; between skeletal muscle mass (%) and alternate run; between skeletal muscle mass (%) and alternate run; between body mass (kg) and alternate run. 1000 m running time and skeletal muscle mass (kg) and body mass (kg). A strong positive correlation: between skeletal muscle mass (%) and 1000 m running time; between body mass (kg) and 1000 m run (Table 15).

Table 15. Analysis of the correlation between the body mass components and the results of fitness tests for the judo competitors with a championship sports class (n = 10).

Variables	Hand strength	Pull-ups	Bend	1000 m run	50 m run	Alternate run	Long jump	Sit-ups
Fat tissue [%]	–0.48	–0.59^	0.09	–0.32	–0.20	–0.38	–0.39	0.24
Fat tissue [kg]	–0.29	–0.51	0.26	–0.10	–0.31	–0.09	–0.25	0.19
Lean tissue mass [kg]	0.58^	0.33	0.40	**0.72***	–0.14	**0.83****	0.28	–0.22
Skeletal muscle mass [%]	0.44	0.58^	–0.09	0.31	0.22	0.38	0.37	–0.22
Skeletal muscle mass [kg]	0.57^	0.32	0.37	**0.68***	–0.13	**0.82****	0.36	–0.20
Water content [%]	0.21	0.45	0.04	0.28	0.20	0.20	–0.31	–0.24
Water content [kg]	0.42	0.21	0.21	0.51	–0.06	0.61^	0.37	–0.03
Body mass [kg]	0.50	0.43	0.43	**0.65***	–0.22	**0.78****	0.29	–0.15

*$p<0.05$; **$p<0.01$; ^$p<0.10$

The obtained results of the analyses showed statistically significant differences for F (2.51): pull-ups on the bar 5.58 (p = 0.006); torso lean 4.49 (p = 0.016); 50 m run 8.09 (p = 0.001) and the long jump 5.93 (p = 0.005). Effect sizes ranged from 0.15 to 0.25 η2, which proves that the intergroup differences accounted for 15% to 25% of the explained variance. The analysis of post-hoc pair comparisons using Tukey's tests showed a significantly higher number of pull-ups repetitions in championship-class athletes (M = 17.90 ±5.95) than in class II (M = 11.50 ±3.45) and an average greater number of repetitions of class I competitors (M = 15.64 ±5.55) than in class II. The difference between the I class and the championship class was not significant. In the case of torso bends, a significant difference was found only between class I (M = 41.93 ±4.88) and class II (M = 35.63 ±7.09). In the 50 m run, the championship class (M = 7.08 ±0.20) and class II (M = 7.50 ±0.30) had a significantly shorter time than class I (M = 7.33 ±0.25). On the other hand, in the long jump, athletes from the championship class (M = 242.67 ±12.87) jumped significantly further from the class I competitors (M = 238.14 ±12.85) (Table 16).

DISCUSSION

It is assumed that the correct body weight is "the optimal value that favours the longest life span, is the most acceptable for a given human being and depends on gender, age, height and body type" [44]. Based on this definition, it can be assumed that in terms of sports, the optimal body weight will be a value that favours the achievement of the best result while maintaining the health of the athlete. The athlete's body weight does not provide sufficient data on the body image, hence the interest of researchers in methods allowing to assess the composition of tissue components.

Attempts have been made to study the correlation between body composition and motor potential [45]. It was shown that the percentage of adipose tissue was negatively correlated with effectiveness in endurance exercise, while judo players with greater aerobic power performed better intense but interrupted exercise tests. In the study of the impact of exercise on isometric strength and body balance, it was observed that judo players had a higher level of lean body mass (68.23 kg ±16.40 kg) compared to untrained people (60.57 kg ±4.38 kg), however it is worth noting that the percentage of adipose tissue was also higher, as it amounted to 18.36% ±4.24%, and in the untrained people 17.87 kg ±5.28 kg. In the literature, technical and tactical analyses of judo fights are often made [46, 47]. Attempts are also made to evaluate the technical and tactical profile of individual judo athletes [48]. It is estimated that the versatility of a player is crucial in achieving the best sports results.

Researchers are interested in the body composition of judo players in terms of exercise capacity, as well as in the context of their return to sport after an injury. In a study of elite athletes of this discipline after reconstruction of the cruciate ligament, no significant differences were found in the circumference of the thigh or the muscle mass of the lower limbs in athletes after an injury compared to healthy athletes. On the other hand, the isokinetic strength study showed a significantly

Table 16. Analysis of differences between sports classes (ordinal variable from the most numerous group) in selected fitness tests. A series of one-way analyses of variance.

Variable	Class I (n = 28)		Class II (n = 16)		Champion class (n = 10)		Statistical indicator		
	M	SD	M	SD	M	SD	F	P	η^2
Pull-ups	15.64[a]	5.55	11.50[a,b]	3.45	17.90[b]	5.95	5.58	**0.006**	0.18
Torso bend	41.93[a]	4.88	35.63[a]	7.09	41.40	10.77	4.49	**0.016**	0.15
50m run	7.33[a]	0.25	7.50[b]	0.30	7.08[a,b]	0.20	8.09	**0.001**	0.25
Long jump	238.14[a]	12.85	244.19	10.06	242.67[a]	12.87	5.93	**0.005**	0.18
Sit-ups	33.11	3.07	32.13	2.92	32.60	1.65	0.63	0.538	0.03

a, b – statistically significant differences in post-hoc tests greater laterality of the knee flexors and extensors in previously injured athletes [49]. In a study [50] of the correlation analysis between somatic indices and fitness tests, it was observed that lower fat tissue values and higher lean body mass values are correlated with lower HR values (measured 1 minute after the end of the test), which, according to the authors, suggests faster restitution after a specific load.

Assessment of body composition using bioelectric impedance analysis in sports that classify players by body weight is still relatively unexplored [51], although it is used more widely than the DXA dual absorptiometry method, the limitations of which are mainly due to low availability resulting from high purchase costs of the highly specialized equipment. This is a limitation not only for Polish researchers [52-54]. Another limitation of BIA is the fact that each manufacturer uses different algorithms to calculate the total water content, which then forms the basis for calculating the other components of the body mass composition [55]. It has also been proven that some analysers, which use a smaller number of electrodes than eight in the tetrapolar system, are not a good tool for monitoring the components of the body composition of judo athletes [51].

In addition, researchers often use the following classification to assess the level of adipose tissue: “below normal”, “normal”, “above normal” in an inconsistent manner. Some authors take “below normal” as a determination of the level of adipose tissue in men below 8%, and “above normal” as a measurement of more than 25% of adipose tissue [56]. However, in earlier studies, these values were considered “norms” for the general population, and not for physically active people, and even more so for athletes who are characterized by a lower level of adipose tissue: low for adipose tissue less than 5%, medium 10% , high over 15% [56]. Moreover, although the term “norm” is common in Polish literature, it is worth considering whether in the context of body composition it is more appropriate to use the phrase “reference values”. This term provides a reference point, and at the same time leaves a margin for taking into account individual conditions, especially if the research work is to be the basis for training staffs during individual work with the player, and not only to constitute a statistical database.

The works from 2009-2015 period [58] were reviewed, in which 10 groups of judo athletes, 421 athletes in total, were compiled. Only in two groups (59 athletes in total) body composition analyses were performed using the DXA method [59-61], 138 athletes were tested by means of electrical bioimpedance analysis on various types of analysers [62, 63], the body composition of the remaining players was assessed on the basis of skin and fat fold measurements [64-68].

These discrepancies in measurement methods and interpretation of results cause a large contamination in this area of knowledge at the very stage of body composition analysis. Adding a variable in the form of physical fitness tests introduces additional distortions throughout the research process. Difficult to locate and eliminate in the study are psychological factors, such as the player’s personality and motivation to perform the designated test [69]. The values of the results of physical fitness tests depend on the motivational conditions in which the tests are carried out, and this applies mainly to the male sex [70]. The results of tests and measurements are also influenced by external conditions, such as ambient temperature or atmospheric pressure, and these are not always monitored by researchers [70, 71].

Score maximization is a multi-subject concept, therefore it is worth considering the interdisciplinary cooperation of researchers when assessing the motor potential of judo athletes.

The advantage of the IPFT is that the results are standardized to points (according to the T scale). Therefore, it is possible to compare the training effects of different age groups and sports (from 7 to 19 years of age and older, assuming that the norms for the population of 19 years old are applied) [12, 25, 27, 50, 72-74] – it is not the most important that the authors of some papers provide raw results. Unfortunately, the IPFT does not measure body balance. Meanwhile, this coordination ability is very important in judo and in all combat sports, where breaking off balance is the only way to win (e.g. kurash, sumo) or with one of the ways of gaining a point advantage (e.g. wrestling). That is why Andrzej Tomczak’s (also with co-authors) many years of research on, inter alia, sleep deprivation combined with other psychophysical burdens of various groups of students and soldiers (pilots, commandos, military cadets, etc.) attract attention [75-82]. He used a non-apparatus version of the Rotational Test (without measuring the test execution time) which measures the body balance disturbation tolerance skills (BBDTS) [83] both in the field and in the laboratory. Moreover, it turned out to be the most sensitive diagnostic tool among the coordination tests used [84]. The Rotational Test belongs both to the group of non-apparatus [85] and to quasi-apparatus test, and in the non-apparatus version it can be a complement to IPFT.

CONCLUSIONS

The higher level of lean body mass of the tested was accompanied by an increase in the level of adipose tissue. Promotion to the group of championship class was associated with clearly noticeable significant differences in body composition compared to the other classes. This may indicate a precise match to a given weight category of these. The championship class were better prepared in terms of strength and speed abilities, which confirms the importance of these two indicators in sports combat. Higher lean body mass generated higher levels of strength in, but it was accompanied by a lower level of endurance. Therefore, in the training of of all tested levels, attention should be paid to the development of this motor ability in the training process. Muscular hypertrophy and the related increase in body weight of the tested athletes with a decrease in the level of adipose tissue were a desired factor influencing the increase in motor potential.

REFERENCES

1. Witkowski K, Maśliński J, Kubacki R. Kompendium judo. Tom 1: Podstawy tachi-waza. Wrocław: Wydawnictwo Akademii Wychowania Fizycznego; 2009: 17 [in Polish]
2. Witkowski K, Maśliński J, Kotwica K. Analysis of fighting actions of judo competitors on the basis of the men's tournament during the 2008 Olympic Games in Beijing. J Combat Sports Martial Arts 2012; 3(2): 121-129
3. Sterkowicz S, Franchini E. Kompleksowa ocena sprawności motorycznej w judo w świetle rezultatów specyficznego testu – Special Judo Fitness Test (SJFT). In: Kuder A, Perkowski K, Śledziewski D, editors. Proces doskonalenia treningu i walki sportowej. Tom 3. Warszawa: Wydawnictwo Akademii Wychowania Fizycznego; 2006: 23 [in Polish]
4. Franchini E. Judo combat: time-motion analysis and physiology. Int J Perf Anal Spor 2017; 13(3): 624-641
5. Kujach S, Smaruj M, Grzywacz T et al. Dehydrogenase Curve in a Judo Competition. A Case Study. Rocz Nauk AWFiS Gdańsk 2010; 20: 24-31
6. Piepiora P. Obciążenia treningowe i kontrola procesu szkoleniowego zawodnika trenującego karate. In: Adamczuk F, editor. Proceedings of the 3rd Międzynarodowa Konferencja Młodych Naukowców Szkół Wyższych Euroregionu Nysa; 2009 May 14-15; Jelenia Góra, Poland. Wrocław: Uniwerysytet Ekonomiczny we Wrocławiu; 2009: 98-102 [in Polish]
7. Sterkowicz S, Spelak S. Optymalizacja planu szkolenia techniczno-taktycznego młodzików judo. Zesz Nauk AWF Kraków 2001; 83: 166-178 [in Polish]
8. Artioli G, Franchini E, Nicastro H et al. The need of a weight management control program in judo: a proposal based on the successful case of wrestling (2010). J Int Soc Sport Nutr 2010; 7: 15
9. Roelofs E, Smith-Ryan A, Melvin Blue M et al. Muscle size, quality, and body composition: characteristics of division I cross-country runners. J Strength Cond Res 2015; 29(2): 290-296
10. Sterkowicz-Przybycień K, Błach W, Żarów R. Somatotype components in judoists. J Combat Sports Martial Arts 2012; 3(2): 73-78
11. Andrzejewska J, Burdukiewicz A, Chromik K et al. Budowa morfologiczna oraz charakterystyka stóp zawodników dżudo. Acta Bio-Opt Inform Med 2010; 16(1): 21-24 [in Polish]
12. Wolska B. Sprawność fizyczna a poziom sportowy zawodniczek judo na wybranych etapach wieloletniego szkolenia. Gdańsk: Akademia Wychowania Fizycznego i Sportu; 2018: 41 [in Polish]
13. Thomas S, Coc M, LeGal Y et al. Physiological profiles of the Canadian National Judo Team. Can J Sport Sci 1989; 14(3): 142-147
14. Callister R, Callister RJ, Staron R et al. Physiological characteristics of elite judo athletes. Int J Sports Med 1991; 12(2): 196-203
15. Kim J, Cho H, Jung H et al. Influence of performance level on anaerobic power and body composition in elite male Judoists. J Strength Cond Res 2011; 25(5): 1346-1354
16. Triki M, Rebaia H, Abrougb T et al. Comparative study of body composition and anaerobic performance between football and judo groups. Sci Sport 2012; 27(5): 293-299
17. Durkalec-Michalski K, Podgórski T, Sokołowski M et al. Relationship between body composition indicators and physical capacity of the combat sports athletes. Arch Budo 2016; 12: 247-256
18. Calmet M, Pierantozzi E, Sterkowicz S et al. Judo rules: searching for a wind of changes. Int J Perf Anal Spor 2017; 17(6): 863-871
19. Sterkowicz S, Lech G, Almansba R. The course of fight and the level of sports achievements in judo. Arch-Budo 2007; 3: 72-81
20. Pałka T, Lech G, Tyka A et al. Wydolność fizyczna i morfologiczna budowa ciała profesjonalnych judoków i nietrenujących mężczyzn. Antropomotoryka 2010; 50: 85-89 [in Polish]
21. Maciejczyk M, Wiecek M, Szymura J et al. Effect of body composition on respiratory compensation point during an incremental test. J Strength Cond Res 2014; 28(7): 2071-2077
22. Lech G, Jaworski J, Lyakh V et al. Effect of the level of coordinated motor abilities on performance in junior judokas. J Hum Kinet 2011; 30: 153-160
23. Sterkowicz S, Lech G, Pałka T et al. Body build and body composition vs. physical capacity in young judo contestants compared to untrained subjects. Biol Sport 2011; 28(4): 271-277
24. Szopa J, Mleczko E, Żak S. Podstawy antropomotoryki. Warszawa: Wydawnictwo Naukowe PWN; 2000: 107-119 [in Polish]
25. Maśliński J, Witkowski K, Jatowtt A et al. Physical fitness 11-12 years boys who train judo and those who do not practise sport. Arch Budo Sci Martial Art Extreme Sport 2015; 11: 41-46
26. Fugiel J, Czajka K, Posłuszny P et al. Motoryczność człowieka. Podstawowe zagadnienia z antropomotoryki. MedPharm Polska 2017; 43 [in Polish]
27. Witkowski K, Piepiora P, Migasiewicz J et al. Physical fitness, developmental age and somatic development of youth Greco-Roman wrestlers and school youth aged 15 years. Arch Budo Sci Martial Art Extreme Sport 2018; 14: 63-74
28. Piepiora P, Superson M, Witkowski K. Osobowość a masa ciała i poziom tkanki tłuszczowej na przykładzie zawodniczek piłki siatkowej. Rocz Nauk Wyż Szk Wychow Fiz Tur Białyst 2017; 20: 52-55 [in Polish]

29. Piepiora P, Superson M, Witkowski K. Personality and the body composition of athletes using the example of the Polish national youth female wrestling team. J Combat Sports Martial Arts 2017; 8(2): 107-109
30. Piepiora P, Superson M, Witkowski K. Personality and the nutritional habits of athletes using the example of the Polish national youth female wrestling team. Arch Budo Sci Martial Art Extreme Sport 2017; 13: 103-110
31. Piepiora P, Superson M, Witkowski K et al. Characteristics of body composition and subjective assessment of body weight and eating habits of wrestlers on the example of the Polish youth team. Arch Budo Sci Martial Art Extreme Sport 2018; 14: 87-91
32. Litwiniuk A, Grants J, Kravalis et al. Personality traits of athletes practicing eastern martial arts. Arch Budo 2019; 15: 195-201
33. Coufalová K, Cochrane D, Malý T. Changes in body composition, anthropometric indicators and maximal strength due to weight reduction in judo. Arch Budo 2014; 10(1): 161-168
34. Silva A, Field D, Heymsfield S et al. Relationship between changes in total-body water and fluid distribution with maximal forearm strength in elite judo athletes. J Strength Cond Res 2011; 25(9): 2488-2495
35. Degoutte F, Jouanel P, Bègue R. Food restriction, performance, biochemical, psychological, and endocrine changes in judo athletes. Int J Sports Med 2006; 27(1): 9-18
36. Lech G, Sterkowicz S, Rukasz W. Significance of body height in martial arts (as exemplified by judo fighters). Hum Movement Sci 2007; 8(1): 21-26
37. Kuźmicki S, Kruszewski A, Kruszewski M. The individual technical and tactical profile of a leading Polish judoka in the +100 kg weight category and his somatic composition in comparison to the world elite. Balt J Health Phys Act 2016; 8(4): 69-78
38. Melekoğlu T, Öcal D, Baydil B et al. Muscle strength in relation to body composition in the Turkish male national judo team. Ann Ovidius U Constanta Phys Educ Sport Sci Movement Health 2012; 12(2): 175-181
39. Coelho M, Oliveira T, Fernandes R. Biochemistry of adipose tissue: an endocrine organ. Arch Med Sci 2013; 9(2): 191-200
40. Ahima R, Osei S. Adipokines in obesity. Front Horm Res 2008; 36: 182-197
41. Chevalier S, Burgos S, Morais J et al. Protein and glucose metabolic responses to hyperinsulinemia, hyperglycemia, and hyperaminoacidemia in obese men. Obesity (Silver Spring) 2015; 23(2): 351-358
42. Chen W, Jiang H, Yang J et al. Body composition analysis by using bioelectrical impedance in a young healthy Chinese population: Methodological considerations. Food Nutr Bull 2017; 38(2): 172-181
43. Pilicz S, Ulatowski T. Testowanie sprawności ogólnej. In: Ulatowski T, editor. Zastosowanie metod naukowych na potrzeby sportu. Warszawa: Polskie Towarzystwo Naukowe Kultury Fizycznej; 2002 [in Polish]
44. Chwałczyńska A. Wskaźnik tłuszczowo-beztłuszczowy zależny od wieku, jako nowe narzędzie oceny masy ciała. Wrocław: Akademia Wychowania Fizycznego; 2017: 5 [in Polish]
45. Franchini E, Nunes A, Moraes J et al. Physical fitness and anthropometrical profile of the Brazilian male judo team. J Physiol Anthropol 2007; 26(2): 59-67
46. Kalina R, Kulesza A, Mysłowski A et al. Dynamics of judo, boxing and taekwon-do contests performed by finalists of Olympic Games in Sydney. In: Szopa J, Gabryś T, editors. Sport training in interdisciplinary scientific researches. Częstochowa: Sekcja Wydawnictwa Wydziału Zarządzania Politechniki Częstochowskiej; 2004: 326-331
47. Adam M. A profile of Paweł Nastula's individual technical-tactical preparation. Arch Budo Sci Martial Art Extreme Sport 2013; 9: 69-75
48. Adam M, Smaruj M, Laskowski R. A technical and tactical profile of the double olympic judo champion: a case study. Int J Sports Sci Coa 2014; 9(1): 123-138
49. Prill R, Michel S, Schulz R et al. Body composition and strength parameters in elite judo athletes 5 years after anterior cruciate ligament reconstruction. Int J Sports Med 2019; 40(1): 38-42
50. Wolska B, Adam M, Mekic A. The correlation of general and special physical fitness indices with somatic indicators in 16–18-year-old female judokas. J Martial Arts Anthropol 2016; 16(3): 27-33
51. Domingos C, Matias C, Cyrino E et al. The usefulness of Tanita TBF-310 for body composition assessment in Judo athletes using a four-compartment molecular model as the reference method. Rev Assoc Med Bras 2019; 65(10): 1283-1289
52. Liu L, Roberts R, Moyer-Mileur L et al. Determination of body composition in children with cerebral palsy: bioelectrical impedance analysis and anthropometry vs. Dual-energy X-ray absorptiometry. J Am Diet Assoc 2005; 105(5): 794-797
53. Jakubowska-Pietkiewicz E, Prochowska A, Fendler W et al. Comparison of body fat measurement methods in children. Pediatr Endocrinol Diabetes Metab 2009; 15(4): 246-250
54. Hsieh KC, Lu HK, Chen CH et al. The validity and accuracy in foot-to-toot bioelectrical impedance analysis measuring models referenced by dual-energy X-ray absorptiometry in body composition in standing position. Afr J Biotechnol 2011; 16(10): 3222-3231
55. Santos D, Matias C, Rocha P et al. Association of basketball season with body composition in elite junior players. J Sport Med Phys Fit 2014; 54(2): 162-173
56. Orzech J. Kształtowanie sylwetki ciała. Monografia treningu siły mięśniowej. Tom 3. Tarnów: Wydawnictwo Sport i Rehabilitacja; 2002: 93-98 [in Polish]
57. Lohman T, Houtkooper L, Going S. Body Fat Measurement Goes High-Tech. Not all are created equal. ACSMS Health Fit J 1997; 1(1): 30-35
58. Strong C. Motivation related to performance of physical fitness tests. Res Q Exercise Sport 2013; 34 (4): 497-507
59. Silva A, Field D, Heymsfield S et al. Body composition and power changes in elite judo athletes. Int J Sports Med 2010; 31(10): 737-741
60. Slater G, Rice A, Jenkins D et al. Body mass management of lightweight rowers: nutritional strategies and performance implications. Brit J Sport Med 2014; 48(21): 1529-1533
61. Gonçalves E, Matias C, Santos D et al. Assessment of total body water and its compartments in elite judo athletes: comparison of bioelectrical impedance spectroscopy with dilution techniques. J Sports Sci 2015; 33(6): 634-640
62. Knuiman P, Hopman M, Mensink M. Glycogen availability and skeletal muscle adaptations with endurance and resistance exercise. Nutr Metab (Lond) 2015; 12: 59
63. Torres-Luque G, Hernandez-Garcia R, Garatachea N et al. Anthropometric characteristics and neuromuscular function in young judo athletes by sex, age and weight category. Sport Sci Health 2015; 11: 117-124
64. Koral J, Dosseville F. Combination of gradual and rapid weight loss: Effects on physical performance and psychological state of elite judo athletes. J Sports Sci 2009; 27(2): 115-120
65. Sterkowicz-Przybycień K, Almansba R. Sexual dimorphism of anthropometrical measurements in judoists vs untrained subject. Sci Sports 2011; 26(6): 316-323
66. Bonitch-Góngora J, Bonitch-Domínguez J, Padial P et al. The effect of lactate concentration on the handgrip strength during judo bouts. J Strength Cond Res 2012; 26(7): 1863-1871
67. Papacosta E, Gleeson M, Nassis G. Salivary hormones, IgA, and performance during intense training and tapering in judo athletes. J Strength Cond Res 2013; 27(9): 2569-2580
68. Schwartz J, Takito M, Del Vecchio F et al. Health-related physical fitness in martial arts and combat sports practitioners. Sport Sci Health 2015; 11(2): 171-180
69. Montero-Carretero C, Moreno-Murcia J, Amado D et al. Self-confidence and flow in judo. Arch Budo Sci Martial Art Extreme Sport 2015; 11: 47-55
70. Strong C. Motivation related to performance of physical fitness tests. Res Q Exercise Sport 2013; 34(4): 497-507
71. Mrozkowiak M, Sokołowski M, Kaiser A. An attempt to determine the effect of the axial load on selected posture fencers. J Educ Health Sport 2016; 6(10): 309-320

72. Jagiełło W, Kalina RM, Tkaczuk W. Age peculiarities of speed and endurance development in young judo athletes. Biol Sport 2001; 18(4): 281-295

73. Jagiełło W, Kalina RM, Tkaczuk W. Development of strength abilities in children and youth. Biol Sport 2004; 21(4): 351-368

74. Witkowski K, Piepiora P, Migasiewicz J et al. Physical fitness, developmental age and somatic development of youth Greco-Roman wrestlers and school youth aged 13-14 years. Arch Budo Sci Martial Art Extreme Sport 2018; 14: 63-74

75. Dąbrowski J, Ziemba A, Tomczak A et al. Physical performance of health men expose to long exercise and sleep deprivation. Med Sportiva 2012; 16(1): 6-11

76. Tomczak A. Effects of a 3–day survival training on selected coordination motor skills of special unit soldiers. Arch Budo 2013; 3: 168-172

77. Tomczak A, Bertrandt J, Kłos A et al. Comparison of Dynamic Balance Level of the Polish Special Forces Soldiers and Civilians During Survival School Training. Book of abstracts 3rd International Congress On Soldiers' Physical Performance; 2014 Aug 18-21; Boston, USA. Natick: United States Army Research Institute of Environmental Medicine; 2014: 82

78. Tomczak A. Coordination motor skills of military pilots subjected to survival training. J Strength Cond Res 2015; 29(9): 2460-2464

79. Tomczak A, Dąbrowski J, Mikulski T. Psychomotor performance of air force cadets after 36 hours of survival training. Ann Agric Environ Med 2017; 24(3): 387-391

80. Tomczak A, Różański P, Jówko E. Selected coordination motor abilieties of students of the University of Physical Education during survival training. Pol J Sport Tour 2017; 24: 102-105

81. Tomczak A, Różański P, Jówko E. Changes in coordination motor abilities of Naval Academy cadets during military survival training. Aerosp Med Hum Perform 2019; 90(7): 632-636

82. Tomczak A, Jówko E, Różański P. Survival training effects on oxidative stress and muscle damage biomarkers of naval cadets. Aerosp Med Hum Perform 2020; 91(9) 720-724

83. Kalina RM, Jagiełło W, Barczyński BJ. The method to evaluate the body balance disturbation tolerance skills – validation procedure of the 'Rotational Test'. Arch Budo 2013; 9(1): 59-80

84. Tomczak A. Changes in coordination motor abilities of young men during survival school simulation training. Warszawa: Akademia Sztuki Wojennej; 2021 [in Polish]

85. Kalina RM. Non-apparatus safe falls preparations test (N-ASFPT) – validation procedure. Arch Budo 2013; 9(4): 255-265

86. Dictionary of Sport and Exercise Science. Over 5,000 Terms Clearly Defined. London: A & B Black; 2006

87. Kalina RM. Methodology of measurement, documentation and programming optimal workload continuous with variable intensity – applications in sports medicine, physiotherapy, geriatrics, health-related training, sport for all. Arch Budo 2012; 8(4): 235-249

88. http://hometoroam.blogspot.com/2012/07/sabantuy.html (accessed 2019 Oct 5)

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