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CORRELATION BETWEEN BODY COMPOSITION AND FUNCTIONAL ABILITIES OF JUDOKASSELECTED FOR THE NATIONAL TEAM

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SUMMARY

The aim of this study is to establish if there is a correlation between body composition and the functional abilities of judokas selected for the national team.The sample consisted of the extended male judo national team of Serbia – 25 judokas in under-18 and under-21 age categories. The subjects were aged 15 to 21. The weight categories ranged from 50 to 100 kg.The body composition of the subjects was assessed by using the InBody 720 body composition analyzer. To determine the functional abilities, a special judo fitness test and the shuttle run test were used. Canonical correlation analysis was used to determine the correlation between the body composition test and the group of functional ability tests. The canonical correlation analysis revealed that there is a statistically significant correlation between body composition and functional abilities, but no statistically significant correlation between body composition and anaerobic capacity was found.The results obtained in the study can be used as guidelines for more efficient programming of the training process, with special emphasis on individual work. They can also be used for comparison with other similar studies for the given age categories and can serve as a good basis for broader selection within judo.

Keywords: aerobic capacity, anaerobic capacity, special judo fitness test, elite judo athletes

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INTRODUCTION

Judo is described as an explosive sport with large reserves of anaerobic capacity and well-developed aerobic characteristics (Callister, Callister, Staron, Fleck, Tesch & Dudley, 1991; Takahashi, 1992). The sport is characteristic for its short duration high-intensity activity, which makes it an anaerobic sport. Competitive success in judo depends on a number of factors, which include functional abilities. The control of competitive and training loads is becoming more accurate and it provides significant information for the coaches (Koprivica, 2018). The fact that there are significant links between the functional characteristics and the technical elements in judo implies that the improvement of specific functional abilities can influence the performance of techniques during training and competitions. Todorov et al. state that enhanced anaerobic capacity with reduced quantities of body fat allow the performance of a large number of actions during combat, while high values of aerobic capacity accelerate the recovery process between fights (Todorov, Bratić, Nurkić, & Radovanović, 2013).

The functional abilities of judokas suggest that there is a connection between aerobic capacity and the speed of recovery after high-intensity intermittent activity (Franchini, Takito, Nakamura, Regazzini, Matsushigue & Kiss, 1999; Muramatsu, Horiyasu, Sato, Hattori, Yanagisawa, Onozawa & Tezuka, 1994).Judokas with high aerobic capacity are able to withstand sub-maximal activity levels with a more reduced sense of exertion than judokas with lower aerobic capacity (Gorostiaga, 1988). In addition, high aerobic capacity allows a judoka to preserve glycogen, which delays the onset of fatigue during combat and accelerates the recovery from an anaerobic effort by removing metabolic products. High anae

robic capacity enables short-lived but intense use of maximum muscle strength, typical for judo combat. Longer efforts to reach a better grip in modern judo involve more intense activation of the upper body, especially the muscles in the upper extremities. This is the main reason why some authors stress the importance of upper body anaerobic capacity, as well as the high values of maximum and relative upper body strength (Little, 1991; Mickiewitz, 1991).

Body composition is the proportion ofadipose, muscle, and bone tissue in the overall body mass (AAHPERD, 1989). This proportion is a better indicator of an athlete's fitness than body weight. Programmed training, diet, and supplementation are used to directly improve body composition (Ugaraković, 2001). The selected judokas should maintain their body fat percentage below 10% through programmed training and proper nutrition (Franchini et al., 2011), except in heavyweight and super-heavyweight categories (up to 100 kg and over 100 kg). Studies have shown that winners of Olympic and world championship medals have less than 10% body fat (Sbriccoli, Bazzucchi & Di Mario, 2007).

Scientific community continuously investigates the key features that are important for achieving success in the competition. Some of the aspects studied include the optimal level of physical (motoric) preparedness required for an elite sports performance (Degoutte, Jouanel & Filaire, 2003) and the significance of determining body composition and somatotype(Claessens, Beunen, Welles & Geldof, 1987). The aim of this study is to attempt to establish if there is a correlation between body composition and the functional abilities of judokas selected for the national team.

METHODS

The testing was conducted in training halls at the "Karataš" Youth Camp, where the athletes were finishing their preparations for the European championship in Lithuania. The sample consisted of the extended male judo national team of Serbia – 25 judokasin under-18 and under-21 categories. The subjects were aged 15 to 21.The weight categories ranged from 50 to 100 kg. The basic criteria for participation in the study were that all subjects had to have completed a medical examination, that they had not had any health issues in the ten days prior to the testing, and that they had not sustained any injury that might affect their test results.

The body composition of the subjects was assessed directly through the laboratory method of bioelectrical impedance analysis using the InBody 720 body composition analyzer. The InBody 720 utilizes a body composition measurement technology based on low-voltage electricity, which is transported to the human body through electrodes, thus providing an exceptional degree of accuracy in body composition assessment **(**Silva, Fields, Heymsfield & Sardinha, 2010).

To determine the functional abilities, a special judo fitness test and the shuttle run test were used. The special judo fitness test was conducted in the following manner: two subjects (*ukes*) in the same weight category and of similar height were positioned 6 meters away from one another, while the subject beingtested (*tori*) was placed between them (Franchini, Vecchio & Sterkowicz, 2009). At the measurer's signal, the tori subject was asked to run to one of the ukes to perform a throw and then to perform the same throw on the other uke. The test consists of three parts, followed by the determination of heart rate (HR) immediately after the test and after 60 seconds of rest(HR after recovery). The index was calculated as the sum of HR results after the test and after the 60-second recovery and was then correlated to the total number of throws (N). The shuttle run test assesses the cardiorespiratory endurance and maximum aerobic capacity(Mahar, Welk, Rowe, Crotts & McIver, 2006). A test subject's first task is to start walking or jogging. The subject moves between two lines 20 meters apart. Running speed is controlled by means of sound signals in regular intervals, whereby the speed

increases by 1.2 km/h after each level. The level at which the subject is no longer able to run or to follow the sound signal is the indicator of their aerobic capacity. Based on the test score, the maximum rate of oxygen consumption (VO_2max) is calculated with the following formula:

$$VO_{2max} \text{ (ml/kg/min)} = 18.043461 + (0.3689295 \times TS) + (-0.000349 \times TS \times TS)$$

Statistical analysis included descriptive statistics and result distribution. Canonical correlation analysis (CCA) was used to determine the correlation between the body composition test and the group of functional ability tests. Raw data were processed and analyzed using the IBM SPSS statistical data processing software(version 20.0; Inc., Chicago, IL, USA).

RESULTS

Table 1 shows the basic statistical parameters of the variables for body composition assessment and the variables for functional ability assessment in the judokas selected for the national team. The observed deviations from recommended values and large ranges of body composition assessment variables were expected, considering that the sample of subjects consisted of athletes who compete in different weight categories. The study encompassed national team judokas from the extra-lightweight (-50 kg) to the half-heavyweight (-100 kg) weight category; only the super-heavyweight(+100kg) category was excluded from the study.

Table 1. Descriptive statistical parameters

Variable	Mean	Std. Dev.	Min	Max	Range	Skewness	Kurtosis
Body mass	70.15	10.95	51.40	101.40	50.00	0.98	2.28
Adipose tissue %	10.95	2.84	6.00	17.50	11.50	0.29	0.04
Adipose tissue kg	7.91	3.19	3.20	17.80	14.60	1.40	3.37
Muscle tissue %	50.53	1.38	47.93	52.78	4.85	0.05	-1.02
Muscle tissue kg	35.38	5.09	26.10	48.60	22.50	0.67	1.26
Lean tissue %	89.02	2.86	82.45	94.02	11.57	-0.28	0.00
Lean tissue kg	62.24	8.24	47.20	83.60	36.40	0.65	1.23
HR min	53.82	6.06	45.00	66.00	21.000	0.42	-0.53
HR max	196.56	6.48	179.00	208.00	29.000	-1.07	1.82
$VO2_{max}$ ml/kg/min	52.16	4.59	43.66	58.55	14.890	-0.45	-0.72
$VO2_{max}$ L/min	3.65	0.59	2.24	4.87	2.630	-0.37	0.44
SJFT index	12.51	1.02	10.11	14.32	4.210	-0.49	0.36

Table 2 shows the cross-correlations of body composition and functional abilities. Analysis of the cross-correlation matrix was used to examine the correlations between variables of the two systems. Considerably high and statistically significant correlations were observed for the criterion variable *Maximum rate of oxygen consumption* (VO2max L/min) with the variables Adipose tissue % (.58), Adipose tissue kg (.72), Muscle tissue % (.30), Muscle tissue kg (.85), Lean tissue % (.58), Lean tissue kg (.85). The variable *Maximum heart rate* (HR max) has a lower statistically significant correlation with the variables Muscle tissue kg (.23) and Lean tissue kg (.23).

Table 2. Cross-correlation of body composition and functional abilities

Variable	HR min	HR max	VO2max ml/kg/min	VO2max L/min	SJFT index
Adipose tissue %	.01	.09	-.11	**.58**	-.17
Adipose tissue kg	-.13	.20	-.14	**.72**	-.10
Muscle tissue %	-.04	-.02	.16	**-.30**	.10
Muscle tissue kg	**-.23**	**.25**	-.07	**.85**	-.11
Lean tissue %	-.01	-.09	.11	**-.58**	.17
Lean tissue kg	**-.23**	**.25**	-.07	**.85**	-.11

Table 3 shows the significance of extracted pairs of the canonical factors of body composition and functional abilities. The establishment of correlations between body composition and functional abilities revealed two statistically significant factors. The first factor has a considerably high canonical correlation of.99 (Canonical R .99), which is explained by 99% of the total variance (Canonical R^2 .99) and is statistically significant at the level .000.The second factor has a canonical correlation of .91, which is explained by 84% of the total variance (Canonical R^2 .84) and is statistically significant at the level p< .05 (.046).

Table 3. Significance of extracted pairs of canonical factors

	Root	Canonicl R	Canonicl R^2	Chi-sqr.	df	p
Body composition – Functionalabilities	0	.99	.99	134.52	35	.000**
	1	.91	.84	36.74	24	.046*

Canonicl R – maximumcorrelation between predictor and criterion variables; Canonicl R^2– %

of covariance of examined spaces; Chi-sqr. –chi-squared test of statistical significance; df – degrees of freedom; p –significance level; ** - p< .01; * - p< .05.

Table 4 shows the structure of isolated canonical factors, which presents the correlations between body composition and functional abilities. In the space *Body composition*, the first factor is explained by the variables Adipose tissue kg(.88), Muscle tissue kg (.98), andLean tissue kg (.98); in the space *Functional abilities*, the first factor is explained by the variable *Maximum rate of oxygen consumption in liters* (VO_{2max} L/min) (.84) and to a lesser extent by the variables *Maximum heart rate* (HR max) (.24) and *Minimum heart rate*(HR min) (.20). The second factor in the space *Functional abilities* is defined by the variables*Maximum rate of oxygen consumption in milliliters per kilogram* (VO_{2max} ml/kg/min)(.73) and *Special judo fitness test* (SJFT) index (.67).

Table 4. Structure of isolatedcanonical factors

Body composition	Root 1	Root 2	Functional abilities	Root 1	Root 2
Adipose tissue %	.71	-.07	HR min	-.20	-.25
Adipose tissue kg	**.88**	.03	HR max	.24	.03
Muscle tissue %	-.43	-.03	VO_{2max} ml/kg/min	-.11	-**.73**
Muscle tissue kg	**.98**	-.02	VO_{2max} L/min	**.84**	-.39
Lean tissue %	-.70	.07	SJFT index	-.12	**.67**
Lean tissue kg	**.98**	-.01			

DISCUSSION

Upon analysis of the basic statistical parameters of the variables for body composition assessment in the selected judokas, it can be claimed that young Serbian judokas displayed similar results to the elite judokas of their age from other countries. The fat percentage obtained in the present study (11 ± 2.8%) corresponds to the results obtained in other studies conducted on the same age categories of judokas (Franchini et al., 2011; Kim, Cho, Jung & Yoon, 2011; Koral & Dosseville, 2009), considering that the sample contained under-18 and under-21 test subjects. With regard to muscle mass, compared to the Spanish national under-18, under-21, and senior teams, who had 48.5%, 50.3%,and 53.2% of muscle mass, respectively (Franchini et al., 2011), the results obtained from the Serbian judokas (50.53 ± 1.38% of muscle mass) are in accordance with the aforementioned study in terms of age categories.

To achieve competitive success in judo, it is essential to possess well-developed functional abilities. It is understood that an athlete's anaerobic metabolism is responsible for high-intensity activity during a match, whereas the

aerobic metabolism plays a chief role in the recovery process between multiple consecutive matches (Todorov, Bratić, Nurkić, & Radovanović, 2013). Elite European senior fighters,aged 25.60 ± 3.64, who won medals in European championships and World and European cups, have the mean value of maximum oxygen consumption rate (VO_{2max}) of 55.99 ± 2.24 ml/kg/min. A $VO_{2max}$of 48.72 ± 1.72 ml/kg/min was recorded in senior category judokas (aged 25.80 ± 4.08) who won medals in national championships of Serbia or Bosnia and Herzegovina(Drid et al., 2015). The mean $VO_{2max}$of the selected Serbian judokas was 52.16 ± 4.59 ml/kg/min. This is in keeping with the results (53.3 ± 3.9 ml/kg/min) obtained in a study in which the authors used the same method for VO_{2max}assessment as in the present study (20-m shuttle run test), applied to the sample of the Tunisian national judo team in the same age categories (Chaouachi et al., 2009). Similar results were obtained by Mala et al. (2015), who studied a sample of Czech national team judokas and obtained the mean $VO_{2max}$of 53.58 ± 4.74 ml/kg/min, the difference being that the authors used the ergometer test. The 20-m shuttle run test and a similar sample were also used in the study by Cuk (2016), where the test was used to assess VO_{2max}in Slovenian judokas, who were a part of the extended selection for the under-18 and under-21 national team. Divided into three groups according to weight, the Slovenian judokas achieved significantly worse results. Thus, in the -60kg group the estimated $VO_{2max}$was 43.72 ± 2.62 ml/kg/min, in the 60-73kg group the average $VO_{2max}$was 44.00 ± 3.04 ml/kg/min, while the average VO_{2max}in the +73kg group was41.62 ± 3.41 ml/kg/min. A somewhat better result (57.2±7.2 ml/kg/min) was obtained byPapacosta, Gleeson, & Nassis(2013) in a study conducted on the sample of the Cypriot national team. The only difference is that the subjects in the study were older on average (age 20±6 as opposed to 18±3) and that the bicycle ergometer testwas used instead of the 20-m shuttle run test.

The special judo fitness test is predominantlyused to assess the anaerobic-alactic capacity of judokas (Franchini, Sterkowicz, Szmatlan-Gabrys, Gabrys, & Garnys, 2011). Since the sample of nationally selected judokas tested in the present study comprised prevalently under-18 fighters, the obtained average result of the special judo fitness test (12.51±1.02) can be considered from two or even three aspects. First, if the selected judokas are taken to be mostly in the under-18 age group, the obtained result can be interpreted as borderline good (index 12.39 and lower), but still falls into the average category. Second, if the selected judokas are taken to be in the under-21 age group, the obtained result is interpreted as average and almost exactly between the good (lower than 11.30) and the bad results (higher than 13.52) (Agostinho, Junior, Stankovic, Escobar-Molina, & Franchini, 2018). Finally, if the goal is to determine where the judokas were tested according to the results designated for the senior category, in which many of the younger judokas already compete, the comparison will be made against the given values for seniors; accordingly, it can be concluded that the

result is good (11.74-13.03). Nevertheless, this result should not be taken for granted, because the senior test subjects had different levels of competitive achievement, while the samples of under-18 and under-21 subjects consisted only of elite competitors (national teams of Brazil, Spain, and Serbia). The maximum heart rate of 196.56 ± 6.48 bpm is in accordance with the previously recorded results for under-18 and under-21 judokas, which range from 190 to 200 bpm (Hernández-García, Torres-Luque, & Villaverde-Gutierrez, 2009; Little, 1991). Among the seniors who competed in the Olympics, the maximum heart rate ranges from 177 to 194 bpm; measured during a combat match, the heart rate averages at 180.2 ± 10.5 bpm (Sbriccoli, Bazzucchi, Di, Marzattinocci & Felici, 2007).

The canonical correlation analysis revealed that there is a statistically significant correlation between body composition and functional abilities, but *no* statistically significant correlation between body composition and anaerobic capacity was found, which differs from other related studies (Kim et al., 2011; Franchini et al., 2007; Sterkowicz et al., 2011).

CONCLUSION

The results of this study provide insight into the current level of training of judokas selected for the national team in terms of body composition and functional ability parameters. The study is significant because it reveals a correlation between body composition and functional abilities of nationally selected young judokas. The results obtained in the study can be used as guidelines for more efficient programming of the training process, with special emphasis on individual work. They can also be used for comparison with other similar studies for the given age categories and can serve as a good basis for broader selection within judo. Future studies should be conducted so as to examine the correlation between body composition and other motor skills, both general and specific, and to also include female subjects, all for the purpose of an even more detailed examination of how body composition and functional abilities are connected.

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ВЗАИМОСВЯЗЬ МЕЖДУ СОСТАВОМ ТЕЛА И ФУНКЦИОНАЛЬНЫМИ ВОЗМОЖНОСТЯМИ ДЗЮДОИСТОВ ВЫБРАННЫХ ДЛЯ НАЦИОНАЛЬНОЙ КОМАНДЫ

АННОТАЦИЯ

Цель данного исследования - установить, существует ли корреляция между составом тела и функциональными способностями дзюдоистов, выбранных для национальной сборной. Выборка состояла из расширенной мужской дзюдо сборной Сербии - 25 дзюдоистов. Субъектам было от 15 до 21 года. Весовые категории варьировались от 50 до 100 кг. Состав тела испытуемых оценивали с использованием анализатора состава тела InBody 720. Для определения функциональных способностей использовались специальный фитнес-тест по дзюдо и тест по пробежке. Канонический корреляционный анализ использовался для определения корреляции между тестом состава тела и группой тестов функциональных способностей. Канонический корреляционный анализ показал, что существует статистически значимая корреляция между составом тела и функциональными способностями, но не было обнаружено статистически значимой корреляции между составом тела и анаэробной способностью. Результаты, полученные в исследовании, могут использоваться в качестве руководства для более эффективного программирования учебный процесс, с особым упором на индивидуальную работу. Они также могут быть использованы для сравнения с другими аналогичными исследованиями для данных возрастных категорий и могут служить хорошей основой для более широкого выбора в дзюдо.

Ключевые слова: аэробная нагрузка, анаэробная нагрузка, специальный фитнес-тест по дзюдо, элитные дзюдо спортсмены

КОРЕЛАЦИЈА ИЗМЕЂУ ТЕЛЕСНЕ КОМПОЗИЦИЈЕ И ФУНКЦИОНАЛНИХ СПОСОБНОСТИ ЏУДИСТА СЕЛЕКТОВАНИХ ЗА НАЦИОНАЛНИ ТИМ

САЖЕТАК

Циљ овог истраживања је био да се утврди да ли постоји повезаност телесне композиције са функционалним способностима селекционисаних џудиста.Узорак испитаника био је састављен од ширег састава мушке џудо

репрезентације Србије, 25 такмичара кадетског и јуниорског узраста. Испитаници су били старости од 15 до 21 године. Тежинске категорије које су обухваћене студијом су од 50 до 100 килограма. Процена телесногсастава испитаника извршена је апаратом за процену телесне композиције In Body 720.За одређивање функционалних способности користили су се специјални џудо фитнес тест и „Shutlle run“ тест.Канонička корелациона анализа примењена је за утврђивање повезаности теста телесне композиције са групом тестова функционалних способности.Канонички корелационом анализом утврђена је статистички значајна повезаност телесне композиције и функционалних способности, али статистички значајна повезаност између телесне композиције и анаеробних способности није утврђена. Резултати ове студије могу да послуже као смернице за ефикасније програмирање тренажног процеса, са посебним освртом на индививидуални рад. Резултати студије се могу употребити за упоређивање са сличним истраживањима код наведеног узраста и послужити као добра база за ширу селекцију у џудо спорту.

Кључне речи: аеробни капацитет, анаербони капацитет, специјални џудо фитнес тест, врхунски џудисти

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