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RELATIONS OF CERTAIN ANTHROPOMETRIC VARIABLES WITH THE PERFORMANCE QUALITY OF THROWING TECHNIQUES IN JUDO

ODNOS NEKATERIH ANTROPOMETRIJSKIH SPREMENLJIVK S KAKOVOSTJO IZVEDBE TEHNIK METOV V JUDU

Abstract

The overall aim of the present research study was to determine the magnitude and direction of the relations of certain anthropometric variables with the quality of throwing technique performance in judo. The research was conducted with a sample of 122 male sophomores of the Faculty of Kinesiology at the University of Zagreb. The set of predictor variables consisted of a battery of 18 anthropometric variables. The quality of stationary performance throwing techniques was the variable criterion. It was assessed by five expert judo judges. The following hypothesis was established: sufficient quality performance of throwing techniques depends on the anthropometric characteristics of a thrower. For testing the hypothesis and for determining the relations between certain anthropometric variables and throwing technique performance, quality regression analysis and factor analysis were used. Statistically significant relations were obtained between the predictor groups of anthropometric variables in the latent space with the criterion of judo throwing technique performance from a standing-still-position.

Key words: judo, anthropometry, throwing technique, performance quality

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Izvleček

Cilj predstavljene raziskave je bil ugotoviti velikost in smer odnosov nekaterih antropometrijskih mer s kakovostjo izvedbe tehnike metov pri judu. Raziskava je bila izvedena na vzorcu 122 študentov drugega letnika Fakultete za kineziologijo v Zagrebu. Serijo prediktorskih spremenljivk je sestavljala baterija 12 antropometrijskih mer. Kakovost statične izvedbe tehnik metov je bila odisna spremenljivka, ki jo je določala peterica sodnikov juda. Preverjali smo hipotezo, po kateri je zadostna kakovost izvedbe tehnik metov odvisna od antropometrijskih lastnosti izvajalca meta. Za preverjanje hipoteze in ugotavljanje odnosov med nekaterimi antropometrijskimi spremenljikami in kakovostjo izvedbe metov smo uporabili regresijsko in faktorsko analizo. Pokazale so se statistično značilne povezave med serijo prediktorskih antropometrijskih spremenljivk v latentnem prostoru in tehnikami metov, izvedenimi iz statičnega položaja.

Ključne besede: judo, antropometrija,tehnika metov, kakovost izvedbe

INTRODUCTION

Judo is, from the structural analysis point of view, a combat sport that belongs to the martial art family of polystructural acyclic sports; this is so because acyclic motion patterns prevail in it. The application of these movement structures by the two competitors engaged in a contest eventually results in the binary outcome variable of *victory - defeat* (Sertić, 2004). From the functional point of view, kinesiology describes judo as a sport whose technique is characterised by both the open and the closed kinetic chains of motion structures. A vast variety of perfected technical elements, manifested as acyclic motions with extremely complex structures may bring the desirable outcome (victory) only if a judoka (a practitioner of judo) applies them on time (proper timing) and in the most effective way from the aspects of energy consumption and balance. Because of the oppositional relationship, which predominates in a judo bout, it is a dynamic, continuously changing environment whose nature imposes high demands on athletes: the technical-tactical routines they apply in a combat must be perfected to the maximum, they must possess ability to quickly reorganize these motor programmes, and to constantly and instantly create new defensive, offensive, or counter-attacking courses of action.

Each judo technique is performed under the conditions of direct combat contact with the opponent, and they are all performed to symbolically destroy the opponent and to win control over him/her; that is, to win. Success in a judo bout is defined as the victory which can be accomplished by the application of any of techniques from four groups: throws *(nage-waza),* chokes *(shime-waza),* leverages *(kansetsu-waza)* or holds *(osae-komi-waza).* The fact that each technique is applied in a bout against the opponent's constant resistance and his/her intentions to perform a counter-attack, and that each bout lasts five minutes indicate the high energy consumption in a contestant.

The magnitude of energy consumption in an athlete depends on the duration and intensity of work, and on the portion of the engaged musculature. Consequently, it can be said that a judoka works very hard in training sessions and competitions with a high level of psychological pressure. Since the competition rules allow a quick end, a bout is in fact a psychological battle, which considerably contributes to enhanced energy consumption. Due to the existence of weight categories in judo (up to 60 kg; up to 66 kg; up to 73 kg; up to 81 kg; up to 90 kg; up to 100 kg; over 100 kg), whose role is to diminish the influence of morphological characteristics on performance in a bout, each weight category, theoretically and practically, is characterized by a different model of successful contestant. Consequently, performance in each weight category is described by its own equation of success, which comparatively differs from the others according to their distance on the weight measurement scale.

There are seven weight categories, and since certain research studies (Shaw & Kavanal, 1995; Sterkowicz, 1998; Sterkowicz & Franchini, 2001) have demonstrated that within a particular weight category the hierarchical order of throwing technique efficiency may differ from the throwing technique efficiency order in other weight categories, it is feasible to presume that the described difference has been provoked by the differences in anthropological dimensions of judokas. The goal of the present research was to determine the magnitude and the direction of the relations of certain anthropometric variables with the quality of throwing technique performance in judo.

METHODS

Sample of subjects

The subjects were defined as a group of regular full-time students at the Faculty of Kinesiology of the University of Zagreb. The sample of subjects, drawn from the population of sophomores, consisted of 122 male students (aged between 19 and 21 years) four of whom had never before been involved in the training of judo or any other similar martial art. All subjects can be described as judo beginners or novices, according to the level of judo skills attainment (level of mastery) and their combat competition experience.

Sample of variables

Sample of predictor variables

The battery of 18 anthropometric variables (measures) was selected for the present research under the presumption that there were four hypothetical latent anthropometric dimensions: the longitudinal dimension of the skeleton, the transversal dimension of skeleton, the circular dimension of the skeleton, and the amount of subcutaneous fat tissue.

Six measures were selected to assess body mass and body volume (the circular dimension of the skeleton): *thigh circumference* (OPSNAT), *calf circumference* (OPSPOT), *extended upper arm circumference* (OPSNAD-O), *flexed upper arm circumference* (OPSNAD-F), *forearm circumference* (OPSPOD), and *body weight* (MASTIJ). To assess the longitudinal dimension of the skeleton, four measures were used: *body height* (VISTIJ), *leg length* (DUZNOG), *arm length* (DUZRUK) and *shoulder width* (BIAKRAS).

Subcutaneous fat tissue was assessed with five measures: *upper arm skinfold* (NABNAD), *forearm skinfold* (NABPOD), *lower leg skinfold* (NABPOD), *subscapular skinfold* (NABLEĐ), and *abdominal skinfold* (NABTRB).

The transversal dimension of the skeleton was determined by means of three measures: elbow diameter (DIJLAK), knee diameter (DIJKOLJ), and hip width (BIKRIS). The measurements were conducted in the morning. All subjects were barefoot and wore only shorts. Before the actual measuring, the relevant, selected anthropometric points were marked. Bilateral body segments were measured on the right side of the body.

Sample of criterion variables

Evaluation of the quality of judo throw technique performance embraced 14 techniques, which are representatives of the following groups of throwing techniques: arm, hip, leg, and self-sacrificing throws, as classified by Kudo (1976). Those techniques were assessed as the most effective judo tournament combat techniques at the Barcelona Olympic Games.

According to the 1992 Olympic Games' (OG) tournament statistics, the rank list of the most frequently performed and registered actions in male judo tournament comprised the following techniques in descending order: 1. *seoi-nage,* 2. *uchi-mata,* 3. *ouchi-gari,* 4. *koshiki-taoshi,* 5. *tani-otoshi,* 6. *harai-goshi + makikomi,* 7. *osoto-gari,* and 8. *kouchi-gari.* The rank list of the point-winning techniques in male judo tournament '92 OG in Barcelona consisted of the following techniques: 1. *seoi-nage,* 2. *uchi-mata,* 3. *tani-otoshi,* 4. *ouchi-gari,* 5. *osoto-gari,* 6. *tomoe-nage,* 7. *tai-otshi,* and 8. *ura-nage.*

The following 14 throws, composing the sample of criterion variables, were evaluated[1]:

1. *ippon-seoi-nage* (ipp); 2. *morote-seoi-nage* (mor); 3. *tai-otoshi* (tai); 4. *te-guruma* (teg); *5. tsuri-goshi* (tsg); 6. *koshi-guruma* (kog); 7. *harai-goshi* (hag); 8. *uchi-mata* (ucm); 9. *de-ashi-barai* (dab); 10. *osoto-gari* (osg); 11. *ouchi-gari* (oug); 12. *kouchi-gari* (kcg); 13. *soto-makikomi* (stm), 14. *tomoe-nage* (tmn).

Five highly competent judo experts, holders of black belts and judo trainers with many years of experience in coaching, assessed the quality of performance of each throwing technique. Prior to the experiment, the judges reached the consensus on the evaluation criteria and together performed a trial assessment on a sample of students which were not included in the experiment. Simultaneously, they agreed on the most common errors and the weight classes in which they might occur and compromise the performance of the throwing techniques. The quality of a throw performance was evaluated on the classic scale from 0 to 5 according to the following criteria:

Grade 5 was given for a perfect performance or for a proper execution of a throwing technique (no technical errors noticed); in which power and speed applied were adequate with a good amplitude of flight.

Grade 4 was given for a throw that was not quite perfectly performed, from the technical point of view, nor it was performed with sufficient power or speed; the *uke* (the person receiving a throwing technique) did not attain a satisfactory flight amplitude, or the participant made a mistake in the proper technique execution, like the insufficient *kuzushi* (breaking balance), or improper *tsukuri* (assuming proper position for a throw and making the contact).

Grade 3 was awarded for a throw in which at least two mistakes were made, either in the technical or in the energy sense, or for a throw with insufficient flight amplitude, or for a throw in which all the three phases were not distinctly recognizable *(kuzushi, tsukuri,* and *kake).*

Grade 2 was awarded for a throw with an obvious mistake in execution. It implies evident omission or faulty execution of one out of the first two throwing phases (either *kuzushi* or *tsukuri),* or omission or improper execution of any segment of a throw; or that the thrower did not apply the needed speed or power because of which the *uke* did not attain the desired flight amplitude, but a throw is still recognisable because at least two phases of a throw (out of three: *kuzushi, tsukuri* or *kake)* were somehow performed.

Grade 1 was given for an unsatisfactory throwing performance, especially from the basic technical point of view. The participant did not meet the basic technical requirements: he performed a particular throw with insufficient speed and power, and the *uke* did not attain the desired flight amplitude. The examinee failed to properly execute two out of the three throwing phases.

Grade 0 was given for a completely faulty execution of a particular throw: all three phases were incorrectly performed at a too slow a speed and with a too little power applied, causing a too small an amplitude of flight. The performance could not be classified as a judo throw, so experts did not evaluate it at all.

Data analysis

The goal of the present research was to determine the magnitude and the direction of the relations of certain anthropometric variables in the latent space with the performance (bout outcomes)

[1]A detailed description of each throw can be found in Kudo, 1976b; Okano, 1989; Kano, 1994.

and the quality of throwing technique performance in judo. The multivariate approach to the issue solving was applied; therefore, the data analyses applied were also multivariate.

Multiple regression analysis was chosen as the basic method for determining the relations of anthropometry space with throwing technique performance quality in judo. Besides the already standardized anthropometric measures and motor tests, a quite new expert evaluation system was applied.

All the predictor and criterion variables were subjected to the standard statistical procedures. The following descriptive parameters were computed: mean (Mean), standard deviations (SD), the minimum (MIN) and the maximum (MAX) value of the results obtained, as well as the distribution coefficients of asymmetry (skewness) and peakedness (kurtosis). The latent space was determined by factor analysis under the model of principal components (Hotelling's method).

In Table 1, in which the latent space is treated, in the column Eigenvalues characteristic roots are displayed, which can be interpreted as the variances of dimensionalities defined as principal components.

Table 1: Eigenvalues and magnitude of the explained variance of anthropometric measures correlation matrix

Factor	Eigenvalue	% variance	Cumulative % var.
1	8.02076	44.6	44.6
2	3.49498	19.4	64.0
3	1.54161	8.6	72.5

In order to determine the significance of principal components, the Guttman-Kaiser criterion was used, according to which the significant component is the one with the variance; that is, with the characteristic root equal or greater than 1. Also, the partial (% variance) and the cumulative (cumulative % variance) contributions were calculated of particular factors to the total of explained variance, as well as the communalities of the variables (h^2). The final factor solution was obtained by means of OBLIMIN oblique rotation. The matrices of parallel projections (pattern matrix) and of orthogonal projections (structure matrix) were calculated, as well as the matrix of correlations between the obtained factors.

The relations between the manifest and latent anthropometric variables with judo throwing technique performance quality were determined by regression analysis.

RESULTS

Detailed analysis of descriptive statistical parameters (Table 2) of anthropometric variables indicates a fairly normal distribution of the applied anthropometric variables, except for the variable *upper leg circumference* (OPSNAT). The mentioned variable has higher *kurtosis* values, meaning the curve is pointed.

Table 2: Descriptive parameters of anthropometric variables

Variable	MEAN	MIN	MAX	SD	Skewness	Kurtosis
MASTIJ	76.31	56.80	104.80	8.44	0.52	0.46
VISTIJ	180.70	163.30	201.30	6.84	0.18	0.04
DUZNOG	101.40	90.30	115.00	5.17	0.14	-0.12
DUZRUK	78.79	71.10	86.90	3.25	0.00	-0.25
BIAKRAS	41.75	34.00	45.40	1.73	-0.56	2.31
BIKRIS	28.79	24.70	33.40	1.68	0.19	0.11
DIJLAK	7.09	6.50	7.80	0.32	0.03	-0.52
DIJKOL	9.74	8.70	11.00	0.42	-0.07	0.07
OPSNAD-O	30.57	26.10	38.50	2.06	0.72	1.54
OPSNAD-F	33.93	29.00	40.10	2.07	0.39	0.24
OPSPOD	27.65	24.80	31.20	1.37	0.35	-0.02
OPSNAT	56.82	35.50	67.90	3.92	-1.14	6.38
OPSPOT	38.17	33.10	45.90	2.07	0.37	0.93
NABLEĐ	9.48	6.00	17.47	2.34	1.24	1.60
NABNAD	9.05	3.83	19.87	2.88	1.03	1.39
NABPOD	5.85	3.00	10.17	1.42	0.74	0.35
NABTRB	11.90	4.83	31.77	5.61	1.30	1.43
NABPOT	7.07	3.40	16.23	2.36	1.03	1.54

Legend: MEAN – arithmetic mean, SD – standard deviation, MIN – the lowest value, MAX – the highest value, skewness – asymmetry, and kurtosis – peakedness of the results distribution

In order to precisely interpret the relations between the predictor group of anthropometric variables and the *judo in-place-throwing technique performance quality* criterion, in the further course of solving the investigation, a factor analysis was applied under the OBLIMIN rotation criterion, the role of which is to reduce the number of the predictor manifest variables to a smaller number of latent anthropometric dimensions. So, by means of factor analysis, eighteen anthropometric measures were reduced to three statistically significant latent dimensions (Table 2). In other words, three statistically significant characteristic roots were isolated; consequently, three significant principal components were obtained according to the Guttman-Kaiser criterion (all the components with eigenvalues equal to or greater than one were retained). The first principal component of anthropometric measures, the eigenvalue of which was 8.02, explained 44.6 % of the variance of total space.

Eigenvalues of the second principal component were 3.49, which explained 19.4 % of the variance of anthropometric measures, whereas the third principal component, eigenvalues of 1.54, explained 8.6 % of the variance of total space. With regard to the obtained values and the total percentage of the variance explained (72.5 %), it is possible to conclude that the three dimensions obtained thoroughly describe the space of anthropometry (Table 2).

Table 3: Factor anlysis of anthropometric variables

	Pattern			Structure			h^2
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	
MASTIJ	**.58**	.15	.49	.86	.45	.77	.94*
VISTIJ	.04	-.08	**.92**	.41	.06	.90	.86*
DUZNOG	-.01	.03	**.91**	.40	.14	.91	.82*
DUZRUK	-.02	-.13	**.97**	.33	-.02	.90	.83*
BIAKRAS	.14	-.04	**.63**	.40	.10	.69	.49*
BIKRIS	-.04	.04	**.77**	.31	.12	.76	.57*
DIJKOL	.10	.32	**.46**	.43	.42	.54	.43*
DIJLAK	**.46**	.11	.32	.65	.34	.54	.52*
OPSNAD-O	**.93**	.08	-.10	.92	.44	.32	.86*
OPSNAT	**.51**	.34	.27	.77	.58	.54	.73*
OPSNAD-F	**.90**	.00	-.08	.87	.36	.31	.76*
OPSPOD	**.85**	-.07	.14	.89	.30	.51	.81*
OPSPOT	**.77**	-.07	.08	.78	.26	.41	.62*
NABLEĐ	.28	**.71**	-.20	.48	.80	.00	.70*
NABNAD	-.11	**.95**	.02	.29	.91	.09	.84*
NABPOD	.02	**.87**	.05	.39	.88	.17	.78*
NABPOT	-.16	**.91**	.08	.24	.85	.13	.74*
NABTRB	.23	**.77**	-.15	.48	.84	.05	.76*

The greatest parallel and orthogonal projections on the first extracted factor are with the measures of body volume and mass; that is, all five circumference measures (OPSNAD-O, OPSNAT, OPSNAD-F, OPSPOD and OPSPOT) and *body weight* (MASTIJ). Therefore, this factor can be named: body volume and mass.

The second factor can be also easily interpreted due to the greatest projections of only "skinfolds", that is, the measures of subcutaneous fat tissue: NABLEĐ, NABNAD, NABPOD, NABPOT and NABTRB. The same variables established the highest correlations with that factor. Therefore, with great certainty, as demonstrated in certain previous research studies (Popović, 1985; Neljak, 1999), it can be interpreted as subcutaneous fat tissue.

The greatest parallel and orthogonal projections on the third extracted factor were obtained for the four measures of longitudinal body dimension: VISTIJ, DUZNOG, DUZRUK and BIAKRAS. Somewhat lower, but still satisfactory projections on the same factor were obtained for the two measures of traversal dimensions of skeleton: BIKRIS and DIJKOL. A moderately high projection of *body weight* on the third factor can be explained by the portion of the variance that includes bone-joint system. Since the measures of two hypothetical anthropometric dimensions have the greatest projections on the third factor, we shall name it the longitudinal and transversal body dimension, thus giving it a combined name while respecting the magnitude of relations and their hierarchical order.

The analysis of the relatedness of the predictor group of variables, consisting of 18 tests aimed at assessing anthropometric dimensions, with the criterion variable *judo in-place-throwing technique performance quality* (MOCJNM) is presented in Table 4.

Multiple correlations between the predictor group of variables, defined by the manifest anthropometric measures for assessing circular, transversal and longitudinal dimensions of the body and subcutaneous fat tissue, and the criterion variable, defined as *judo in-place-throwing technique performance quality* is .49 at the significance level of .05. Thus, 24 % of the variance of the criterion variable has been explained.

Table 4: Relations of stationary judo throwing technique performance quality with the manifest anthropometric variables

Criterion	R	R^2	F	p	df1	df2
MOCJNM	0.49	0.24	1.77	0.04	18	103

MOCJNM	B	SE B	BETA	T	p (BETA)
MASTIJ	0.02	0.04	0.17	0.47	0.64
VISTIJ	**-0.07**	**0.04**	**-0.48**	**-2.04**	**0.04**
DUZNOG	0.06	0.05	0.31	1.31	0.19
DUZRUK	-0.02	0.06	-0.07	-0.35	0.73
BIAKRO	-0.10	0.07	-0.16	-1.35	0.18
BIKRIS	-0.05	0.07	-0.08	-0.64	0.52
DIJLAK	0.19	0.43	0.06	0.43	0.67
DIJKOL	‘0.20	0.28	-0.09	-0.73	0.47
OPSNAD-O	**0.20**	**0.10**	**0.41**	**1.95**	**0.05**
OPSNAD-F	-0.10	0.08	-0.19	-1.17	0.24
OPPODL	0.09	0.13	0.12	0.69	0.50
OPNATK	-0.07	0.05	-0.25	-1.35	0.18
OPPOTK	0.04	0.07	0.07	0.54	0.59
ANABLED	-0.24	0.15	-0.24	-1.54	0.13
ANABNDL	-0.19	0.18	-0.19	-1.04	0.30
ANABPDL	0.27	0.17	0.27	1.62	0.11
ANABPOT	0.05	0.14	0.05	0.36	0.72
ANABTRB	-0.01	0.17	-0.01	-0.04	0.97

Legend: R – multiple correlation coefficient, R^2 - determination coefficient, F – f-value, p – multiple correlation coefficient significance level, B - standardized regression coefficient, SE B - standardized regression coefficient standard error, T – t-value, p(BETA) – regression coefficient significance level

Individual statistically significant contributions to the explanation of the criterion variable *judo in-place-throwing technique performance quality* were obtained only for two variables: *body height* (VISTIJ) and *extended upper arm circumference* (OPSNAD-O). The higher beta coefficient, but with a negative sign, was obtained for the variable body height (-.48), whereas the variable *extended upper arm circumference* has a somewhat lower value of beta coefficient (.41).

In Table 5, a regression analysis is presented for the relation between the group of latent anthropometric dimensions of the factors and the *judo in-place-throwing technique performance quality* criterion variable (MOCJNM). Multiple correlation coefficients between the predictor group of variables, defined by means of anthropometric factors of the assessed circular, transversal and longitudinal body dimensions and subcutaneous fat tissue, and the criterion variable, defined as the judo throwing technique in place performance quality, is .31 at the significance level of .01. The three latent anthropometric factors explained only a small 10 % of the variance of the *judo in-place-throwing technique performance quality* criterion variable.

A survey of the established individual relations of the latent anthropometric variables and the analysed criterion variable reveal that two factors (interpreted as *body volume and body mass* and *longitudinal and transversal body dimension)* realized a statistically significant individual contribution to the explanation of the *judo in-place-throwing technique performance quality* criterion variable variance. Both factors establish a statistically significant correlation at the level of .01. The factor defined as *body volume and body mass* established the positive relation with the criterion variable and partial contribution to the explanation of the criterion variable of .27. The factor of *longitudinal and transversal body dimension* has a somewhat higher but negative partial contribution to the explanation of the criterion variable (.33).

Table 5: Relations of stationary judo throwing technique performance quality with the latent anthropometric variables

Criterion	R	R^2	F	P	df1	df2
MOCJNM	**0.31**	**0.10**	**4.27**	**0.01**	18	103

MOCJNM	B	SE B	BETA	T	p (BETA)
ANTFAC1	0.27	0.11	0.27	2.57	0.01
ANTFAC2	-0.08	0.10	-0.08	-0.79	0.43
ANTFAC3	-0.33	0.10	-0.33	-3.35	0.01

DISCUSSION

The comparison of the central and dispersive parameters obtained in the present study with the results obtained in the previous research studies conducted on the population of the University of Zagreb students and on the previous generations of PE teacher students at the Faculty of PE (today the Faculty of Kinesiology) (Medved, Janković & Ivanek, 1992; Medved et al., 1992; Mišigoj-Duraković, Matković B.R. & Heimer, 1998) reveals a somewhat greater body mass in our sample.

In the comparison of the kinesiology students, the sample used in the present research with the PE students and the students of other faculties at the University in Zagreb, investigated in the research studies of Medved et al. (Medved, Janković & Ivanek, 1992; Medved et al., 1992) and of Mišigoj-Duraković et al. (1998), the former students are also somewhat heavier and have higher values of transversal dimensions – circumferences and skinfolds, and significantly higher values upper arm circumferences, in extension and flexion, whereas there were no differences in body height and elbow and knee diameters. The greater differences were registered between the sample of the present research and the other students of the University of Zagreb than between the actual and the former generations of PE and kinesiology students, respectively.

The negative influence of body height on the performance of a technique in place may be explained by a greater number of techniques in which a *tori* must perform a half squat or a squat, which is easier for a smaller person with strong legs than for a taller judoka. The smaller subjects had a shorter distance to cover in their lowering and rising up in all hip and certain arm techniques. Also, in taller persons forcing an opponent into a state of imbalance should be more powerful and accentuated than in smaller rivals, especially in the case where the *uke* is smaller. In that case, such types of errors later become multiplied and, therefore, much more noticeable. Further, mistakes in technique performances, even when executed very quickly, are more easily observed in tall judokas than in smaller ones. Therefore, that might be one of the reasons why the taller subjects got poorer grades of technique performance. It is also an additional explanation for the negative influence of body height on judo throwing techniques in place performance. An additional reason is the fact that smaller persons perform the arm, self-sacrifice and certain hip techniques better, easier and more harmoniously than extremely tall people. Furthermore, according to their performance structure a somewhat greater number of the utilized techniques, that is, criterion variables, were more appropriate for smaller than for taller students. Only the leg and certain hip techniques were better performed by taller subjects, which were also found in certain previous research studies (Sertić, 1993).

The positive relation between the variable *extended upper arm circumference* and *judo in-place-throwing technique performance quality* speaks in favour of the significant influence of the muscle mass of arms and shoulder girdle on the quality of performance of judo technique, under the condition that the upper arm circumference is understood as and equalized with the amount of muscle mass and physiological cross-section of a muscle. Powerful arms and shoulder girdle are welcome in the performance of throwing techniques in place because they facilitate interference with the opponent's balance and the establishment of firm contact and, consequently, a successful throw. Obviously, such subjects perform techniques with less coordination problems because they have met all the required prerequisites for a quality throw. In contrast, subjects with less powerful arms and shoulder girdles do not have sufficient prerequisites for a throw performance; therefore, they experienced coordination problems, their technique performance was discontinued and they had serious problems in the final phase of a throw. All that resulted in lower assessment grades.

The obtained positive, statistically significant influence of the entire analysed anthropometric space on the quality of judo in-place-throwing technique performance confirmed once again the findings of previous research (Franchini et al. 2005, Kuleš; 1990, 1996; Sertić, 1993) regarding the influence of anthropometric variables or just one anthropometric dimension on judo technique performance. Respecting the hierarchical sequence of the influence of manifest variables on the third factor, we can feasible conclude that the longitudinal dimension is predominant. Specifically, the longitudinal dimension is primarily responsible for the establishment of negative relation of the mentioned factor with the criterion of judo technique performance in place. The negative influence of the longitudinal dimension may be explained with the same reasons used in the explanation of the influence of the manifest variable *body height* on the same criterion variable. Poorer in-place-throwing technique performance in older judo novices can be explained with a somewhat poorer coordination ability in taller persons than in smaller ones, which interferes with new motor structures learning and mastering, but also with certain visual perceptive reasons. Specifically, in the persons with prominent longitudinal dimension it is easier, even in a very

quick motion performance, to notice motor errors, whereas in persons with shorter extremities and smaller body height these errors are less obvious.

The positive relation between the factor of body volume and body mass and the quality of the performance of judo technique in place can be explained with the definition of the factor which is primarily determined by circumferences, and only then by body weight. Respecting the age, gender and selectivity of the sample of the Faculty of Kinesiology students, we can conclude that muscular mass is in the background of the established relation. Similar results were obtained in the research study by Kubo and associates in 2006.

If we accept the inference that muscular mass is responsible for the relation of this factor with the criterion defined as the judo in-place-throwing technique performance quality, then in the sequence of movements that precede a throw, as well as in the final phase of flight, the role of strength and power must be accentuated. The extremely important role of strength and power is manifested in the first phase *(kuzushi)* of disbalancing the opponent, then in the second phase *(tsukuri)* when the body contact is established with *uke* and when a squat or a semi-squat is performed, as well as in the third phase of a throw performance *(kake),* when the opponent's foot is swept, or when he/she is lifted up by hips and simultaneously drawn down to the mat by the *tori's* strong arms.

The determined influence of the entire analysed anthropometric space on the quality of stationary throwing technique performance in judo is another confirmation of the findings of previous research studies (Kubo et al., 2006; Franchini at al., 2005; Kuleš, 1990, 1996; Sertić, 1993) obtained by means of both the multivariate and the univariate analyses of the relations between anthropometric dimensions and efficiency performance in judo.

CONCLUSION

The analysis of the relations of judo technique performance in place with the manifest and the latent anthropometric variables indicated diversity in the established relations. Between the manifest anthropometric variables and the criterion There is a statistically significant correlation (R = .49) between the manifest anthropometric variables and the criterion. Individual statistically significant contribution to the relation establishment between the manifest variables and the criterion a grade attained for the in-place-throwing technique performance quality was obtained for the variables body height (negatively) and upper arm circumference. The analysis of the relation of the latent anthropometric dimensions and the quality of technique performance in place revealed that a statistically significant correlation exists between them (R = .31).

In the latent anthropometric space, two factors out of the three isolated (interpreted as body volume and body mass, and longitudinal and transversal dimension of body) also contributed individually to the relations of latent anthropometric variables with the criterion of judo in-place-throwing technique performance quality.

From the obtained relations, the following emerged: somewhat smaller (not so tall) subjects, with relatively low centres of gravity, and the subjects with higher values of body volume and body mass (which represent the influence of muscular mass of arms and shoulder girdle) performed better in judo throwing technique performance.

The following conclusion emerged from the obtained results and discussion: anthropometric dimensions of a judoka are crucial for efficient throwing technique performance, in additional to his/her motivation and preferences for a particular throwing technique. Therefore, in the decision making process of which throwing technique to learn and adopt as a specialty (pet move), it is suggested to take into account not only judoka's preferences for a particular throw, but his/her anthropometric characteristics. In that way low competition effectiveness of the long and hard-to-train throws can be avoided.

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