MORPHOLOGICAL, FUNCTIONAL, AND DYNAMICAL ASYMMETRY IN FEMALE JUDOKAS

Saša Krstulović, Goran Kuvačić and Marko Erceg

Faculty of Kinesiology, University of Split, Croatia

Original scientific paper

Abstract

The aim of this paper was to determine the differences between elite and sub-elite female judokas in the level of morphological, functional and dynamical asymmetry. Twenty-eight female judokas (aged 21.0±2.3 yrs) were divided into two groups based on their competitive success (elite vs. sub-elite). Ten different test instruments for assessing morphological, functional and dynamical asymmetry were used: five morphological measures (wrist breadth (WB) and elbow breadth (EB), flexed arm girth (FAG) and forearm girth (FG), and triceps skinfold (TS)), two instruments for assessing handedness (Edinburgh Handedness Inventory (EHI) and Purdue Pegboard Test (PPT)), and three motor performance tests (maximum dynamometric force (MDF), maximum number of flexion on the grip machine (MNFG), and seated shot put (SSP). Each test was measured on both right and left side of the body. The coefficient of asymmetry was calculated based on the original results. To determine the differences in the level of morphological, functional and dynamical asymmetry between the elite and sub-elite judokas, Student's t-test for independent groups was applied. The biggest differences between the right and the left side of the body in all participants were recorded in the variable assessing functional asymmetry (EHI). Statistically significant differences in the coefficients of asymmetry between elite and sub-elite female judokas were recorded in only two variables assessing dynamical asymmetry (MDF and SSP).

Keywords: *anthropometry, handedness, motor abilities, combat sports.*

Introduction

Judo is an acyclic sport, in which competitive performance is determined by a combination of many factors, including different physical abilities (Franchini, Vecchio & Matsushigue, 2011; Kuvačić, Krstulović & Djapić Caput, 2017), as well as technical-tactical (Franchini, Sterkowicz, Meira Jr, Gomes, & Tani, 2008), and psychological aspects (Ziv & Lidor, 2013). The combat is dominated by complex motor movements in which the body is moved by different speed in different space planes with varying duration, without a tendency to repeat the same movements (Sterkowicz & Lech, 2007). Considering its structure, judo can be categorised as an "asymmetric" sport, in which the combat techniques are performed in certain direction, which dominantly engages the muscles of either left or right side of the body. The lateralization process starts with the simplest techniques in the very beginning of practising judo, until it reaches elite performance level of complex techniques on the preferred side of the body. Usually, the guard, so called *kumi kata*, determines the direction of technique performance to the left or to the right, and thereby also the dominant engagement of one side of the body.Definition of asymmetry is not unambiguous, and different authors offer different definitions. Jaszczak (2008) says there are three types of asymmetry in humans: a) morphological, b) functional, c) dynamical. Morphological asymmetry is manifested in the differences regarding girth, length, breadth, shape and proportion between the left and the right side of the body, and it can lead to reduction of an athlete's range of movement in certain joints (Grobbelaar & de Ridder, 2001). There have been many studies indicating the existence of morphological asymmetry in sport (Dorado, Sanchis Moysi, Vicente, Serrano, Rodriguez & Calbet, 2002; Tate, Williams, Barrance, & Buchanan, 2006; Krzykala, 2010), especially of the upper body (Tomkinson, Popović & Martin, 2003; Malina, Bouchard & Bar-Or, 2004; Auerbach & Ruff, 2006). Handedness, or manual asymmetry, can be defined as the preferential and more skilful use of one hand in relation to the other in motor activities, and it is considered the clearest example of lateralization of brain function in humans, i.e., functional asymmetry (Goble, Lewis & Brown, 2006). Lateralization of motor functions is a developmental process influenced by several factors, such as hemispheric specialisation of the brain, however, it seems that, as opposed to the morphological asymmetry, it occurs before sports engagement (Hepper, Shahidullah & White, 1991). The difference in strength and motor abilities in general, between the two sides of the body, is called dynamical asymmetry (Wieczorek & Hradzki, 2009). There have been numerous studies showing that strength asymmetry in the left or the right extremity can lead to injury (Croisier, Forthomme, Namurois, Vanderthommen & Crielaard, 2002; Noffal, 2003). However, only a few studies have investigated how bilateral asymmetry in strength affects sports performance. Previous studies have shown that motor and morphological characteristics are highly important in learning and improving different movement skills (Krstulović, Maleš, Žuvela, Erceg & Miletić, 2010), and that symmetric

exercises have a positive impact on motor skills of athletes involved in asymmetric sports (Rynkiewicz, Rynkiewicz, Żurek, Ziemann, & Szymanik, 2013). Practising complex sports skills on both sides of the body benefits performance, not only with the dominant but also with the non-dominant side of the body (Haaland & Hoff 2003; Teixeira, Silva & Carvalho, 2003). Thus, Dana (2009) confirmed that equal use of both left and right hand in handball significantly contributes to performance quality. Similar results for lower extremities were confirmed by Grouios, Kollias, Koidou & Poderi (2002), who established that good performance of specific motor tasks with both legs in soccer was an important factor for athletes' efficacy in the soccer game.

Therefore, it might be assumed that good motor performance by the left and right side of the body, i.e., ambidexterity, is directly related to success in certain sports. By reviewing the small number of previous studies dealing with this problem in judo, it can be observed that judokas, in general, are bilaterally symmetrical (Stradijot, Pittorru & Pinna, 2012), and that long-term judo training creates specific lateral preferences, probably due to neuroplasticity of the brain (Mikheev, Mohr, Afanasiev, Landis & Thut, 2002).

Accordingly, elite judokas should have a higher level of ambidexterity as opposed to the sub-elite, which allows them equally successful realisation of different techniques (especially throwing techniques) to both sides, but also an equally good reaction to attacks from the left-handed and right-handed alike. Therefore, the main aim of this paper was to determine the differences between elite and sub-elite female judokas in the level of morphological, functional, and dynamical asymmetry.

Methods

Participants

Twenty-eight female judokas (aged 21.0±2.3 yrs), younger seniors and seniors, gave their written informed consent to participate in this study after being informed of the procedures approved by the local ethics committee and in agreement with the Declaration of Helsinki (The Ethical Committee of the Faculty of Kinesiology, University of Split, Croatia (Chairperson Marko Erceg, Ph.D). To determine the differences in the level of morphological, functional and dynamical asymmetry between female judokas, the participants were divided into two groups based on their competitive success. The first group consisted of fourteen elite female competitors (body mass 62.1±9.7 kg, height 168.9±3.6 cm, judo practice 10.1±1.5 yrs), members of the Croatian national team and some of them European medal holders. The second group consisted of fourteen sub-elite female competitors (body mass 66.1±7.8 kg, height 170.3±4.1 cm, judo practice 9.2±1.7 yrs). They participated in the Croatian Senior National Championship in 2015, in which they were ranked from third to seventh place.

The inclusion criteria for participation in the study were: (1) regularly participating in previous competitive seasons, (2) having a valid sport medical certification, and (3) being healthy (no pain or injury) and clear of any drug consumption. Participants refrained from drinking alcohol or caffeine-containing beverages for 24 h and did not eat for 2-3 h before testing, to reduce any interference on the experiment.

Procedures

The testing was done for one day in the pre-competition period of the semi-annual training cycle (except for the newly-constructed test – seated shot put – which was performed on two occasions, 24 h apart, to determine the reliability of the test). All the participants were warned to avoid any physical strain 24 hours before the measuring, especially activities involving fist (hand) activities, to avoid accumulation of fatigue in that body part. All measurements were taken in the morning time. The testing order was the same for all the subjects: 1) variables assessing morphological asymmetry, 2) variables assessing functional asymmetry, 3) variables assessing dynamical asymmetry. To assess morphological asymmetry of female judokas, 5 morphological measures were taken on the left and the right side of the body: 1) wrist breadth (WB), 2) elbow breadth (EB), 3) flexed arm girth (FAG), 4) forearm girth (FG), 5) triceps skinfold (TS).

To assess functional asymmetry, 2 tests (short versions) determining the participants' handedness were applied. Handedness is not a one-dimensional characteristic and can be assessed by two factors: hand preference and hand performance or proficiency (Brown, Roy, Rohr, Snider & Bryden, 2004). To assess hand preference, the Edinburgh Handedness Inventory - EHI (Oldfield, 1971) was applied. To assess hand performance, a test of manual dexterity was applied – the Purdue Pegboard Test – PPT (Tiffin, 1948).

To assess dynamical asymmetry, three tests were applied: a) maximum dynamometric force (MDF) (Arslanoglu, 2015; Bootsikeaw, Chaikittiporn, Pulket, Singhakajen & Chentanez, 2012), b) maximum number of flexion on the grip machine (MNFG) (Kuvačić, Vrdoljak & Dražić, 2013), c) the newly-constructed test – seated shot put (SSP). A test of maximum dynamometric force (MDF) was used in evaluation of maximum forearm strength, using the Takei A5401 Japanese manufacturer digital dynamometer. Every participant had a task of generating as much force as possible by squeezing the right and left arm, separately. All three values were read off in kilograms, and the maximum value of the attempts was used in analysis. A maximum number of flexion on the grip machine test (MNFG) was conducted in the evaluation of the forearm muscular endurance. A steel Heavygrip 200 instrument was used in measuring the maximum number every repetition where a participant would press the instrument all the way to the end.

For the performance of the newly-constructed seated shot put - SSP test, a 3 kg-ball was used, ø 95 mm, manufactured by Polanik (Figure 1). In the initial position, a participant sits on an elevated bench, which is 45 cm high. One arm, by which the participant holds the ball, is flexed at chest height, while the other one is placed at the waist. The participant's task is to explosively shoot the ball with one hand as far as possible, not changing the initial position of other parts of the body while doing so.

Figure 1 Seated shot put.

Statistical analyses

Coefficients of asymmetry (CA) for all the variables, except for the EHI variable, were calculated based on the following equation:

$$CA = \frac{|valueoftherightlimb - valueoftheleftlimb|}{(valueoftherightlimb + valueoftheleftlimb)}$$

Based on the equation above, the direction of asymmetry was eliminated, and absolute values of the coefficient of asymmetry were obtained. The following descriptive statistical parameters were calculated: mean (M), standard deviation (SD), and coefficient of variation CV (%) of all the variables. The Kolmogorov-Smirnov test was applied to determine the normality of distribution. The reliability of the newly-constructed test (SSP) was analysed by applying the correlation analysis between two instances of measuring (test-retest). To determine the differences in the level of morphological, functional and dynamical asymmetry between the elite and sub-elite judokas, Student's t-test for independent groups was applied, and a 95% confidence interval for mean differences between groups was also presented. Additionally, to evaluate the magnitude of differences, the Cohen's effect size was calculated. Threshold values to effect size were <0.25 (trivial), 0.25 to 0.50 (small), 0.50 to 1.0 (moderate), >1.0 (large) (Rhea, 2004).

Results

The mean and standard deviations of all the applied tests are presented in Table 1. The testing of distribution normality was performed by Kolmogorov-Smirnov test. Analysis of distribution parameters indicates that the variables showed no significant deviations from the normal distribution (P>0.20). Coefficients of correlation between the two measurements (left r=0.89; right r=0.90) indicate the high reliability of the newly-constructed seated shot put (SSP) test.

Table 1 General descriptive characteristics of all applied tests.

variables		Elite (n=14)			Sub-elite (n=14)		
BREADTH (mm)	Wrist L	51.8	±	3.2	51.3	±	2.3
	Wrist R	52.5	±	3.0	51.5	±	2.3
	Elbow L	61.2	±	4.0	62.5	±	3.1
	Elbow R	61.7	±	4.5	62.5	±	3.6
GIRTH (mm)	Arm, flexed L	325.6	±	36.6	312.6	±	21.3
	Arm, flexed R	324.0	±	35.4	316.0	±	20.8
	Forearm L	260.4	±	23.5	255.1	±	10.9
	Forearm R	261.5	±	21.7	253.5	±	10.2
SKINFOLD (mm)	Triceps L	14.8	±	7.6	15.5	±	5.1
	Triceps R	14.7	±	7.4	15.3	±	4.9
EHI (n)	Left hand	3.9	±	2.0	6.00	±	4.1
	Right hand	12.5	±	3.3	11.5	±	3.7
PPT (n)	Left hand	14.4	±	1.2	15.8	±	2.1
	Right hand	14.7	±	1.9	15.2	±	2.4
MDF (kg)	Left hand	34.3	±	8.9	33.1	±	4.7
	Right hand	35.6	±	9.2	34.8	±	5.0
MNFG (n)	Left hand	11.5	±	12.0	8.5	±	4.7
	Right hand	14.0	±	11.0	13.1	±	6.8
SSP (m)	Left hand	3.6	±	0.6	3.2	±	0.4
	Right hand	4.0	±	0.7	3.3	±	0.5

Legend: EHI - Edinburgh Handedness Inventory, PPT - Perdue Pegboard Test, MDF - maximum dynamometric force, MNFG - maximum number of flexion on the grip machine, SSP- seated shot put, elite - more successful female judokas, sub-elite - less successful female judokas. Data are expressed as mean (M) ± SD (standard deviation). Measurements are presented in mm millimeters, n number, kg kilograms, m meters.

The biggest differences between the right and the left side of the body (Table 2.)in both subsamples were recorded in the variables EHI (elite r=8.6, 51.7% vs. sub-elite r=7.6, 41.4%), and MNFG (elite r=4.6, 25.3% vs. sub-elite r=4.9, 22.7%). Statistically significant differences between the elite and sub-elite female judokas were found only in two of the ten coefficients of asymmetry (MDF t=2.28, ES=1.0, 95%CI=0.02 to 0.038 and SSP t=-3.44, ES=1.5, 95%CI=-0.054 to -0.013). Thus, statistically significant differences were found only in coefficients of asymmetry in the variables assessing dynamical asymmetry, i.e., in tests assessing maximum dynamometric force and power. In the MDF test, sub-elite judokas exhibited a higher level of asymmetry, whereas, in the SSP test, elite judokas exhibited a higher level of asymmetry. The magnitude of differences (ES) for FAG was moderate (0.6), but not statistically significant.

Table 2 Differences in coefficients of asymmetry.

CA	Elite					Sub-elite					t	ES	95%CI
	m	±	SD	r	%	m	±	SD	r	%			
WB	0.009	±	0.008	0,9	0,9	0.011	±	0.008	1,2	1,1	0,77	0.3[b]	-0.005 to 0.10
EB	0.007	±	0.008	0,9	0,7	0.013	±	0.022	1,6	1,3	-0,82	0.4[b]	-0.009 to 0.021
FAG	0.012	±	0.009	7,3	1,2	0.007	±	0.007	4.3	0,7	-1,35	0.6[c]	-0.12 to 0.003
AG	0.004	±	0.005	1,9	0,4	0.007	±	0.008	3,7	0,7	1,19	0.4[b]	-0.003 to 0.009
TS	0.016	±	0.015	0,4	1,6	0.014	±	0.016	0,4	1,6	-0,22	0.1[a]	-0.015 to 0.012
EHI	0.517	±	0.215	8,6	51,7	0.414	±	0.432	7,6	41,4	-0,71	0.3[b]	-0.407 to 0.200
PPT	0.063	±	0.056	1,8	6,3	0.069	±	0.066	2,1	6,9	0,22	0.1[a]	-0.049 to 0.060
MDF	0.029	±	0.023	2,0	2,9	0.049	±	0.018	3,3	4,9	2.28*	1.0[d]	0.02 to 0.038
MNFG	0.253	±	0.158	4,6	25,3	0.227	±	0.139	4,9	22,7	-0,41	0.1[a]	-0.159 to 0.107
SSP	0.058	±	0.025	0,5	5,8	0.024	±	0.021	0,2	2,4	-3.44*	1.5[d]	-0.054 to -0.013

Legend: CA- coefficient of asymmetry, WB - wrist breadth, EB - elbow breadth, FAG - Flexed arm girth, AG - arm girth, EHI - Edinburgh Handedness Inventory, PPT - Perdue Pegboard Test, MDF - maximum dynamometric force, MNFG - maximum number of flexion on the grip machine, SSP- seated shot put, elite - more successful female judokas, sub-elite - less successful female judokas, r - difference between left and right side, % - difference expressed in percentage, t - Student's test of differences; ES - effect size, [a] trivial, [b] small, [c] moderate , [d] large, *p<0.05; 95%CI - confidence interval of 95% for mean differences between groups. Data are expressed as mean (M) ± SD (standard deviation).

Discussion and conclusion

The main findings of the present study were that: a) the biggest differences between the right and the left side of the body in all participants were recorded in the variable assessing functional asymmetry (EHI); b) reliability of the newly-constructed test assessing explosive power of the arms showed to be satisfactory; c) there were no significant differences found between the observed groups of subjects in variables assessing morphological and functional asymmetry, which is explained by insufficiently sensitive tests for assessing morphological dimensions and comparable inappropriate test for assessing functional asymmetry in a sample of athletes – judokas; d) statistically significant differences in coefficients of asymmetry between elite and sub-elite female judokas were obtained only in the two variables assessing dynamical asymmetry (MDF and SSP).The results in Table 2 suggest there was no significant difference in coefficients for assessing morphological asymmetry between elite and sub-elite female judokas.

Previous studies have shown that even everyday activities (the tendency for greater functional use of dominant extremity in relation to the non-dominant) may be the factor which would lead to morphological asymmetry (Roy, Ruff & Plato, 1994; Steele & Mays, 1995). Moreover, in asymmetrical sports disciplines, development of a certain level of morphological asymmetry often occurs due to physical and neurological demands of the locomotor apparatus of the dominant extremity in relation to the non-dominant, which can even lead to ossification of some parts of the body in elite athletes (Krzykała, 2012). However, there were no significant asymmetries in morphological variables recorded among the participants in this study. Namely, descriptive indicators point to a relatively low level of asymmetry in morphological variables in both groups of female judokas (from 0.4 % to 1.6 % in elite judokas, i.e., from 0.7 % to 1.6 % in sub-elite judokas). Some of the previous studies have confirmed that there is no significant correlation between morphological dimensions and judo combat success, which is ascribed to the very similar anthropometric structure of judokas in each weight category. Briefly, in judo, the athletes are divided into weight-categories, implying that the variance of the anthropometric status in the single weight category is particularly contracted. It does not allow for any calculation of the significant correlation between the anthropometric variables and judo achievement, and therefore does not allow significant differentiation of the successful and less successful judokas in the anthropometric status (Krstulović, Sekulić, & Sertić, 2005).

Handedness, assessed by the EHI test, cannot be generalised, rather it should be viewed as a specific arm skill, i.e., a type of motor task (Dopico-Calvo, Iglesias-Soler, Morenilla, Giraldez, Santos & Arda, 2016). Thus, it is not rare that a judoka who prefers left grip in a fight also favours the use of right hand when performing some other motor task. In other words, left preference for sports tasks does not necessarily indicate the preference of the left hand in everyday activities, such as writing (Loffing, Sölter, & Hagemann, 2014). Descriptive parameters of the EHI test (Table 1) indicate a distinct right preference in everyday activities in all participants. However, regardless of the right-hand preference in daily activities, 28% of the overall participants preferred left grip of judogi. Left-hand or right-hand preference may occur due to sensory-motoric experience, environmental influence, genetics, or cultural influence (Corballis, 2003; Corbetta & Thelen, 2002). However, the view that hand preference dominantly has its roots in genetics and is manifested early in childhood still prevails (Corballis, Badzakova-Trajkov, & Häberling, 2012).

This fact could explain the lack of differentiation between the two analysed groups of participants in the test, and lead to the conclusion that in this research sports engagement had no significant influence on hand preference. The other factor of hand dexterity is hand proficiency, i.e., the level of manual dexterity and it was assessed by PPT test. For the purposes of this study, two components of the test were applied. The test was performed separately by left hand and right hand, and then by a mathematical equation, the coefficient of asymmetry was calculated, i.e., the difference in fine motor skills between the left and the right hand. By examining the descriptive parameters of the PPT test, it is evident that a relatively low value of asymmetry between the right and the left hand (elite 6.3 % vs. sub-elite 6.9 %) prevailed in both subsamples (as opposed to the EHI test).

Hand dexterity is multidimensional, and these types of tests measure only one aspect of manual dexterity (e.g., speed or accuracy) and the differences in performing such tasks between the right and the left hand are often small (Roy, Bryden & Cavill, 2003). More complex tasks result in greater differentiation in performance between the left and the right hand, in relation to the less complex tasks (Bryden, Roy, Rohr & Egilo, 2007). The fact is that judo elements are very complex and are performed by engaging major muscles and muscle groups. On the other hand, the PPT test is performed dominantly by minor muscles and muscle groups of the forearm, so this is likely the reason why female judokas were not differentiated in the said variable. Of all the variables assessing dynamical asymmetry, ultimately the highest differences between the right and the left side of the body in both subsamples were obtained in the variable MNFG (elite 25.3% vs. sub-elite 22.7%). It is well known that training dominated by the load on one side of the body may lead to bilateral imbalance, i.e., muscle strength imbalances of the opposite sides of the body (Newton, Gerber, Nimphius, Shim, Doan, Robertson & Kraemer, 2006). In the observed sample, this muscle imbalance is obviously most manifested in muscle endurance. As opposed to the variables assessing morphological and functional asymmetry, statistically, significant differences were found between elite and sub-elite female judokas in the coefficients of asymmetry of the two variables assessing dynamical asymmetry. In both variables (MDF and SSP), elite judokas on average achieved better results in comparison to the sub-elite judokas (Table 1). However, in the MDF test, the sub-elite judokas exhibited the higher level of asymmetry, whereas, in the SSP test, the elite judokas exhibited the higher level of asymmetry. Even though the participants in this study were healthy and free of injury during the testing, data on topology, causes and types of injuries during the whole career had not been collected. Precisely these data would be valuable for determining the reason for the obtained asymmetries, as it is known that muscle imbalance, which is manifested through asymmetry in muscle strength, is often the reason for injuries in judo (Croisier, 2004). Therefore, in future research, those variables should be considered when drawing relevant conclusions. Moreover, considering the differences in the applied anthropometric variables between the left and the right side of the body were very small, in future research, it would be advised to use more sensitive devices (e. g., Dual-energy X-ray absorptiometry - DXA, Magnetic resonance imaging - MRI, Computed Tomography - CT).

References

Arslanoglu, E. (2015). Physical profiles of Turkish young Greco-Roman wrestlers. *Educational Research and Reviews*, *10*(8), 1034-1038.

Auerbach, B.M., & Ruff, C.B. (2006). Limb bone bilateral asymmetry: variability and commonality among modern humans. *Journal of Human Evolution*, *50*(2), 203-218.

Bootsikeaw, S., Chaikittiporn, C., Pulket, C., Singhakajen, V., & Chentanez, T. (2012). Hand muscle strength and hand dexterity after exposure to hand and arm from grinder vibration among grinding workers. *Journal of Sports Science and Technology*, *12*(1), 11-32.

Brown, S.G., Roy, E.A., Rohr, L.E., Snider, B.R., & Bryden, P.J. (2004). Preference and performance measures of handedness. *Brain and Cognition*, *55*(2), 283-285.

Bryden, P.J., Roy, E.A., Rohr, L.E., & Egilo, S. (2007). Task demands affect manual asymmetries in pegboard performance. *Laterality*, *12*(4), 364-377.

Corballis, M.C. (2003). From mouth to hand: gesture, speech, and the evolution of right-handedness. *Behavioral and Brain Sciences*, *26*(2), 199-208.

Corballis, M.C., Badzakova-Trajkov, G., & Häberling, I.S. (2012). Right hand, left brain: genetic and evolutionary bases of cerebral asymmetries for language and manual action. *Wiley Interdisciplinary Reviews: Cognitive Science*, *3*(1), 1-17.

Corbetta, D., & Thelen, E. (2002). Behavioral fluctuations and the development of manual asymmetries in infancy: contributions of the dynamic systems approach. *Handbook of Neuropsychology*, *8*(1), 311-330.

Croisier, J.L. (2004). Muscular imbalance and acute lower extremity muscle injuries in sport. *International SportMed Journal*, *5*(3), 169-176.

Croisier, J.L., Forthomme, B., Namurois, M.H., Vanderthommen, M., & Crielaard, J.M. (2002). Hamstring muscle strain recurrence and strength performance disorders. *American J of Sports Med*, *30*(2), 199-203.

Dana, B. (2009). The role of symmetrization in the game of handball. *Ovidius University Annals, Series Physical Education & Sport/Science, Movement & Health*, *9*(2), 189-191

Dopico-Calvo, X., Iglesias-Soler, E., Morenilla, L. Giraldez, A.M., Santos, L., & Arda, A. (2016). Laterality and performance in combat sports. *Archives of Budo*, *12*, 167-177.

Dorado, C., Sanchis Moysi, J., Vicente, G., Serrano, J.A., Rodriguez, L.R., & Calbet, J.A. (2002). Bone mass, bone mineral density and muscle mass in professional golfers. *Journal of Sports Sciences*, *20*(8), 591-597.

Franchini, E., Sterkowicz, S., Meira Jr, C.M., Gomes, F.R.F., & Tani, G. (2008). Technical variation in a sample of high level judo players. *Perceptual and Motor Skills*, *106*(3), 859-869.

Franchini, E., Vecchio, F.D., & Matsushigue, K. (2011). Physiological profiles of elite judo athletes. *Sports Medicine*, *41*(2), 147-166.

Goble, D., Lewis, C., & Brown, S. (2006). Upper limb asymmetries in the utilization of proprioceptive feedback. *Experimental Brain Research*, *168*(1-2), 307-311.

Grobbelaar H.W. & de Ridder J.H. (2001). Asymmetry in the upper body of high school fast bowlers in cricket in South Africa. *African Journal for Physical, Health Education, Recreation and Dance*, *7*(1), 61-76.

Grouios, G., Kollias, N., Koidou, F., & Poderi, A. (2002). Excess of mixed-footedness among professional soccer players. *Perceptual and Motor Skills*, *94*(2), 695-699.

Haaland, E., & Hoff, J. (2003). Non-dominant leg training improves the bilateral motor performance of soccer players. *Scandinavian Journal of Medicine & Science in Sports*, *13*(3), 179-184.

Hepper, P.G., Shahidullah, S., & White, R. (1991). Handedness in the human fetus. *Neuropsychologia*, *29*(11), 1107-1111.

Jaszczak, M. (2008). The Dynamical Asymmetry of the Upper Extremities During Symmetrical Exercises. *Human Movement*, *9*(2), 116-120.

Krstulović, S., Maleš, B., Žuvela, F., Erceg, M., & Miletić, Đ. (2010). Judo, soccer and track-and-field differential effects on some anthropological characteristics in seven-year-old boys. *Kinesiology*, *42*(1), 56-64.

Krstulović, S., Sekulić, D., & Sertić, H. (2005). Anthropological determinants of success in young judoists. *Collegium antropologicum*, *29*(2), 697-703.

Krzykala, M. (2010). Dual Energy X-Ray Absorptiometry in Morphological Asymmetry Assessment among Field Hockey Players. *Journal of Human Kinetics*, *25*, 77-84.

Krzykała, M. (2012). *Dual Energy X-Ray Absorptiometry.* Rijeka: InTech.

Kuvačić, G., Krstulović, S., & Caput, P. (2017). Factors Determining Success in Youth Judokas. *Journal of Human Kinetics*, *56*(1), 207-217.

Kuvačić, G., Vrdoljak, J., Dražić, M. (2013). Relations between some types of forearm strength in kinesiology students. *International Journal of Scientific Issues in Physical Eduction, Sport and Health*, *2*(1), 89-94.

Loffing, F., Sölter, F., & Hagemann, N. (2014). Left preference for sport tasks does not necessarily indicate left-handedness: sport-specific lateral preferences, relationship with handedness and implications for laterality research in behavioural sciences. *PloS one*, *9*(8).

Malina, R.M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity*. New York: Human Kinetics.

Mikheev, M., Mohr, C., Afanasiev, S., Landis, T., & Thut, G. (2002). Motor control and cerebral hemispheric specialization in highly qualified judo wrestlers. *Neuropsychologia*, *40*(8), 1209-1219.

Newton, R.U., Gerber, A., Nimphius, S., Shim, J.K., Doan, B.K., Robertson, M., &Kraemer, W.J. (2006). Determination of functional strength imbalance of the lower extremities. *Journal of Strength & Conditioning Research*, *20*(4), 971-977.

Noffal, G.J. (2003). Isokinetic eccentric-to-concentric strength ratios of the shoulder rotator muscles in throwers and nonthrowers. *American Journal of Sports Medicine,31*(4), 537-541.

Oldfield, R.C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*(1), 97-113.

Rhea, M.R. (2004). Determining the magnitude of treatment effects in strength training research through the use of the effect size. *Journal of Strength & Conditioning Research*, *18*(4), 918-920.

Roy, E.A., Bryden, P.J., & Cavill, S. (2003). Hand differences in pegboard performance through development. Brain and Cognition, *53*(2), 315-317.

Roy, T.A., Ruff, C.B., & Plato, C.C. (1994). Hand dominance and bilateral asymmetry in the structure of the second metacarpal. *American Journal of Physical Anthropology*, *94*(2), 203-211.

Rynkiewicz, M., Rynkiewicz, T., Żurek, P., Ziemann, E., & Szymanik, R. (2013). Asymmetry of muscle mass distribution in tennis players. *Trends in Sport Sciences*, *20*(1), 47-53.

Steele, J., & Mays, S. (1995). Handedness and directional asymmetry in the long bones of the human upper limb. *International Journal of Osteoarchaeology*, *5*(1), 39-49.

Sterkowicz, S., & Lech, G. (2007). The course of fight and the level of sports achievements in judo. *Archives of Budo*, *3,* 72-81.

Stradijot, F., Pittorru, G.M., & Pinna, M. (2012). The functional evaluation of lower limb symmetry in a group of young elite judo and wrestling athletes. *Isokinetics and Exercise Science*, *20*(1), 13-16.

Tate, C.M., Williams, G.N., Barrance, P.J., & Buchanan, T.S. (2006). Lower extremity muscle morphology in young athletes: An MRI-based analysis. *Medicine and Science in Sports and Exercise*, *38*(1), 122-128.

Teixeira, L.A., Silva, M.V., & Carvalho, M. (2003). Reduction of lateral asymmetries in dribbling: the role of bilateral practice. *Laterality*, *8*(1), 53-65.

Tiffin, J. (1948). *Purdue pegboard test*. Chicago: Science Research.

Tomkinson, G.R., Popović, N., & Martin, M. (2003). Bilateral symmetry and the competitive standard attained in elite and sub-elite sport. *Journal of Sports Sciences*, *21*(3), 201-211.

Wieczorek, M., & Hradzki, A. (2009). Functional and dynamic asymmetry in youth aged 14 and 16 years (comparative research). *Acta Gymnica*, *37*(1), 51-61.

Ziv, G., & Lidor, R. (2013). Psychological preparation of competitive judokas–A Review. *Journal of Sports Science & Medicine*, *12*(3), 371-380.

MORFOLOŠKA, FUNKCIONALNA I DINAMIČKA ASIMETRIJA KOD JUDAŠICA

Sažetak

Cilj ovog rada bio je utvrditi razlike između uspješnih i manje uspješnih judašica u stupnju morfološke, funkcionalne i dinamičke asimetrije. Dvadeset i osam judašica (21,0 ± 2,3 god.) podijeljeno je u dvije skupine temeljem njihovog natjecateljskog uspjeha (uspješne i manje uspješne). Korišteno je deset različitih testova za procjenu morfološke, funkcionalne i dinamičke asimetrije: pet morfoloških mjera (dijametar ručnog zgloba (ADRZ), dijametar lakta (ADL), opseg nadlaktica u fleksiji i kontrakciji (AONF), opseg podlaktica (AOP), te kožni nabor podlaktica (AKNP), dva testa za procjenu funkcionalne asimetrije Edinburgh Handedness Inventory (EHI) i Perdue Pegboard Test (PPT) i tri motorička testa (maksimalna dinamometrijska sila ruke (MMDS), maksimalni broj fleksija šake na grip spravi (MMFG) i bacanje kugle iz sjedećeg stava (MBK). Svaki od testova izmjeren je na lijevoj i desnoj strani tijela. Temeljem originalnih rezultata, izračunat je koeficijent asimetrije. Da bi se utvrdile razlike u stupnju asimetrije između dviju skupina ispitanica primijenjen je T - test za nezavisne uzorke. Najveće razlike između desne i lijeve strane tijela kod svih ispitanica dobivene su u varijabli za procjenu funkcionalne asimetrije (EHI). Statistički značajne razlike u koeficijentima asimetrije između uspješnih i manje uspješnih judašica dobivene su samo u dvije varijable za procjenu dinamičke asimetrije (MMDS i MBK).

Ključne riječi: *antropometrija, ljevorukost-desnorukost, motoričke sposobnosti, borilački sport.*

Received: July 27, 2017
Accepted: August 16, 2017
Correspondence to:
Saša Krstulović, Ph.D.
Faculty of Kinesiology
University of Split
Email: sasa@kifst.hr