Influence of maximal anaerobic performance on body posture stability in elite senior and junior male judo athletes

Lucia Mala[ABDE], Tomas Maly[ACD], Frantisek Zahalka[AB]

Charles University in Prague, Faculty of Physical Education and Sport, Czech Republic

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Received: 17 February 2016; **Accepted:** 15 April 2016; **Published online:** 09 May 2016

AoBID: 10959

Abstract

Background & Study Aim: The ability to maintain postural stability under the variable conditions of *randori* and during judo tournaments is one of the most important determinants of a judoka´s performance. The aim of this study was to answer the question whether under the maximal anaerobic performance followed there are changes of postural stability (PS) among elite junior and senior male judo athletes. If so, whether the differences concern both visual control and then limb preference and the type of the test used.

Material & Methods: Nineteen judo athletes (9 junior, 10 senior category) were tested. The multi-sensorial platform was used for posturographic examination. Anaerobic variables were detected using the Wingate test with a Monark 824E mechanical ergometer.

Results: Senior judo athletes achieved significantly better values of PS in comparison to juniors ($F_{(1,34)} = 11.24$, $p = 0.00$, $\eta^2 = 0.25$). In the one leg stance test, both groups produced significantly higher values than in the bipedal test ($F_{(1,72)} = 159.81$, $p = 0.000$, $\eta^2 = 0.69$). In the monitored groups, we found a significant effect of the physical load in the bipedal test ($F_{(1,34)} = 19.56$, $p = 0.00$, $\eta^2 = 0.37$), as well as in the one limb test ($F_{(1,34)} = 49.03$, $p = 0.00$, $\eta^2 = 0.59$). Changes in PS after exercise are manifested more in the non-preferred limb than in the preferred one.

Conclusions: The effect of maximal anaerobic exercise applied in our study was reflected in both senior and junior participants. Adult athletes appeared to have significantly better postural stability in comparison to juniors.

Keywords: combat sports • physical performance • training and testing • visual control • balance training • *randori*

Conflict of interest: Authors have declared that no competing interest exists

Ethical approval: The research was approved by UK FTVS Ethics Committee

Provenance & peer review: Not commissioned; externally peer reviewed

Source of support: This research was supported by GACR 16-21791S and Programme for Development of Fields of Study at Charles University, no. P38 Biological aspects of the investigation of human movement.

Author's address: Lucia Mala, Faculty of Physical Education and Sport, Charles University in Prague, José Martího 31, 162 52 Prague, Czech Republic; lucilali@yahoo.de

Body postural stability – ability to maintain balance and compensate for deviations from external factors, which are important in judo and randori.

Anaerobic variables – variables determining a judo athlete's anaerobic capacity (peak power, mean power, and fatigue index).

Ashi-waza – sub classification (leg techniques) of throwing techniques in judo.

Dan (dan'i) – a term used to denote one's technical level or grade [38].

***Randori* –** a match controlled by judo rules.

Preferred leg – a preferred standing leg during the ashi-waza throwing techniques in judo.

Introduction

Judo is a dynamic and complex sport in which many variables, such as technical as well as tactical, physiological, and psychological factors, determine the final result [1]. If we consider sport performance in judo to be a complex of separate operating components, athletes have to possess or develop a variety of muscular qualities, such as endurance, strength, stretch, flexibility and speed. These qualities are enhanced and/or acquired through intensive training. They also condition the athlete's motor skill level, which determines the aptitude of the sportsman to reach his maximal physical potential at the right time [2].

During judo *randori*, the ability to throw the opponent onto tatami mats depends on the synchronisation of the muscular and nervous system apparatuses. During *randori*, each judo athlete learns to use unstable dynamic situations to turn them to his advantage [3]. All muscular, articular and cutaneous mechanoreceptors are stimulated because of the constant modifications of posture, support, ground and partner contact, articular angles, joint positions, muscular tensile strength and spindle activity. This rigorous posture control is crucial for the precision and efficiency of judo-specific techniques and therefore depends heavily on proprioceptive afferent performance [2]. It is very important for a judo athlete during the *randori* to regain disrupted stability because the foundation for dynamic balance is an excellent level of static balance. Standing posture is a complex system that involves maintenance of the relative positions of body segments. The use of numerous muscles and the integration of different sensorial inputs (visual, vestibular, proprioceptive) is a part of the complexity of this system.

The importance of postural stability for judo performance, i.e., for combat sports, has been emphasized in a number of studies. Cesari and Bertuco [4] examined the relationship between postural stability and success in karate. They reported that elite karate athletes are able to apply efficient motor strategies in order to keep their body stable while applying huge amount of force. Perrot et al. [2] examined the influence of trauma induced by judo practice on postural control. They concluded that previously injured judoist achieved the best performances in maintaining proper balance. This performance shows that athletes after injured developed sensory and cognitive abilities with compensation of a new patterns for balance control. Mickheev et al. [5] investigated motor control and cerebral hemispheric specialization in highly qualified judo wrestlers. They reported that during long-term judo training, motor and postural skill acquisitions lateral preferences are modified, probably clue to neuroplasticity. Barrault et al. [3], Mesure et al. [6] and Perrin et al. [7] reported on the importance of a judo athletes' reaction to proprioceptive signals. The authors found that judo athletes have better balance performance than dancers and suggested that this was the result of the high level sensorimotor adaptation of the judo athletes. In addition, a judo athletes nervous system acts effectively to maintain balance by organizing postural patterns and strategies with the available proprioceptive information. Paillard et al. [8] examined the relationship between the direction of fall and certain indicators of the judokas' postural activities (static and dynamic). Authors reported that average posture of anteroposterior dynamic oscillations was inversely related to the judokas' direction of fall.

In view of the necessity to maintain balance during *randori* and the consequences of sustaining injuries or losing points from falls during competitions, it is important to examine the role that sensory inputs play on balance performance in people with judo training to guide the training method to improve their postural balance and to prevent injuries.

The aim of this study was to answer the question whether under the maximal anaerobic performance followed there are changes of postural stability (PS) among elite junior and senior male judo athletes. If so, whether the differences concern both visual control and then limb preference and the type of the test used.

Material and methods

Subjects

We tested 10 elite senior male judokas and 9 elite junior male judokas, all of whom are members of the Czech national team. All participants practise judo at an elite level, participate in international A category tournaments and have even won medals. The screened sample consisted of a junior world champion, the winner of the Judo Grand Slam Paris and the 2013 Kano Cup, the 2014 junior world champion, the 2014 senior world champion, the 2013 and 2014 European champion and other medallists who placed from 1st to 5th place in European and world tournaments. All participants had practised judo for at least 10 calendar years and had attained a level of competency between the 1st and 3rd dan. Concerning the sport training periodization, the research was carried out at the beginning of the competition period. The volume of the load in the preparatory period in the monitored groups is 720-1200 min in senior and 600 min in the junior category, i.e., 60 to 80 tournaments in senior and 40 to 50 tournaments in the junior category during the competition period. Basic anthropometric characteristics (average age, average body weight, average body height, fat mass, fat free mass) are listed in Table 1.

Procedures

Anthropometric assessment

Body height was measured using a digital stadiometer (SECA 242, Hamburg, Germany), and body weight was assessed using a digital scale (SECA 769, Hamburg, Germany). To determine whole-body bioimpedance, we used a BIA 2000M multi-frequency bioimpedance analyser (Data Input GmbH, Germany). The standardized conditions of bioimpedance measurement were met [9]. The blood lactate concentration was set electrochemically using a Biovendor Super GL device before the physical load and in the fifth minute of recovery.

Postural stability. The multi-sensoric FOOTSCAN platform (RS scan; Belgium; 0,5 m x 0,4 m; approximately 4100 sensors; sensitivity from 0.1 of $N*cm^{-2}$; sampling frequency 500 Hz) was used for the posturographic examination. Pressure on individual sensors was measured, and the centre of pressure (COP) was calculated on the contact area. Resulting force reacting to the ground is calculated from pressure and contact area under both feet by the equation (1):

$$F = p * S \quad (1)$$

where: F is reacting force [N], p is pressure [Pa], S is area [m^2]) and this force is called centre of force (COF).

Testing of stability was composed of 3 partial tests (wide stance with visual control lasting for 30 s and flamingo stance on the preferred and non-preferred leg for 60 s). The preferred leg was set as a standing leg during the *ashi-waza* throwing techniques in judo. Stability was measured before and immediately after physical load in the above-mentioned order of the tests. During the measurements, participants stood at a distance of 3 metres from a wall on which a visual point (a black circle with a diameter of 3 cm) was located at the level of the participant's eyes. The standard standing position (vertical posture) with a wide base was measured according to standard practice [10], and transparent sheeting for the tracing foot position was used during the examination. We measured (recorded, monitored) the entire course of total travelled way (TTW) of COP.

Anaerobic performance assessment

Load in the form of the anaerobic Wingate test was performed on a Monark 824E modified mechanical ergometer. A standardized warm-up [11] load, i.e., braking torque, of 6 $W*kg^{-1}$ was applied (at frequency of 60 rpm), which in a Monark mechanical ergometer represents a load of 0.106 $kg*kg^{-1}$ of the participant's body weight. This braking resistance corresponds to the requirements of optimizing conditions to achieve the highest possible mechanical performance from the perspective of speed and power according to the fitness level of the examined population [12].

The research was approved by the Ethical Committee of the Faculty of Physical Education

Table 1. Basic somatometric characteristics of the screened sample.

Variable	Senior (n = 10)		Junior (n = 9)	
	x	SD	x	SD
Age (years)	22.41	2.88	17.13	1.79
Body height (cm)	185.04	7.93	177.54	7.77
Body mass (kg)	85.67	11.01	72.25	13.91
FM (%)	13.75	28.79	14.08	29.91
FFM (kg)	73.89	7.84	62.08	9.75

FM fat mass, **FFM** absolute value of fat free mass, **x** arithmetic mean, **SD** standard deviation and Sports at Charles University in Prague. Measurements were carried out in accordance with the ethical standards of Declaration of Helsinki and ethical standards in sport and exercise science research [13].

Statistical analysis

The normality of the distributions was assessed using the Shapiro-Wilks test. Descriptive statistics were calculated for the junior and senior judo athletes. Three-way mixed-design ANOVA with two between subject effects (age, visual control and laterality) and one within subject effect (physical load) was used for evaluating differences in TTW between the factors.

Paired differences between the pre- and post-test were evaluated using Student's t-test for dependent variables. The probability of a type I error (alpha) was set at 0.05 in all statistical analyses. The probability of a type II error (beta) was controlled using post hoc (retrospective) analysis and was set at 0.2 (conventional value). When the criterion of sphericity, which was one of the conditions of ANOVA, as assessed by Mauchly's test (χ^2), was not met, the degrees of freedom were adjusted by means of Greenhous-Geisser's (GG) sphericity correction, and then, the statistical significance was assessed according to particular degrees of freedom. The effect size was evaluated using the "Eta square" coefficient (η^2), which explains the proportion of the variance of the monitored factor.

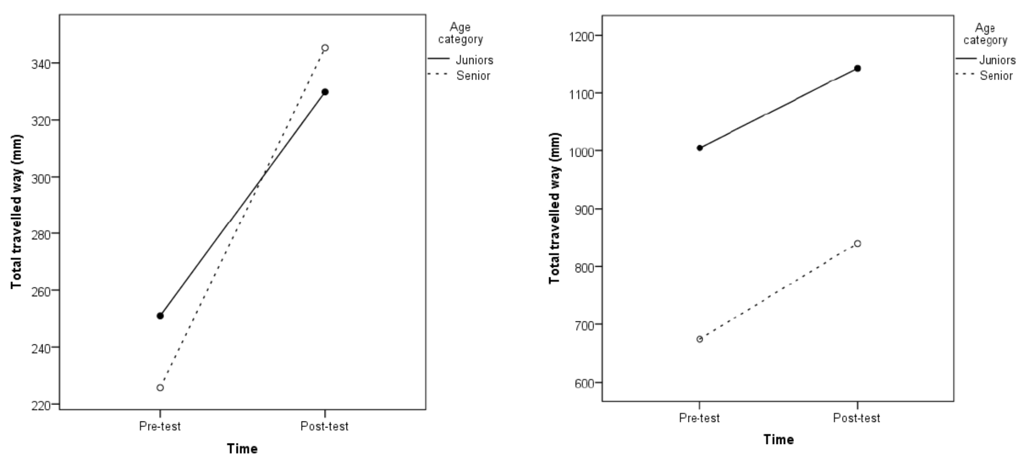
Statistical analyses were performed using IBM® SPSS® v21 (Statistical Package for Social Science, Inc., Chicago, IL, USA).

Results

Mixed design ANOVA showed a significant effect of physical load on changes in TTW in the selected tests of postural stability ($F_{(1,72)} = 62.31$, $p = 0.00$, $\eta^2 = 0.46$). We found a significant effect of the category (AGE) on the level of postural stability, regardless of the type of test performed ($F_{(1,72)} = 10.48$, $p = 0.002$, $\eta^2 = 0.13$) (Figure 1A, B). In the one leg stance test, both groups produced significantly higher values in comparison to the bipedal stance ($F_{(1,72)} = 159.81$, $p = 0.000$, $\eta^2 = 0.69$). The interaction effect between the type of test and age category was also significant ($F_{(1,72)} = 9.86$, $p = 0.000$, $\eta^2 = 0.12$).

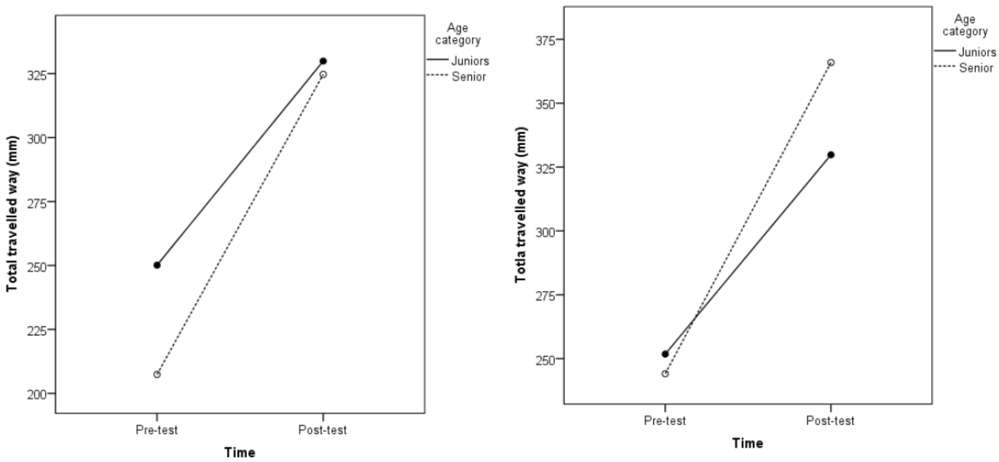
In the bipedal test, we discovered a significant effect of the physical load on the deterioration of postural stability in the monitored groups ($F_{(1,34)} = 19.56$, $p = 0.00$, $\eta^2 = 0.37$). Tests of between subjects' effects revealed a nonsignificant effect on the AGE ($F_{(1,34)} = 0.29$, $p = 0.87$, $\eta^2 = 0.00$) and VISUAL CONTROL ($F_{(1,34)} = 0.49$, $p = 0.51$, $\eta^2 = 0.01$) (Figure 2A, B).

In the one leg stance (flamingo test), we found a significant effect of the physical load on the changes in postural stability in the examined judokas ($F_{(1,34)} = 49.03$, $p = 0.00$, $\eta^2 = 0.59$) (Figure 3A, B). Moreover, we found a significant



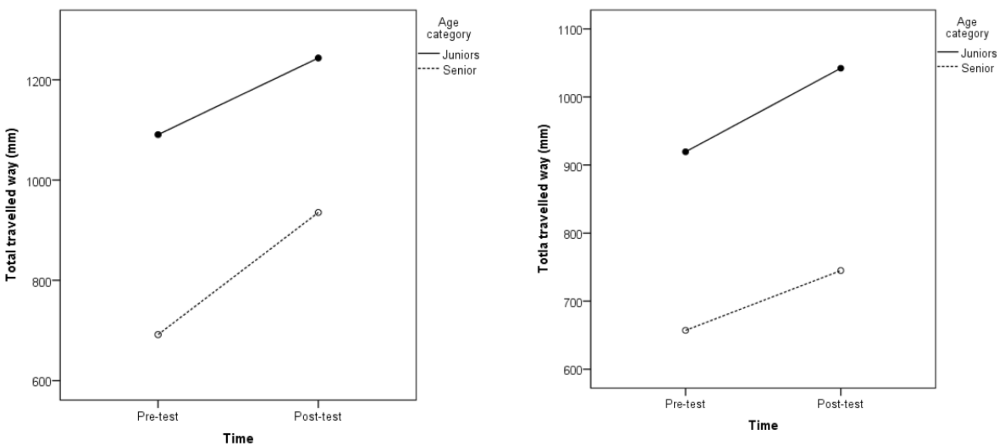
(A) (B)

Figure 1. Changes in TTW in the bipedal test (A) and in the flamingo test (B).



(A) (B)

Figure 2. Changes in TTW in the bipedal test with visual control (A) and without visual control (B).



(A) (B)

Figure 3. Changes in TTW in the flamingo test on the preferred leg (A) and non-preferred leg (B).

interaction effect of TIME*PREFERRED LEG ($F_{(1,34)}$ = 4.60, p = 0.04, η^2 = 0.12), which indicates that changes in stability after exercise are better reflected in the non-preferred leg in comparison with the preferred leg. Junior athletes achieved significantly worse values of postural stability than the senior athletes ($F_{(1,34)}$ = 11.24, p = 0.00, η^2 = 0.25). The factor of laterality without the effect of the physical load did not significantly influence the level of judokas' postural stability ($F_{(1,34)}$ = 0.15, p = 0.70, η^2 = 0.00).

Discussion

Sports or judo training have been reported to improve one´s postural control ability. Belej et al. [14] reported that Polish judokas' ability to maintain their balance on the right leg for a long duration supports the stimulating influence of judo training on these coordination abilities. Postural stability in all of our examined participants was at the level of elite sports [7, 14-16]. Significant differences between junior and senior athletes were reported by Suzanna and Pieter [17], who compared the balance performance between adult and teenage combative athletes. The authors found that the junior athletes could maintain standing balance longer than their older counterparts. The COP was lower in our tested adult athletes than in junior athletes, which means that adults possess a greater sensitivity of sensory receptors or better integration of information than juniors [18]. It appears that visual information is more important to the higher level judo athletes. Perhaps the level of competition influences the sensory canals involved in balance [15].

There was a higher level of postural stability in our tested senior athletes in all test situations. However, the TTW values were only significant in the bipedal stance without visual control after physical load and in the more difficult test of stance on the non-preferred leg, both before and after exercise. The effect of load was evident in both groups. Nevertheless, the values achieved by junior athletes were significantly higher only in the test on the non-preferred leg. We believe that this may be the result of the greater training of for the preferred leg in judokas presenting *ashi-waza* as their personal technique (80 % of the tested judokas). Senior participants in the test on the preferred leg after exercise achieved lower TTW values (744.90 mm) in comparison to the values recorded in junior athletes in the same test before the physical load (919.44 mm). Of all of the tests used, this test is the most similar to *ashi-waza* techniques. Herein, a judoka standing on the preferred leg has to turn the opponent and transfer balance with the opponent on him up to the completion of the throwing technique when the opponent is falling down. The athlete must exert active resistance while simultaneously maintaining his own balance.

Our recorded data revealed a significant effect of load on changes in TTW in the selected stability tests. This result is in accordance with the available literature regarding the effort of a physical load on postural stability when the authors recorded a decreased level of postural stability [19-22]. Melnikov et al. [19] significantly greater sways of COP in the basic stance ($p<0.01$) and in half squat ($p<0.001$) after physical load in wrestlers (n = 31, PWC 170 test). The authors recorded lower sways and faster recovery in wrestlers in comparison with the control group in half squat.

Wojciechowska-Maszkowska et al. [21] confirmed in taekwondo fighters (n = 12) that an intensive physical load (Wingate test) negatively affects the dynamics of body control, which is more emphasized in the sagittal plane. Moran-Navarro et al. [22] reported a negative effect of physical load (model of wrestling combat in the Olympic Games, Wingate anaerobic test) on postural stability in elite and subelite wrestlers. Nikolaev et al. [20] found that submaximal physical loading of the upper and lower extremities has a negative influence on the level of postural stability. In wrestlers, the decreased level of postural stability after exercising their upper extremities lasted for 20 seconds (in non-athletes in the control group it was 100 seconds), while after exercising the lower extremities, the wrestlers recovered in 1 minute (non-athletes recovered in 3 minutes).

In our tested judo athletes, a nonsignificant difference between the values before and after exercise was only evident in adult participants in the test with visual control. This may be due to the low sensitivity of the selected test in a sporting population with a higher level of postural stability because of sports training. The simplicity of the test and the effect of training are also reflected in the nonsignificant difference between the input TTW values in senior and junior athletes before physical load. Despite the statement by Wojciechowska-Maszkowska et al. [21] that in the presence of fatigue, eye contact is an important factor for stability control, removing visual control did not cause any difference between our tested groups. This result is consistent with the available literature [23-25]. In these studies, researchers did not simulate the dynamic nature that judo athletes are exposed to during training.

Although maintaining a stable body posture is a basic prerequisite to gaining an advantage over a competitor with one's defensive or offensive actions [26], postural stability is not the only factor affecting judo performance. Achieving optimal sport performance requires optimal harmonization of all engaged factors and fields. There is limited data on the influence of balance training on the motor skills of elite athletes [27-29].

Balance is a complex task that requires intact information be transmitted from the somatosensory, visual, and vestibular systems and depends on an intact central nervous system to maintain an upright stance [30]. In the presence of fatigue, one of these sensory systems provides inaccurate information, thus disturbing balance. Muscle regeneration 3-5 minutes after load [31] is not possible in judo because of multi-joint exercise. Furthermore, a more extensive effect on maintaining balance is expected [32]. Due to repeated judo *randori* within the system of sequential combats with individual opponents, an important factor is the time required to fully recover maximal muscle force, body strength, and muscular endurance, which the authors report ranges from 15 – 20 min [33]. Because maintaining a stable posture does not require full muscular strength or endurance, it seems reasonable that balance recovery should occur within 20 minutes [32, 34]. The limited available literature suggests that immediately after exertion, balance is decreased [32], although there are no apparent deficits as early as 20 minutes after exertion [34, 35].

A limitation of our study is the small number of participants. This is because the selection process included only athletes competing at the national level. In addition, we only recorded static balance, which does not address the need to compensate for deteriorated stability during *randori*. However, all of the tested athletes were elite judokas. Our findings have added to the results of other studies, such as that of Drowatzky and Zuccato [36], who correlated the results of the Marching Test and Flamingo Test [26]. We have also supported the statement by Kalina et al. [37] that a lack of correlation contradicts the hypothesis that one common mechanism is fundamental for maintaining body balance in various circumstances of motor activity (locomotor activities, postural activities, manipulating activities combined either with locomotor activities or postural activities).

Conclusions

The effect of maximal anaerobic exercise applied in our study was reflected in both senior and junior participants. Adult athletes appeared to have significantly better postural stability in comparison to juniors. A limitation of the study is the small number of participants and the selected stability tests that are specific for throwing techniques and specific movements in *randori*. Further research should focus on the relationship between postural stability and performance level and injury prevention management. It is hoped that the data collected in our study and the changes recorded during exercise will contribute to scientific knowledge and optimize judo performance in practice and health promotion.

References

1. Franchini E, Takito MY, Bertuzzi RCD. Morphological, physiological and technical variables in high-level college judoists. Arch Budo 2005; 1: 1-7
2. Perrot C, Mur JM, Mainard D et al. Influence of trauma induced by judo practice on postural control. Scand J Med Sci Spor 2000; 10(5): 292-297
3. Barrault D, Brondani JC, Rousseau D. Médecine du Judo. Paris: Masson; 1991
4. Cesari P, Bertucco M. Coupling between punch efficacy and body stability for elite karate. J Sci Med Sport 2008; 11(3): 353-356
5. Mikheev M, Mohr C, Afanasiev S et al. Motor control and cerebral hemispheric specialization in highly qualified judo wrestlers. Neuropsychologia 2002; 40(8): 1209-1219
6. Mesure S, Amblard B, Cremieux J. Effect of physical training on head-hip co-ordinated movements during unperturbed stance. Neuroreport 1997; 8(16): 3507-3512
7. Perrin P, Deviterne D, Hugel F et al. Judo, better than dance, develops sensorimotor adaptabilities involved in balance control. Gait Posture 2002; 15(2): 187-194
8. Paillard T, Montoya R, Dupui P. Influence of postural regulation in male judokas' direction of falls'. Percept Motor Skill 2005; 101(3): 885-890
9. Kyle UG, Bosaeus I, De Lorenzo AD et al. Bioelectrical impedance analysis principles and methods. Clin Nutr 2004; 23(5): 1226-1243
10. Kapteyn TS, Bles W, Njiokiktjien CJ et al. Standardization in platform stabilometry being a part of posturography. Agressologie 1983; 24(7): 321-326
11. Inbar O, Bar-Or O, Skinner JS. The Wingate anaerobic test. Champaign: Human Kinetics; 1996
12. Heller J, Peric T, Dlouha R. Physiological profiles of male and female taekwon-do (ITF) black belts. J Sport Sci 1998; 16(3): 243-249
13. Harriss DJ, Atkinson G. Update – Ethical Standards in Sport and Exercise Science Research. Int J Sports Med 2011; 32(11): 819-821
14. Belej M, Junger J. Motor tests of coordination abilities. Prešov: Prešov University, Faculty of Sports; 2006
15. Paillard T, Costes-Salon C, Lafont C et al. Are there differences in postural regulation according to the level of competition in judoists? Brit J Sport Med 2002; 36(4): 304-305
16. Leong HT, Fu SN, Ng GYF et al. Low-level Taekwondo practitioners have better somatosensory organisation in standing balance than sedentary people. Eur J Appl Physiol 2011; 111(8): 1787-1793
17. Suzana MA, Pieter W. Motor ability profile of junior and senior taekwondo club athletes. Braz J Biomotr 2009; 3(4): 325-331
18. Vuillerme N, Teasdale N, Nougier V. The effect of expertise in gymnastics on proprioceptive sensory integration in human subjects. Neurosci Lett 2001; 311(2): 73-76
19. Melnikov AA, Savin AA, Emelianova LV et al. Postural stability during static strain before and after submaximal aerobic bicycle test in athletes. Fiziologiia cheloveka 2012; 38(2): 66-72 [in Russian]
20. Nikolaev RY, Melnikov AA, Vikulov AD. Peculiarities of postural stability during physical fatigue of higher and lower extremities in fighters. Izv Eng Sci 2012; 9(134): 251-6 [in Russian]
21. Wojciechowska-Maszkowska B, Borysiuk Z, Wasik J et al. Effects of anaerobic fatigue on postural control in taekwondo practitioners. JCSMA 2012; 3(2): 103-107
22. Moran-Navarro R, Valverde-Conesa A, Lopez-Gullon JM et al. Can balance skills predict Olympic wrestling Performance? J Sport Health Res 2015; 7(1): 19-30

23. Wikstrom EA, Tillman MD, Borsa PA. Detection of dynamic stability deficits in subjects with functional ankle instability. Med Sci Sport Exer 2005; 37(2): 169-175
24. Brown CN, Mynark R. Balance deficits in recreational athletes with chronic ankle instability. J Athl Train 2007; 42(3): 367-373
25. Yen SR, Fu LL. Dynamic balance assessed by force plate and star excursion balance test in taekwondo athletes with ankle instability. Med Sci Sport Exer 2008; 40(5): 441-442
26. Witkowski K, Maslinski J, Remiarz A. Static and dynamic balance in 14-15 year old boys training judo and in their non-active peers. Arch Budo 2014; 10: 323-31
27. Gautier G, Thouvarecq R, Vuillerme N. Postural control and perceptive configuration: Influence of expertise in gymnastics. Gait Posture 2008; 28(1): 46-51
28. Hrysomallis C. Balance Ability and Athletic Performance. Sports Med 2011; 41(3): 221-232
29. Juras G, Rzepko M, Krol P et al. The effect of expertise in karate on postural control in quiet standing. Arch Budo 2013; 9(3): 205-209
30. Horak FB, Nashner LM, Diener HC. Postural strategies associated with somatosensory and vestibular loss. Exp Brain Res 1990; 82(1): 167-177
31. Fulco CS, Rock PB, Muza SR et al. Slower fatigue and faster recovery of the adductor pollicis muscle in women matched for strength with men. Acta Physiol Scand 1999; 167(3): 233-239
32. Susco TM, McLeod TCV, Gansneder BM et al. Balance recovers within 20 minutes after exertion as measured by the balance error scoring system. J Athl Train 2004; 39(3): 241-246
33. Hakkinen K. Neuromuscular fatigue and recovery in male and female athletes during heavy resistance exercise. Int J Sports Med 1993; 14(2): 53-59
34. Nardone A, Tarantola J, Galante M et al. Time course of stabilometric changes after a strenuous treadmill exercise. Arch Phys Med Rehab 1998; 79(8): 920-924
35. Derave W, De Clercq D, Bouckaert J et al. The influence of exercise and dehydration on postural stability. Ergonomics 1998; 41(6): 782-789
36. Drowatzky JN, Zuccato FC. Interrelationships between selected measures of static and dynamic balance. Resh Quart 1967; 38(3): 509-510
37. 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
38. Budō. The Martial Ways of Japan. Japan: Nippon Budokan Foundation; 2009

Cite this article as: Mala L, Maly T, Zahalka F. Influence of maximal anaerobic performance on body posture stability in elite senior and junior male judo athletes. Arch Budo 2016; 12: 117-124