Do maximal aerobic power and blood lactate concentration affect Specific Judo Fitness Test performance in female judo athletes?

AUTHORS: Garbouj H[1], Selmi MA[1], Haj Sassi R[1], Haj Yahmed M[2], Chamari K[3], Chaouachi A[1,4]

[1] Tunisian Research Laboratory ''Sport Performance Optimisation'', National Center of Medicine and Science in Sports (CNMSS), Tunis, Tunisia
[2] Research Unit ''Analysis and Evaluation of Factors Affecting the Sports Performance'', High Institute of Sports and Physical Education, Ksar Said, University of Manouba, Tunisia
[3] Athlete Health and Performance Research Centre, Aspetar, Qatar Orthopaedic and Sports Medicine Hospital, Doha, Qatar
[4] AUT University, Sports Performance Research Institute New Zealand, Auckland, New Zealand

Corresponding author:
Anis Chaouachi
Tunisian Research Laboratory
"Sports Performance Optimisation"
National Center of Medicine and Science in Sports (CNMSS)
Bp263, Ave Med Ali Akid, 1004 El Menzah, Tunis, Tunisa
Tel: +216 21 17 69 40
Fax: +216 71 70 97 89
E-mail: anis.chaouachi@email.ati.tn

ABSTRACT: The Special Judo Fitness Test (SJFT) has become the test most widely used by coaches and physical trainers for assessment of competitors' judo-specific physical aptitude and training programme prescription. The aim of this study was to investigate the relationship between the SJFT performance indices and both maximal aerobic power and the level of blood lactate concentrations in female judo athletes. Seventeen female judokas (age: 21.9±1.6 years, body mass: 74.6±27.4 kg, height: 164.5±8.6 cm; BMI: 27.1±8.0 kg · m^{-2}) took part in this study. All participants performed the SJFT, 20 m multi-stage shuttle run test (MSRT), and 30 m straight sprint test (SST), from which we calculated both acceleration (10 m) and the maximal anaerobic speed (MAnS: flying 20 m sprint). A blood sample was taken 3 min after the SJFT. The number of throws was significantly correlated with estimated VO_2max (r=0.795, p=0.0001) and both acceleration (r=0.63, p =0.006) and MAnS (r=0.76, p=0.0004). Peak blood lactate recorded after the SJFT was 13.90±1.39 mmol · l^{-1}. No significant correlation was found between blood lactate concentration and the SJFT performance indices. The lack of significant correlation between blood lactate and SJFT performance suggests that lactic anaerobic metabolism has no effect on this type of judo-specific supra-maximal exercise. The observed results can provide coaches and strength and conditioning professionals with relevant information for the interpretation of SJFT performance and the prescription of specific training programmes for female judo athletes.

CITATION: Garbouj H, Selmi MA, Haj Sassi R et al. Do maximal aerobic power and blood lactate concentration affect Specific Judo Fitness Test performance in female judo athletes? Biol Sport. 2016;33(4):367–372.

Received: 2015-07-21; Reviewed: 2015-09-01; Re-submitted: 2015-09-15; Accepted: 2016-09-16; Published: 2016-10-11.

Key words:
aerobic power
evaluation
intermittent high-intensity exercise
judo

INTRODUCTION

Among the range of tests available for assessing the aerobic and anaerobic energetic systems of judokas, the Special Judo Fitness Test (SJFT) [1] is considered as the test that simulates most closely the specific physiological capacities underlying judo performance [2, 3, 4]. In fact, judo is characterized by the repetition of brief, high-intensity efforts that require strength, velocity and power interspersed with very short periods of recovery. Although key actions in judo are essentially reliant on anaerobic metabolism, aerobic fitness appears to be very important since it permits better recovery during the short rest periods between high-intensity efforts. Recently, Franchini et al. [2] reported that the contribution of energy systems during the SJFT in male judo athletes is predominantly alactic (42.3 ± 5.9%), with significant contributions from both lactic and aerobic energy systems (29.5 ± 6.2% and 28.2 ± 2.9%, respectively). It is well established today that the greater part of the energy required during a single all-out exercise performance must be provided through a combination of phosphocreatine (PCr) degradation and anaerobic glycolysis [5]. Hirvonen et al. [6] and Dawson et al. [7] highlighted the importance of the PCr stores for short-term maximal exercise performance. However, when brief maximal exercise bouts must be repeated, aerobic metabolism has a major role to ensure the PCr resynthesis and the removal of accumulated intracellular metabolites [8]. This process depends strongly on the recovery time between repetitions. Indeed, it has been suggested that 30 s of short intervals of recovery between repetitions would result in a diminution of the muscle PCr stores and consequently an increase of the glycogenolysis to regenerate ATP during subsequent bouts of exercise [9]. Dawson et al. [7] reported that after the 1 x 6 s sprint and 5 x 6 s sprints, PCr concentration at 10 s of post-exercise recovery was 55% and 27% of the pre-exercise value, respectively. The SJFT consists of

3 series of 15, 30 and 30 s of high-intensity efforts separated by 10 s intervals. Such short periods of recovery seem to prevent ATP regeneration through aerobic pathways [10, 11], making the SJFT efforts highly dependent on the lactic anaerobic system. Indeed, the high blood lactate concentrations recorded at the end of the SJFT suggest significant involvement of anaerobic glycolysis during this test. Nevertheless, although the relationship between the blood lactate concentrations after judo matches and SJFT has been investigated, data from the literature are controversial regarding the possible effects of blood lactate on performance [12, 13]. In this context, coaches and sport scientists are constantly searching for an effective method to assess and develop physical and physiological determinants that may contribute to judo performance. The identification of SJFT determinants can provide useful information regarding what is needed for specific testing and training of judo athletes. To the best of our knowledge, no study has examined the determinants of SJFT performance in female judo athletes. The purpose of the present study was therefore to investigate whether aerobic power and the level of blood lactate concentrations were related to SJFT performance in female judo athletes.

MATERIALS AND METHODS

Participants. Seventeen female judokas (age: 21.9 ± 1.6 years, body mass: 74.6 ± 27.4 kg, height: 164.5± 8.6 cm; BMI: 27.1 ± 8.0 $kg.m^{-2}$) took part in this study. They were all at least at regional level (regional level: n=7, and national level: n=10). They had more than 10 years of experience in state and university championships, and 10 of them had participated in several international tournaments. Their skill level according to the Japanese grade system was black belt of various ranks (Dan). They were informed about the risks of the investigation before giving their written consent, and all procedures were approved by the Local University Research Ethics Committee according to the Declaration of Helsinki 1975.

Procedure

Testing was carried out at the gymnasium of the High Institute of Sport and Physical Education of Tunisia (Kef, Tunisia) during three one-day sessions separated by at least one week. During the first session, anthropometric measurements and the 30 m straight sprint test were performed. Each participant performed 2 trials separated by at least 3 min of rest between trials to ensure adequate recovery. The best performance of the 2 trials was used for the statistical analysis. During the second session, subjects performed the 20 m multi-stage shuttle run test (MSRT) to estimate VO_2max through the maximal shuttle speed reached during the test. During the last session, subjects performed the Special Judo Fitness Test (SJFT) on an official judo mat. For all tests, subjects were verbally encouraged to exert their maximal effort possible. Except for the MSRT, all other tests were preceded with a 15 min warm-up including jogging, dynamic stretching, jumping and accelerations. All tests were performed at the same time of day (±1 h) and athletes were asked to follow their normal diet. Athletes did not intensely train during 48 h prior to the testing sessions.

Special Judo Fitness Test (SJFT)

Judokas performed the specific test (SJFT) proposed by Sterkowicz [1]. Following a 15-minute warm-up, three athletes of similar body weight and height executed the test according to the following protocol: two judokas (*uke*) were positioned at 6 m distance from one another, while the test executor (*tori*) was 3 m from the judokas who would be thrown. The procedure is divided into three periods: 15 s (A), 30 s (B), and 30 s (C) with 10 s intervals between them. During each period, the executor throws partners using the *ippon-seoi-nage* technique, as many times as possible. Performance is determined by the total throws completed during each of the three periods (A+B+C). Heart rate (HR) was measured immediately after the test (HR) and then 1 minute later (HR_1). SJFT performance indices were the number of throws completed during the test and the index of the test calculated from the equation: index =HR ($beats \cdot min^{-1}$) + HR_1 min ($beats \cdot min^{-1}$) / throws (*n*). The smaller the index, the better is the test performance. Heart rate was recorded by using a Polar Vantage NV Sport-tester (Polar Electro Oy, Finland). Three minutes after the last bout, a blood sample was taken to determine blood lactate concentrations [La (3')].

20 m Multi-stage Shuttle Run Test (MSRT)

The MSRT was conducted as previously described by Leger et al. [14]. Briefly, this test consisted of shuttle running between two lines, spaced 20 m apart. Participants were required to run repeated 20 m shuttles in response to an audible signal produced by a beeper (Best Electronique, France). The initial velocity of the incremental test was set at 8.5 $km \cdot h^{-1}$ and was increased by 0.5 $km \cdot h^{-1}$ every minute. Subjects were required to complete as many levels and shuttles as possible. The end of the test was announced when the judoka was unable to follow the specific pace for 2 successive shuttles or she withdrew from the test because of exhaustion. Maximal speed was calculated as the velocity of the last stage fully completed and considered as the speed associated with VO_2max for the shuttle run test (vVO_2max). VO_2max was estimated using the Leger et al. formula [14].

30 m Straight Sprint Test (SST)

The subjects performed a maximal sprint over the distance of 30 m. The performance of the test was recorded using 3 pairs of photocell gates (Brower timing system, Salt Lake City, UT, USA; accuracy of 0.01 s) placed approximately 0.75 m above the floor and positioned 3 m apart facing each other on either side of the starting line, at 10 m and at the finish. Subjects were instructed to begin with their preferred foot forward, placed on a line marked on the floor from a standing position. Speed test performances were expressed as acceleration (10 m speed) and maximal anaerobic speed (MAnS: flying 20 m sprint, time from 10 to 30 m of sprint).

Statistical analyses

Data analyses were performed using SPSS software (SPSS, version 18 for Windows. Inc., Chicago, IL, USA). Values were expressed as

TABLE 1. Performance during special judo fitness test.

Variable	Mean ± SD
Number of throws duiing A	5.4 ± 0.9
Number of throws during B	9.7 ± 1.1
Number of throws during C	8.8 ± 1.1
Total number of throws	23.9 ± 2.6
HR immediately after (beats · min^{-1})	186.7 ± 8.7
HR 1 min after the test (beats · min^{-1})	160.7 ± 11.0
Index (beats · min^{-1} · $throw^{-1}$)	14.8 ± 2.1
[La] (mmol · l^{-1})	13.90 ± 1.39

Note: [La]: Blood lactate concentration at 3 minutes after SJFT

TABLE 2. Performance during the 20 m multi-stage shuttle run test and 30 m straight sprint test.

Variable	Mean ± SD
Sprint performance (s)	
10-m	2.2 ± 0.1
20-m	3.1 ± 0.3
30-m	5.3 ± 0.5
Aerobic measures	
vVO2max (km · h^{-1})	11.6 ± 1.3
VO2max (mL · kg^{-1} · min^{-1})	42.5 ± 7.8

Note: vVO_2max: velocity associated with VO_2max; VO_2max: maximal oxygen uptake; HRmax: maximal heart rate.

mean ± SD. The normality of appropriate data sets was checked using the Kolmogorov-Smirnov test. Pearson's product–moment correlation coefficients were used to determine the relationship of the estimated VO_2max, SST performances, and [La (3')] with the SJFT performance indices. The significance level was set at $P < 0.05$.

RESULTS

Mean ± SD of SJFT parameters and [La (3')] are reported in Table 1. Estimated VO_2max, acceleration and MAnS are reported in Table 2. The relationships between the SJFT performance indices and acceleration, MAnS, and [La (3')] are presented in Table 3. No significant correlation was found between post-SJFT blood lactate concentrations and both SJFT index and number of throws.

The relationship between estimated VO_2max and number of throws completed during the SJFT is presented in Figure 1.

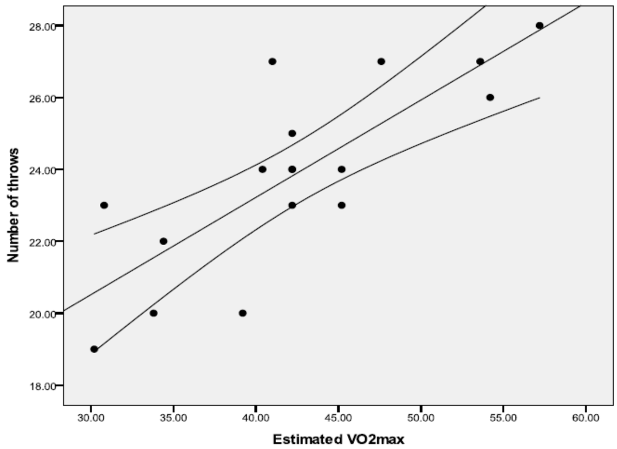

FIG. 1. Relationship between number of throws during the SJFT and estimated VO_2max.

DISCUSSION

The objective of the present study was to verify whether aerobic power and blood lactate concentrations were related to the SJFT performance in female judo athletes. Although SJFT has been widely studied in male judokas, few studies have used this test to assess specific fitness of female judo players [15, 16]. To the best of our knowledge, this is the first study to examine the relationship between SJFT performance indices and both aerobic and anaerobic parameters in female judokas. The main finding of this study was the lack of correlations between the SJFT performance indices and [La (3')]. Previous studies [9, 17] have suggested that intermittent high-inten-

TABLE 3. Pearson product moment correlations (95% confidence interval) between SJFT performance indices and acceleration, MAnS and post-blood lactate concentrations.

	Acceleration (m · s^{-1})	MAnS (m · s^{-1})	[La (3')] (mmol · l^{-1})
SJFT Index (beats.min-1.throw-1)	-0.471	-0.687*	0.192
	p=0.056	p=0.002	p=0.461
	(-0.776 - 0.012)	(-0.878 - 0.308)	(-0.318 - 0.612)
Throws During the SJFT	0.634*	0.764*	0.053
	p=0.006	p=0.004	p=0.841
	(-0.221 - 0.855)	(-0.448 - 0.910)	(-0.439 - 0.520)

Note: [La (3')]: blood lactate concentrations 3min after the SJFT. *: statistically significant sity exercise efforts of brief duration with short recovery periods lead to an increasing demand on anaerobic glycolysis to maintain the rate of energy production because of incomplete repletion of PCr stores. Post-SJFT lactate concentration in the current study was 13.90 ± 1.39 mmol·l^{-1}. This value was comparable to those reported in male and female judokas after both SJFT and judo combats [2, 16, 18, 19]. Generally, the finding of high blood lactate values after a maximal effort indicates a manifest contribution of anaerobic glycolysis, which may be associated with the anaerobic power of a subject. In fact, Franchini et al. [3] reported a significant correlation (r = 0.85) between the peak blood lactate after the randori and the number of attacks using arm techniques (Te-waza), which may suggest that this variable is related to some specific situations in judo. Nevertheless, in this study no significant correlation was found between [La (3')] and either number of throws (r = 0.053; p = 0.841) or SJFT index (r =0.192; p = 0.461). This means that judokas who accumulated a high level of [La (3')] were not necessarily those who had the best SJFT performance. This result is in agreement with those reported by Artioli et al. [12] and Detanico et al. [13], who failed to obtain a significant correlation between peak blood lactate concentrations and single SJFT or three series of SJFT with a 5 min recovery period between the series in male judo athletes, respectively. Likewise, Bonitch-Dominguez et al. [18] demonstrated that four successive 5 min judo bouts, each separated by 15 min of passive rest, produced high acidosis levels, which had no effect on peak power developed by the legs. They also reported that maximum lactate concentration of the fourth bout was lower than that of the first, although there was no difference in their clearance dynamics (P<0.05). In addition, Franchini et al. [19] reported no significant differences in peak lactate concentration after the SJFT between elite and non-elite judo players despite the significant difference observed between the two groups for the number of throws and the SJFT index. This suggests that blood lactate concentrations after the SJFT could not distinguish between the performance of trained and untrained subjects and that fatigue in this test may be due to other blood metabolic markers of anaerobic metabolism such as H^+, accumulated Pi, and ammonia [18]. Recently, Degoutte et al. [20, 21] reported an increase in ammonia concentration after a judo combat. It is well known that after brief bouts of high-intensity exercise, an increase in blood ammonia concentration indicates ATP synthesis by the myokinase pathway and activation of the purine nucleotide cycle. Numerous studies have established a positive significant relationship between peak values of blood lactate and ammonia after very intense exercise [22, 23]. In addition, Banister et al. [22] suggested that blood ammonia accumulation may be a principal "toxin", interfering ultimately with exercise performance by stimulating lactate formation. It seems, therefore, that ammonia could have a considerable effect on intermittent high-intensity exercise performance. Future research should be considered to evaluate with precision the role of ammonia in the SJFT performance and the effect of training programmes on this metabolite both in male and female judo athletes.

Estimated VO_2max of the present study female judo athletes was 43.4 ± 7.8 ml·min^{-1}·kg^{-1}. This value is comparable to those reported in the literature for French, Canadian, Japanese, and Spanish female judokas [24, 25, 26, 27]. In the current study, we found a significant positive correlation between estimated VO_2max and both total number of throws and the SJFT index. This result was in agreement with those reported previously in female [16] and male [13, 28, 29] judo athletes. It seems, therefore, that the maintenance of the intermittent work performed during the SJFT, as well as the recovery process during the short intervals, are mainly supported by aerobic metabolism. Recovery periods during the SJFT are very short and are therefore insufficient for a complete restoration of the PCr. We can assume, as suggested by Feriche et al. [30], that during intermittent high-intensity exercise, such as SJFT, aerobic metabolism contributes to the energy supply during both the work and recovery phases. Furthermore, Bogdanis et al. [10] have shown that aerobic metabolism provides a significant part (49%) of the energy during the second sprint of two cycle ergometer sprints (30 s each) separated by 4 min of recovery. They concluded that an increase in aerobic metabolism partially compensates for the reduction in energy supply from anaerobic pathways during the second sprint and that aerobic metabolism makes an important contribution to the energy supply during repeated sprints. Likewise, Gaitanos et al. [5] reported that in the final sprint of a 10 x 6 s cycling sprint protocol there was no change in muscle lactate concentration even though maximal power output was reduced only to 73% of that generated in the first sprint. They suggested that, during the last sprint, power output was supported by energy that was essentially derived from PCr degradation and increased aerobic metabolism.

Given that VO_2max is not the only indicator of aerobic fitness, it has been suggested that aerobic capacity as represented by the anaerobic threshold or the velocity at the onset of blood lactate accumulation (OBLA) could have a stronger association with intermittent high-intensity effort [13, 29]. In fact, Detanico et al. [12] reported significant correlations between number of throws in the SJFT and both maximal aerobic power (r = 0.70; p <0.01) and velocity at the anaerobic threshold (r = 0.60; p < 0.01). They also found a significant correlation between velocity at the anaerobic threshold and peak blood lactate after the randori (r = - 0.59; p = 0.01) in male judo athletes. These results suggested that the aerobic energy system may play a contributory role, acting both centrally, in the heart (VO_2max), and peripherally, in muscles (anaerobic threshold, OBLA), in delaying fatigue during the SJFT.

On the other hand, our results demonstrated significant correlations between number of throws in the SJFT and both acceleration (r = 0.630, p = 0.006) and MAnS (r = 0.764, p = 0.004). Since the SJFT includes a shuttle run phase (6 m) before performing the throws, it is not surprising that acceleration and MAnS were related to SJFT performance indices. Our results may not adequately reflect (indirectly) the intervention of alactic anaerobic metabolism during the SJFT. In addition, this type of movement (6 m shuttle run) does not mimic the activity of the athlete during the judo combat, which is characterized by greater involvement of upper body strength and power. The use of other tests assessing muscle power and strength of both upper and lower body muscles would be more appropriate to study more objectively the relationship between alactic anaerobic metabolism and SJFT performance in female judo athletes. Furthermore, the athlete's anaerobic reserve and rating of perceived exertion (RPE), which are not taken into consideration in this study, could be relevant parameters that explain the present results [31, 32].

CONCLUSIONS

In conclusion, the results of the current study showed that the SJFT produced high levels of blood lactate, which were not correlated with SJFT performance. This suggests that there is no causal relation between blood lactate and SJFT performance. However, given that recovery periods in the SJFT were very short and insufficient to completely replenish PCr, the strong correlation between estimated VO_2max and SJFT performance indices suggests that maximal aerobic power could have a significant effect during both work and recovery periods during this specific test in female judo athletes. The SJFT is one of the tests most widely used by coaches and fitness trainers to evaluate and develop specific physical capabilities of both male and female judo athletes. Knowledge of the most important factors that limit SJFT performance could help coaches to better understand training strategies that can improve intermittent specific tasks in judo. Based on the findings of this study, coaches should consider these results in interpretation of the SJFT performance and in the interest of its use as a training tool in female judo athletes. Furthermore, the current study could be useful for coaches and strength and conditioning professionals in the choice of the most effective training programmes to improve the ability to recover between high-intensity judo-specific tasks.

Conflict of interests: the authors declared no conflict of interests regarding the publication of this manuscript.

REFERENCES

1. Sterkowicz S. Test specjalnej sprawności ruchowej w judo (Special judo fitness test). Antropomotoryka. 1995;12:29-44.
2. Frainchini E, Sterkowicz S, Szmatlan-Gabrys U, Gabrys T, Garnys M, Energy system contributions to the special judo fitness test. Int J Sports Physiol Perform. 2011;6:334-43.
3. Franchini E, Takito MY, Bertuzzi RCM. Morphological, physiological and technical variables in high-level college judoists. Arch Budo. 2005;1:1-7.
4. Franchini E, Nakamura FY, Takito MY, Kiss MA, Sterkowicz S. Specific fitness test developed in brazilian judoists. Biol Sport. 1998; I5:165-70.
5. Gaitanos GC, Williams C, Boobis LH, Brooks S. Human muscle metabolism during intermittent maximal exercise. J Appl Physiol. 1993;75:712-9.
6. Hirvonen J, Rehunen S, Rusko H, Harkoven M. Breakdown of high energy phosphate-compounds and lactate accumulation during short supra-maximal exercise. Eur J Appl Physiol. 1987;56:253-9.
7. Dawson B, Goodman C, Lawrence S, Preen D, Polglaze T, Fitzsimons M, Fournier P. Muscle phosphocreatine repletion following single and repeated short sprint efforts. Scand J Med Sci Sports. 1997;7:206-13.
8. Gaesser GA, Brooks GA. Metabolic bases of excess post- exercise oxygen consumption: a review. Med Sci Sports Exerc. 1984;16:29-43.
9. Wootton SA, Williams C. The influence of recovery duration on repeated maximal sprints. In: Knuttgen HG, Vogel JA, Poortmans J (eds). Biochemistry of Exercise. Champaign, IL: Human Kinetics. 1983:269–73
10. Bogdanis GC, Nevill ME, Boobis LH, Lakomy HK. Contribution of phosphocreatine and aerobic metabolism to energy supply during repeated sprint exercise. J Apple Physiol. 1996; 80: 876-84.
11. Gharbi Z, Dardouri W, Haj-Sassi R, Chamari K, Souissi N. Aerobic and anaerobic determinants of repeated sprint ability in team sports athletes. Biol Sport. 2015;32(3):207–212.
12. Artioli GG, Coelho DF, Benatti FB, Gailey ACW, Berbel P, Adolpoho BT, Lancha JH A. Relationship between blood lactate and performance in a specific judo test. Med Sci Sports Exerc. 2005;37-S99.
13. Detanico D, Dal Pupo J, Franchini E, Giovana dos Santos S. Relationship of aerobic and neuromuscular indexes with specific actions in judo. Science & Sports. 2012; 27:16-22.
14. Léger LA, Lambert J. A maximal multistage 20m shuttle run test to predict VO2max. Eur J Appl Physiol Ocup physiol. 1982;49:1-12.
15. Drid P, Maksimovic N, Matic R, Obradovic B, Milosevic Z, Ostojic SM. Fitness profiles of elite female judokas of the Serbian national team. Medicina dello Sport. 2009;62:251-63.
16. Wolska B, Smulskij V, Jagiełło W. The Level of Aerobic and Anaerobic Capacity and the Results of a Special Mobility Fitness Test of Female Judo Contestants. Baltic Journal of Health and Physical Activity. 2009;2:105-10.
17. Glaister M, Stone MH, Stewart AM, Hughes M, Moir GL. The influence of recovery duration on multiple sprint cycling performance. J Strength Cond Res. 2005;19:831-7.
18. Bonitch-Domi'nguez J, Bonitch-Go'nngora J, Padial P, Feriche B. Changes in peak leg power induced by successive judo bouts and their relationship to lactate production. J Sports Sci. 2010;28:1527–34.
19. Franchini E, Takito MY, Kiss MAPDM, Sterkowicz S. Physical fitness and anthropometrical differences between elite and non elite judo players. Biol Sport. 2005;22: 315-28.
20. Degoutte F, Jouanel P, Filaire E. Solicitation of protein metabolism during a judo match and recovery. Science & Sports. 2004;19:28–33.
21. Degoutte F, Jouanel P, Filaire E. Energy demands during a judo match and recovery. Br. J. Sports Med. 2003;37:245-9.
22. Banister EW, Allen ME, Mekjavic IB, Singh AK, Legge B, Barbara JCM. The time course of ammonia and lactate accumulation in blood during bicycle exercise. Eur J Appl Physiol. 1983;51:195-202.
23. Ravier G, Dugué B, Grappe F, Rouillon JD. Maximal accumulated oxygen deficit and blood response of ammonia, lactate and pH after anaerobic test: a comparison between international and national elite Karate athletes. Int J Sports Med. 2005;26:1-8.
24. Ebine K, Yoneda I, Hase H. Physiological characteristics of exercise and findings of laboratory tests in Japanese elite judo athletes. Medecine du Sport. 1991; 65:73-9.
25. Little NG. Physical performance attributes of junior and senior women, juvenile, junior and senior men judokas. J Sports Med Phys Fitness. 1991;31:510-20.

26. Santos L, González V, Iscar M, Brime JI, Fernández-Río J, Rodríguez B, Montoliu MA. Physiological response of high-level female judokas measured through laboratory and field tests. Retesting the validity of the Santos test. J Sports Med Phys Fitness. 2012;52: 237-44.
27. Vidalin H, Dubreuil C, Coudert J. Judokas ceinture noire. Suivi physiologique: études biométrique et bioénergétique – suivi de l'entraînement. Med Sport. 1988 ;62:184-89.
28. Franchini E, Nunes AV, Moraes JM, Del Vecchio FB. Physical fitness and anthropometrical profile of the Brazilian male judo team. J Physiol Anthrop. 2007; 26:59-67.
29. Sterkowicz S, Zuchowicz A, Kubica R. Levels of anaerobic and aerobic capacity indices and results for Special Fitness Test in judo competitors. J Hum Kinet. 1999;2:115-35.
30. Feriche B, Delgado M, Calderon C, Lisbona O, Chirosa IJ, Miranda MT, Fernández JM, et al. The effect of acute moderate hypoxia on accumulated oxygen deficit during intermittent exercise in nonacclimatized men. J Strength Cond Res. 2007;21:413-8.
31. Mendez-Villanueva A, Hamer P, Bishop D. Fatigue in repeated-sprint exercise is related to muscle power factors and reduced neuromuscular activity. Eur J Appl Physiol. 2008;103(4):411-9.
32. Tabben M, Chaabène H, Franchini E, Tourny C, Chamari K, Coquart J. The influence of karate practice level and sex on physiological and perceptual responses in three modern karate training modalities. Biol Sport. 2014;31(3):201-7.