Comparison between Special Judo Fitness Test, metabolic variables and energy contribution in young judo athletes

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Abstract

Background and Study Aim: Judo has been characterized as a high-intensity intermittent combat sport. The study's purpose is answer the question whether Special Judo Fitness Test (SJFT) variables are capable of discriminate young judo athlete's performance at different ages, and comparing the test with metabolic indicators and energy contribution.

Material and Methods: Twenty-seven athletes were divided according to their ages: 10 to 12 years ($G_{10\text{-}12}$), 13 to 14 years ($G_{13\text{-}14}$), 15 to 17 years ($G_{15\text{-}17}$), and comparing with a control group ($G_{>18}$). The Athletes were submitted to SJFT, before and immediately after the test, their oxygen consumption and blood lactate samples were collected for estimating energy contributions. The athletes and their parents gave consent for the study's participation

Results: No significant differences were observed in the SJFT variables among groups, with the exception of the relative index, founding statistical differences between the $G_{10\text{-}12}$ with the other groups. Comparing the control group with the groups $G_{10\text{-}12,}$ $G_{13\text{-}14}$, $G_{15\text{-}17,}$ were found significant differences in the aerobic metabolism, aerobic power and anaerobic variables as lactate peak and anaerobic metabolism, indicating which the groups were physiological differents. Were found significant correlations between SJFT index and both (i) anaerobic alactic contribution for $G_{15\text{-}17}$ and (ii) anaerobic lactic contribution for $G_{>18}$. The test presents anaerobic predominance in the $G_{>18}$ and $G_{15\text{-}17}$ group.

Conclusions: For utilization of the SJFT in young athletes we recommend use the relative index is a strategy to discriminating judo athletes of different ages and different physiological characteristics rather the traditional index.

Keywords: age-related • anaerobic fitness • combat sports • youth

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Ippon-seoi-nage – single back throw.

Tori – the person who applies a technique in *jūdō* training. The receiver of the technique is referred to as *uke* [20].

Kyū – the series of grades that precede *dan* ranks. *Ikkyū* is the grade immediately below *shodan* [20].

Dan (dan'i) – a term used to denote one's technical level or grade [20].

Technique– *noun* a way of performing an action [21].

Performance – *noun* the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [21].

Anaerobic metabolism – *noun* the breakdown of carbon and fats into energy without the presence of oxygen [21].

Anaerobic power – *noun* same as **anaerobic capacity** [21].

Callisthenics – *plural noun* energetic physical exercises designed to improve fitness and muscle tone, including press-ups, sit-ups and star jumps [21].

INTRODUCTION

Judo has been characterized as a high-intensity intermittent combat sport [1]. It consists of many different techniques and actions during a match, where athletes alternate explosive throws, which demands physical skills such as balance, power, and maximum strength, intercalated with moments of low intensity, usually involving interruptions (*mates*) during the matches. It is estimated that every 30 seconds of high intensity is followed by 10 seconds of low intensity during the combat time [2].

These characteristics show the importance of anaerobic systems for judo athletes. The basis for any planning and scheduling of training processes lies in the precise test procedures for assessing the initial performance of judo athletes. Thus, the Special Judo Fitness Test (SJFT), which is considered the most used test by coaches and researchers, can be used for training prescription and competitive performance evaluations. The SJFT is composed of three blocks of 15, 30, and 30 seconds, each of which is followed by a resting time of 10 seconds. During each block, the judo athlete (*tori*) will perform the maximum number of throws using one specific technique on the other two judo athletes (*ukes*), who are separated from each other by a distance of 6 meters. Due to the nature of the SJFT, it can be also used as a preliminary assessment of anaerobic performance [3-5]. The SJFT index (I_{SJFT}) is calculated using the total number of throws (NT), heart rate measured at the end of the test (HR_{max}), and the heart rate measured 1 minute after concluding the test (HR_{min}). A lower I_{SJFT} shows a higher performance [6].

Positive responses for this test include: (i) high number of good quality throws during the three blocks, which represents improvement in speed, good anaerobic capacity, and efficiency in technique execution; and (ii) fast heart rate recovery. Both adaptations indicate cardiovascular efficiency and aerobic power improvement [5, 7].

Moreover, some evidence has shown that better comparisons among different athletes can be made using the SJFT relative index (RI_{SJFT}), which was defined by Işik et al. [8] as I_{SJF} divided by the judo athlete´s body mass. After calculating the I_{SJFT} it is possible to classify the test result using a comparative table, however, the table does not have values for young athletes, less than 15 years old. In fact, there are few studies on the application of SJFT for the evaluation of young judo athletes of different ages, facts which make difficult the interpretation of the SJFT variables in training evaluation in young judo athletes, however, this test is used for coaches to assess the anaerobic profile of young judo athletes even with the lack of scientific researchers about the application of the SJFT in young athletes [9].

During the different maturational stages in human development, differences in sports performance are expected. Pre-pubertal athletes do not have totally developed anaerobic metabolism, presenting low lactate concentration, as well as low muscle glycogen reserves, when compared to adult athletes [10]. During puberty, there is an increase in both muscle mass and hormone production (*e.g.* testosterone), as well as increased muscle glycogen, culminating in higher concentrations of lactate. After puberty, young athletes show increased energy production due to the efficient anaerobic metabolism, resulting in increased lactate production [11].

However, no previous study has determined the anaerobic contributions in young judo athletes of different ages and metabolic variables, and their relations on SJFT variables, facts which must be elucidated for better specific training evaluations and training monitoring in young athletes.

Thus, the study's purpose is answer the question whether Special Judo Fitness Test (SJFT) variables are capable of discriminate young judo athlete's performance at different ages, and comparing the test with metabolic indicators and energy contribution.

MATERIAL AND METHODS

Participants

Twenty-seven trained young judo athletes were divided into four groups based on their ages, as summarized in Table 1, group 4 is considered as the developed group/ control group. The judo athletes presented as minimum graduation a green belt (3 *kyu*), with competitive results at the regional or national level and average practice time of the modality of 8 ±4 years. On average the athletes had weekly training approximately 15 hours per week. All participants had good technique and execution of the *nage-waza* throw which was used to carry out the SJFT, being the *ippon-seoi-nage*. None of the judo athletes

Table 1. Anthropometric and age data of participating judo athletes (n = 27).

Group	N	Age range (years)	Age (years)	Height (cm)	Weight (kg)
G_{10-12}	6	10 to 12	11.4 ±0.6	147 ±8	38 ±4
G_{13-14}	9	13 to 14	13.7 ±0.4	161 ±8	51 ±6
G_{15-17}	7	15 to 17	16.2 ±0.9	173 ±3	76 ±10
$G_{>18}$	5	over 18	22 ±5	179 ±6	90 ±30

presented injuries or problems due to dehydration, allowing the successful accomplishment of the SJFT. Prior to the tests the judo athletes, parents, and coaches were informed about the risks and benefits of the studies to be performed. All procedures followed the Helsinki Declaration and were approved by an ethics committee.

Experimental design

All the procedures took two days, during those days the athletes and their coaches realized all the meals and slept in the university, the breakfast, lunch and dinner were the same for all the athletes and the athletes slept approximately 8 hours per night.

After anthropometric measurements, the judo athletes were divided into trios composed of individuals with similar weights, heights, and ages, to perform the SJFT. Preceding the SJFT, they remained seated for approximately 5 minutes to perform resting measurements on oxygen uptake and blood lactate concentrations. The athletes then underwent a 5-minute warm-up phase (calisthenics) and specific judo exercises. After this stage, the athletes were submitted to the SJFT. After completing the SJFT, they remained seated for 10 minutes to perform the second set of measurements of oxygen uptake and blood lactate concentrations. The CPET – Quark gas analyser, Cosmed – Italy, was used for the oxygen uptake measurements, the equipment was calibrated following the manufacture's recommendations.

For the lactate concentration measurements, 25 µL of blood was collected using heparinized capillaries and then stored in Eppendorf tubes with 50 µL of 1 % sodium fluoride. These collected blood samples were analysed using the YSI 2300 STAT blood analyser (Yellow Springs, OH, USA).

Special Judo Fitness Test (SJFT)

As already described in detail in the introduction, the SJFT was applied to all judo athletes mentioned in Table 1. Before, during and after the test, several indicators were measured to calculate I_{SJFT} and metabolic energy contributions. All the experimental procedures and the measured indicators will be discussed in the next sections. To calculate the SJFT index (I_{SJFT}) the following formula was used:

$$I_{SJFT} = \frac{HR_{max} - HR_{min}}{NT} \quad \text{(Eq. 1)}$$

where HR_{max} is the maximum heart rate, HR_{min} is the heart rate after 1 minute of recovery, and NT is the total number of throws.

The SJFT relative index RI_{SJFT} was obtained by dividing I_{SJFT} by the judo athlete´s body mass (in kilograms), as recommended by Isik et al [8].

Calculation of aerobic and anaerobic energy contributions from SJFT

The anaerobic alactic contribution (*AAC*) was calculated by the analysis of the fast component of excess post-exercise oxygen consumption ($EPOC_{fast}$) by a mathematical expression. In the present study, we fitted the kinetics of post-exercise oxygen consumption to a bi-exponential decay and used the exponential indicators of the faster decay, according to Eq. 2 [12]:

$$AAC = A_1 \times T_1 \quad \text{(Eq. 2)}$$

where, and correspond to the amplitude and time constant of the faster exponential decay, respectively [12, 13].

The anaerobic lactic contribution (ALC) was calculated using Eq. 3. In this case, it was considered that a blood lactate concentration of 1 $mmol·L^{-1}$ corresponds to 3 $mLO_2·kg^{-1}$ to calculate the ALC in terms of the volume of O_2 consumed during the SJFT [11].

$$ALC = 3 \times BM \times \left(Lac_{peak} - Lac_{rest}\right)/1000 \quad \text{(Eq. 3)}$$

Where BM is the body mass, the Lac_{peak} is the lactate peak after the test, and the Lac_{rest} is the lactate during resting.

The sum of the AAC and the ALC was considered as the total anaerobic contribution (TAC). Knowing the total effort time during the test, the volume of oxygen consumed in rest (VO_{2rest}), the maximum oxygen uptake after the test (VO_{2peak}) and the TAC, is possible to calculate the aerobic contribution (AC) (Eq.4) [12, 14, 15]:

$$AC = \left(VO_{2peak} - VO_{2rest}\right) \times TE. \quad \text{(Eq. 4)}$$

A caloric equivalent of 20.9 kJ per liters of O_2 was considered for the three energy systems to convert litres to kJ [13].

Statistical analysis

ANOVA one-way repeated measures with Tukey Post-Hoc were conducted to determine whether there were statistically significant differences between groups and variables over the SJFT. There were no outliers, and the data was normally distributed at each time point, as assessed by boxplot and the Shapiro-Wilk test ($p>0.05$), respectively. The assumption of sphericity was assessed by Mauchly's test of sphericity. Pearson's product-moment correlation was run to assess the relationship between dependent variables over SJFT. For all tests, the SPSS statistical package (IBM Statistics for Windows, version 21.0) was used and the significance level was assumed as $p<0.05$.

RESULTS

Regarding the relative index, a significant difference was observed only in group G_{10-12} when compared to the other groups. No differences were evidenced in the number of throws in separate efforts (A, B and C) or total efforts. The G_{10-12} obtained results classified in the SJFT follows [7]: index "REGULAR", HR_{max} "REGULAR", $HR_{after1'}$ "GOOD", and total throws "REGULAR". For G_{13-14}: index "EXCELLENT", HR_{max} "GOOD", $HR_{after1'}$ "EXCELLENT", and total throws "REGULAR". For G_{15-17}: index "GOOD", HR_{max} "GOOD", $HR_{after1'}$ "REGULAR", and total throws "REGULAR". Finally for $G_{>18}$: index "GOOD", HR_{max} "POOR", $HR_{after1'}$

Table 2. All variables obtained by the SJFT.

Variable	G_{10-12} n = 6	G_{13-14} n = 9	G_{15-17} n = 6	$G_{>18}$ n = 5
Throws set A (15 s)	5.5 ±0.5	6.0 ±0.5	5.8 ±0.4	6.2 ±0.4
Throws set B (30 s)	10.0 ±1.2	10.4 ±1.2	10.7 ±0.5	11.2 ±1.7
Throws set C (30 s)	9.0 ±0.9	9.9 ±0.8	9.9 ±0.7	9.4 ±1.7
Total throws	24.5 ±2.3	25.9 ±2.2	26.4 ±0.9	26.8 ±3.8
HR_{max} (bpm)	176.3 ±33.6	164.2 ±25.0	172.9 ±24.7	181.2 ±6.3
HR_{after1}'(bpm)	145.2 ±34.6	125.4 ±25.7	147.1 ±25.1	146.4 ±9.5
I_{SJFT} (AU)	13.3 ±3.5	11.2 ±1.9	12.1 ±1.8	12.4 ±1.7
Relative Index (AU)	0.36 ±0.12	0.22 ± 0.05*	0.16 ±0.03*	0.15 ±0.03*
Metabolic variables				
$[La^-]_{rest}$ (mmol. L^{-1})	1.20 ±0.54	1.15 ±0.42	1.17 ±0.48	1.26 ±0.48
$[La^-]_{peak}$ (mmol. L^{-1})	11.2 ±2.5	12.3 ±1.4	13.2 ±2.3	16.0 ±1.8*§
ΔLac (mmol. L^{-1})	10.0 ±2.2	11.1 ±1.4	12.0 ±1.8*§	14.8 ±2.4*§
VO_{2rest} (mL.min^{-1})	270.5 ±51.2	378.1 ±54.6	439.9 ±84.2	479.7 ±148.1
VO_{2peak} (L.min^{-1})	1.90 ±0.35	2.71 ±0.51*	3.33 ±0.29*§	3.35 ±0.36*§
VO_{2peak} (ml.kg.min^{-1})	50.3 ±4.7	53.2 ±6.0	44.8 ±8.6	41.9 ±12.8

A (15"); B (30"); C (30"); **HR_{max}** maximum heart rate attained during SJFT; **HR_{after1}** heart rate after 1 minute; ***** indicates a significant difference with G_{10-12} ($p<0.05$); § indicates a significant difference with G_{13-14} ($p<0.05$); **HR_{max}** maximum heart rate; **HR_{after1}**' heart rate 1 minute after the test; I_{SJFT} Index of the test; Relative Index relative to weight; **$[La^-]_{rest}$** blood lactate concentrations in rest; **$[La^-]_{peak}$** blood lactate concentrations peak; ΔLac difference between lactate peak and lactate rest; **VO_{2peak}** maximum consumption of oxygen after the test.

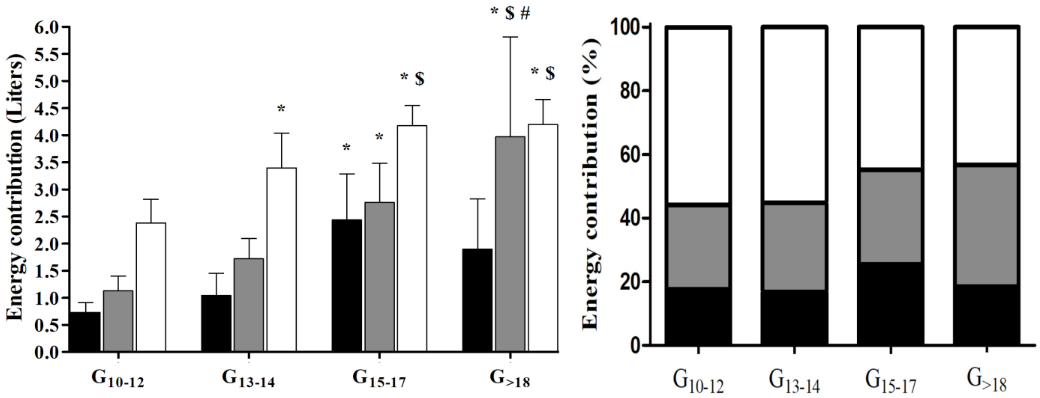

Figure 1. The left panel shows the comparison of the absolute values of the evaluated energy systems for all the studied groups. The right panel presents the same analysis in terms of percentage values. Symbols L *, $, and # are associated with the significant differences for G_{1012}, $G_{13\text{-}14}$, and G_{1517}, respectively; p < 0.05; white, grey and black bars correspond to aerobic, anaerobic lactic, and anaerobic alactic contributions, respectively.

"REGULAR", and total throws "REGULAR". In relation to predicted maximum heart rate (220-age), the participants in $G_{10\text{-}12}$ achieved 84.7 %, $G_{13\text{-}14}$ 79.6 %, $G_{15\text{-}17}$ 84.6 % and $G_{>18}$ 90.6 % of the predicted maximum heart rate.

No differences were observed in $[La^-]_{rest}$. However, a significant difference was found between the groups for the $[La^-]_{peak}$. Statistical differences were observed in $\Delta[La^-]$, with $G_{15\text{-}17}$ and $G_{>18}$ achieving higher values than the younger athletes. For VO_{2peak}, statistical differences were observed in absolute values; all groups were different when compared with $G_{10\text{-}12}$ (p<0.05), and $G_{15\text{-}17}$ and $G_{>18}$ were statistically different from $G_{13\text{-}14.}$ No differences were observed in VO_{2rest}.

The energy contributions measured during the SJFT are described in absolute values and percentage values in Figure 1. In relation to the total energy expenditure during the test, significant differences were identified among groups. $G_{10\text{-}12}$ achieved 4.0 **±0.5** L; $G_{13\text{-}14}$ achieved 6.0 **±1.1** L; $G_{15\text{-}17}$ achieved 9.5 **±1.0** L, and $G_{>18}$ achieved values of 10.00 **±2.0** L. The energy expenditure in kJ during the test for $G_{10\text{-}12}$ was 88 **±9** kJ; $G_{13\text{-}14}$ was 129 **±2** kJ; $G_{15\text{-}17}$ was 197 **±28** kJ, and $G_{>18}$ was 210 **±5** kJ. The metabolic efficiency was also significantly higher among groups; $G_{15\text{-}17}$ (6.7 ±2.5 kJ/throw) was higher than $G_{10\text{-}12}$ (3.6 ±0.5 kJ/throw) p<0.05; $G_{>18}$ (8.0 ±2.0 kJ/throw) was also significantly higher than $G_{10\text{-}12}$ and $G_{13\text{-}14}$ (5.0 ±1.0 kJ/throw) p<0.05.

A strong correlation (r = 0.90, p<0.05) was found between the anaerobic lactic contribution and I_{SJFT} in $G_{>18}$ and moderate correlation (r = 0.68, p<0.05) between anaerobic alatic contribution and I_{SJFT} in $G_{13\text{-}14}$ (Table 3).

A strong inverse correlation was found between the aerobic power (VO_{2Peak}) and the $RI_{SJFT,}$ (r= −0.81; p<0.001), furthermore, when correlating age with AAC, a correlation of r = 0.69 was found with p<0.0001 (Figure 2).

Table 3. Values of Pearson correlation between the Index and anaerobic variables assessed during the SJFT.

Variable	I_{SJFT} $G_{10\text{-}12}$	I_{SJFT} $G_{13\text{-}14}$	I_{SJFT} $G_{15\text{-}17}$	I_{SJFT} $G_{>18}$
AAC (L)	0.27	−0.18	0.68*	0.26
ALC (L)	0.10	0.12	0.11	0.90*
TAC (L)	0.34	−0.04	0.59	0.42
ΔLAC (mmol.L^{-1})	0.29	0.47	0.18	0.32
LAC_{peak} (mmol.L^{-1})	0.44	0.53	0.23	0.44

AAC: anaerobic alatic contribution; **ALC:** anaerobic lactic contribution; **TAC:** total anaerobic contribution; **ΔLAC:** difference between the lactate peak and lactate rest; **LAC_{peak}:** major lactate value after the test; * p<0.05.

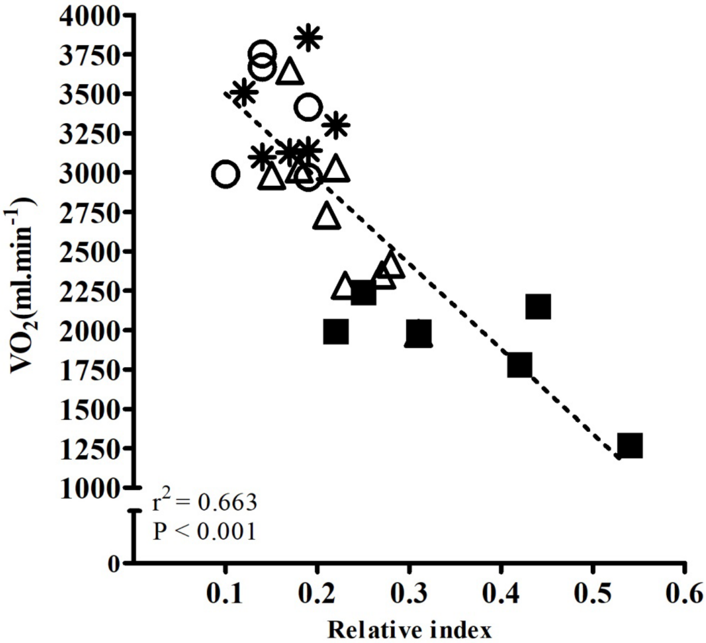

Figure 2. Correlation between relative index and VO_{2peak}. r = –0.81; p<0.001. Symbols: ■, Δ, and *, ○ represent G_{10-12}, G_{13-14}, G_{15-17}, and $G_{>18}$ groups, respectively.

DISCUSSION

The aim of this study is relevant because if a test cannot differentiate athletes of different ages and with different physiological profiles, the results of this test should be analysed with caution when comparing young athletes. We hypothesized that I_{SJFT} would be statistically different among groups and this would correlate with the total anaerobic contribution. However, no statistical differences were observed in I_{SJFT} results among groups, thus the partial rejection of our hypothesis. However, when the comparison was performed with RI_{SJFT}, significant differences were observed among older groups against G_{10-12} (p<0.05). For the metabolic variables, the VO_{2peak} ($L.min^{-1}$) values obtained immediately after the SJFT were significantly higher in the older groups in comparison with G_{10-12} and with G_{13-14}, and ΔLac (p<0.05) among older groups and G_{10-12} and G_{13-14}. Thus the RI_{SJFT} seems to be a better variable to compare young athletes than the traditional I_{SJFT}.

Interestingly, significant differences were found between aerobic contribution values, noting that group $G_{>18}$ had higher aerobic contribution values when compared to groups G_{10-12} and G_{13-14}. Similarly, group G_{15-17} showed higher energy contribution values than groups G_{10-12} and G_{13-14}. For ALC, $G_{>18}$ was significantly higher in relation to all groups, whilst G_{15-17} was significantly higher than the younger groups. Finally, the value of AAC was statistically higher between G_{15-17} and G_{10-12}. Regarding the Pearson correlations between the I_{SJFT} and anaerobic variables, significant correlations were observed in AAC (G_{15-17}) and ALC ($G_{>18}$), and an inverse correlation between VO_{2peak} ($ml.kg.min^{-1}$) and relative index in all cases, and these correlations were classified as a strong correlation.

The first study to measure the energy contributions during SJFT was performed by Franchini et al. [14]; the authors analysed 14 adult judo athletes with a mean age of 19 years and all subjects were judo black belts. The authors found TAC values of 71 %, which highlight the substantial importance of anaerobic metabolism during the SJFT. These data corroborate the findings of our study, wherein our control group ($G_{>18}$) presents about 58 % of energy for SJFT resulting from anaerobic metabolism. These differences in results can be attributed to differences in training status between the subjects [12, 14]. However, in the simulated combat lasting 2 minutes (the approximate SJFT duration), the energy contribution achieved different values than observed in the SJFT, and in this approach, the aerobic metabolism appears predominant rather than the anaerobic, with 60 % of energy for this metabolic demand [1]. Currently, there is a scientific lacuna regarding the energetic contribution in SJFT comparison in judo athletes at different ages, thus this study is the first to analyse the energy contribution during SJFT in different ages, and our results show that in athletes less than 15 years of age, the SJFT cannot be considered a test with anaerobic predominance.

In our study, for the blood lactate concentration values, $G_{>18}$ was significantly higher than $G_{10\text{-}12}$ and $G_{13\text{-}15}$ whilst no differences were observed with $G_{15\text{-}17}$. The increase of [Lac] corroborates with evidence found in the literature which evidenced that after simulated combats (~5 minutes) [Lac] achieved values of 18.12 ±4.40 mmol.L in Spanish high-level judo athletes, with similar values to our study being 16.0 ±1.8 mmol.L in $G_{>18}$ [16, 17]. When analysing Δ[Lac], the results were markedly different, and the older groups ($G_{15\text{-}17}$, $G_{>18}$) were significantly higher than the younger. These differences can be attributed to the possibility of the participants being classified in differences in maturational status.

As human growth occurs, the aerobic power expressed in litres increases throughout adolescence as evidenced in our results, and the relative aerobic power seems not to differ because bodyweight develops in parallel to growth, thus relative aerobic power is not a good variable to compare adolescents of different ages [18].

The I_{SJFT} is commonly used as an indicator of anaerobic performance in adults, as it has been correlated to Wingate performance (I_{SJFT} and total work during the Wingate test, r = −0.71) [3, 19]. It is important to emphasize that a higher I_{SJFT} indicates a poor SJFT performance and this test has been shown to be highly reliable [8], however, in the present study no correlation between anaerobic variables and I_{SJFT} were found, indicating that probably in young judo athletes we have to be cautious to interpret the SJFT variables and avoid using these variables to compare athletes of different ages.

The I_{SJFT} variables were not statistically significant among the groups, this result was also found by Courel-Ibanez et al. [9]. They compared three different groups of judo athletes, two groups of 12-13 years old (one competitive) and 13-15 years old with no significant difference between groups. However, in the relative index, $G_{10\text{-}12}$ has a significantly lower performance related to all groups. A study that analysed adult wrestlers obtained a relative index of 0.21 ±0.03, a similar result found in the present study [8, 14]. We found a strong inverse correlation between aerobic power and relative index (r = −0.81, p<0.05) and this was confirmed by Hezari et al. [18, 19] but with a correlation value of r = −0.87. High levels of aerobic power can be useful, because the participants performing the SJFT have to run between the *ukes*, and higher aerobic performance would improve the recovery energy storage in the intervals and increase tolerance for strenuous exercise. The I_{SJFT} in $G_{>18}$ was strongly correlated with ALC (r = 0.90 p<0.05) evidencing the anaerobic performance of the SJFT in adult athletes [3].

However, the fact that the methods presented for anaerobic evaluation are efficient in demonstrating significant age-related differences of the participants while I_{SJFT} is not, could leads to the conclusion that the SJFT variables is not the best test to evaluate young judo athletes of different ages. However, the relativization of the I_{SJFT} by the total weight is a strategy to identify differences in the test performance when comparing athletes in different ages with different physiological and metabolic characteristics.

Coaches who use the SJFT in young athletes must have caution when comparing young athletes of the same age or similar age to determine who athlete is more conditioning or in better performance using just the traditional variables of the test, the RI_{SJFT} [8] seems to be a better approach for specific evaluation in young athletes. The present study has the limitation of not having carried out the measurement of the maturational level of the participants.

CONCLUSIONS

Given the above discussions, we conclude for the comparison and use of the test in young athletes, we suggest relativizing the test index by the athlete's body weight, to compare the performance of athletes of different ages, since only the use of the index does not evidence age-related differences. However, further studies involving a comparison between SJFT variables and other tests are necessary to elucidate this new perspective.

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