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Original Article

DYNAMIC DISCRIMINATION: SJFT RESULT IN THE EVOLUTION OF STRENGTH AND POWER PERFORMANCE OF ELITE JUDO ATHLETES

DISCRIMINAÇÃO DINÂMICA: RESULTADO DO SJFT NA EVOLUÇÃO DO DESEMPENHO DE FORÇA E POTÊNCIA EM ATLETAS DE ELITE DE JUDÔ

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RESUMO
Objetivou-se verificar se o resultado do SJFT discrimina evolução de força e potência em atletas durante meia temporada. 22 judocas foram divididos em dois grupos (superior e inferior). Força e potência foram testadas por 1RM (agachamento, remada curvada e supino) e salto vertical (CMJ), pré e pós. O treinamento e respostas psicofisiológicas foram monitorados usando a PSE e Hooper *Index*. ANOVA *Two-way*, teste-t independente do % de mudança entre grupos e correlação entre as respostas psicofisiológicas e o % de mudança foram realizados. Não houve interações significativas grupo x tempo para todas as avaliações realizadas. Em relação ao % de mudança, 1RM da remada curvada e supino mostraram valores superiores para o grupo SJFT-inferior (superior = 4.3 ± 4.3%, inferior = 9.0 ± 5.6%; p = 0.05; superior = 4.3 ± 6.7%, inferior = 11.4 ± 12.0%; p = 0.03, respectivamente). Para o CMJ, o % de mudança do grupo SJFT-superior foi maior (superior = 19.5 ± 10.4%; inferior = 11.5 ± 12.4%; p = 0.02). CMJ x respostas psicofisiológicas mostrou uma correlação significativa (r = 0.47; p = 0.01). Assim, ganhos de força em testes de 1RM podem não diretamente refletir melhoria de desempenho específico do SJFT em meia temporada competitiva.
Palavras-chave: Aptidão física; Monitoramento neuromuscular; Monitoramento fisiológico.

ABSTRACT
We aimed verify if the SJFT baseline result could differentiate the rate of evolution of strength and power performance in high-level judo athletes in a half-season. 22 participants were divided into SJFT groups according to specific table. Strength and power were tested by one maximum repetition (1RM) of back squat, curved row, bench press and countermovement jump (CMJ), pre and post six months. Training and the psychophysiological response were recorded every session using the rate of perceived exhaustion. Repeated-measures ANOVA, independent t-test of the %change between groups and Pearson's *r* between the psychophysiological response and %change was done. There were no significant group x time interactions for all neuromuscular tests used, psychophysiological response, Hooper Index and SJFT. Regarding the %change between groups, the 1RM curved row and the 1RM bench press showed higher values for the low SJFT group (High group=4.3±4.3%; Low group=9.0±5.6%; *p*=0.05; High group=4.3±6.7%; Low group=11.4±12.0%; *p*=0.03, respectively). For the CMJ, the %change of the high SJFT group was higher (High group=19.5±10.4%; Low group=11.5±12.4%; *p*=0.02). Finally, only the CMJ x psychophysiological response showed a significant correlation (r=0.47; *p*=0.01). Thus, gains in muscle strength in 1RM tests may not directly reflect a SJFT performance improvement along a half-competitive season.
Keywords: Physical fitness; Neuromuscular monitoring; Physiological monitoring.

Introduction

In sports, monitoring athlete's performance over time is essential to guide training prescription[1]. In sports like judo, which involve complex actions and high physical and technical demands, the use of different assessments such as 1RM, vertical jump tests and the Special Judo Fitness Test (SJFT) could help distinguish between athletes of different skill levels[2]. Although specific assessments are of special challenge due to inherent technical and physical complexity[3,4], its use has been widely suggested in the training scenario. In judo, both strength and power development represent key elements in the competitive performance[2,5], with upper limb dynamic strength discriminating judo athletes from different competitive levels[6].

Thus, the increase in strength and power production might benefit athletes in terms of competitive performance.

To replicate the high-intensity intermittent nature of judo, several sport-specific tests have been developed[7,8]. Among these, the SJFT has been validated as a reliable measure of physical performance in judokas[9]. The SJFT mainly resembles the anaerobic metabolism[10]. Additionally, the numbers of throws in the SJFT significantly correlated with the countermovement jump height ($r = 0.74$), even though physical attributes contribute less than 60% of the variation in the SJFT performance[11]. These results may be due to sample heterogeneity, once specific tests must consider technical aspects[3]. However, it is still unknown whether in a homogeneous group of high-level athletes, the SJFT would discriminate neuromuscular tests performance along a competitive season.

There is evidence that the total number of throws in SJFT is related to the anaerobic fitness due to power generation necessary to execute judo throws as well as the required sprints between throws. Consequently, any improvement in the total number of throws is related to an increase in at least a 6-m run and one throw during the test. Considering that the total duration of effort during the SJFT is 75 s, and that during the test, athletes need to accelerate, decelerate, throw the opponent while changing direction, and accelerate again, an improvement in the total number of throws may be the result of increased speed, muscle power, and agility, either isolated or in combination[12]. Authors have identified the standing long jump and handgrip strength test performance could explain 23% and 31% of the variance in the SJFT performance in boys and girls, respectively[13]. In this sense, the development of muscular strength can contribute to improving performance in SJFT. A previous study identified strength improvement in adult judo athletes after strength training for 8 weeks with transference to SJFT: (block A = 16.5%; block B = 11.3%; sum of 3 blocks = 8.3%, heart rate after 1-minute = 27.0%; and index = -12.5%)[14].

Therefore, this study aims to 1) verify whether athletes with higher or lower scores in the SJFT may present different changes in maximal strength (1RM test) and countermovement jump and 2) verify if the performance change will also be affected by the psychophysiological response to the training physical demands. It is hypothesized that athletes with better SJFT at baseline are also the ones that are going to show the greatest improvement in physical tests.

Methods

Subjects

Twenty-two non-probabilistic sample of judo high-level athletes (13 males and 9 females; age: 22.0 ± 2.0 years; weight: 68.5 ± 16.6 kg; height: 170 ± 6 cm) took part in this study. The training experience was 10 ± 2 years. All athletes had significant national and international titles in their careers, including World, Pan-American and Brazilian championships, and state tournaments. Moreover, the athletes were training regularly (16 ± 4 hours per week) and were absent from musculoskeletal injuries in the 6 months prior to the study. Subjects reported not taking any medication or drugs and nor had any acute illness or infection during data collection. All procedures were approved by the Universidade Federal de Minas Gerais (protocol 12210219.7.0000.5149). The subjects received written instructions describing all the procedures, risks, and benefits related to participation in the study and after reading signed an informed consent form.

Experimental design

A prospective longitudinal study was conducted over half a season. At the beginning of the season and after 6 months, we collected data on the SJFT, one repetition maximum load (1RM) for the Bench Press, Curved Row, Back Squat, and the vertical countermovement jump height (CMJ). Furthermore, during all sessions, psychophysiological stress was assessed using the session ratings of perceived exertion (RPE). In addition, the athletes were divided into two groups based on their SJFT performance. The HIGHER SJFT group ($SJFT_H$) corresponded to the Good and Excellent (n=11), and the LOWER SJFT group ($SJFT_L$), corresponded to the Regular, Poor, and Very poor (n=11)[15]. All the pre- and post-tests were conducted in the same location (i.e., the athletes' habitual training space), always aiming to maintain the most identical conditions possible. The athletes completed the tests over two days, separated by 24 hours. The first day was dedicated to performing the SJFT, while the second day was reserved for the CMJ and 1RM tests.

Special Judo Fitness Test

During the SJFT, two Ukes (thrown athletes) were placed 6m apart, and a Tori (a person who executed the throw) had a starting position 3m apart from each Uke. These two Ukes had similar body masses to the Tori. At the beep, the Tori ran toward one Uke and executed the *ippon-seoi-nage* throw and then immediately ran toward the other Uke performing the same throw. The Tori was instructed to complete as many throws as possible at the given time.

The test was divided into three sets (A, B, C) with a recovery period of 10s between sets. The first set (A) lasted 15s, whereas the other two sets (B and C) lasted 30s. Heart rate (HR) was recorded immediately (HR_{FINAL}) and 1min after the test ($HR_{1\text{-}MIN}$) (Polar S810i, Finland). A physical performance index was calculated by summing the HR_{FINAL} and the $HR_{1\text{-}MIN}$ and dividing the resulting value by the number of throws executed during the three sets. A lower performance index means higher physical performance[15].

Vertical Countermovement Jump Hight

Athletes performed the vertical countermovement jump (CMJ) on a contact mat with 0.1 cm precision (Hidrofit® Ltda, Brazil), connected to Multisprint software (Hidrofit® Ltda, Brazil). Athletes were instructed to place their feet in a parallel position on the mat, with hands resting near the iliac crest, head up, and looking forward. They were required to keep their hands on the iliac crest and extend their knees during the flight phase. Upon hearing the "jump" command, the athletes immediately flexed their knees and jumped vertically as high as possible. Each athlete performed five jumps, and the mean value was used for analysis. The vertical CMJ has been shown to be a reliable measure with a low coefficient of variation in athletes[16].

One Repetition Maximum

The 1RM procedures were the same for the back squat, curved row, and bench press, separated by 10min of rest between exercises. Participants completed an initial set of 8–10 repetitions with the bar load only (20 kg), followed by 5–6 repetitions at 50% of the estimated 1RM. This was increased to 70% of the estimated 1RM for 3–5 repetitions and, 90% estimated of 1RM for a single repetition. Then, the researcher dictated incremental load increases until 1RM was achieved using a proper technique. Achievable load increases were selected to attain a valid RM within 3 to 5 attempts. If an attempt failed, the load was decreased until a single repetition was completed. Each series of repetitions throughout the protocol was interspaced with 3–5 minutes of rest[14].

Psychophysiological Responses

At the end of each training session, the athlete reported value on the perceived exertion of the session (RPE session) scale that covers the range of 0-10[17]. The psychophysiological response was the product of the subjective value of the RPE session and the duration of training in minutes and expressed in arbitrary units[17], and was presented as the monthly sum average (± standard deviation).

Hooper Index

We evaluated subjective self-reported wellness measures through a customized questionnaire comprising four subsets, the perceived sleep quality and quantities of stress, muscle fatigue, and muscle soreness. As an overall wellness measure, the Hooper-Index is the sum of its four subsets[18]. The individual daily data (Hooper Index) were averaged to present the monthly group mean (± standard deviation).

Physical training program

The athletes underwent 104 physical training sessions divided into strength, power, and endurance, complementary to the technical-tactical sessions over 26 weeks (Table 1).

Table 1 - Strength, power, and endurance training sessions were performed over the 26 weeks of the training program.

Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Total
Maximal Strength		2	3	3	4	2		1	1	2	3	3		2	3	4					3	3	2	3		1	45
Muscle Power (50% 1 RM - 70% 1 RM)			2					2	2	2			2	1	1		2	4	2				2	1	1		24
Muscle Power (<50% 1 RM)							1										2			2					1	2	8
Plyometrics								1	1					1	1								1	1			6
Endurance Training		2	2	2	2	2					2	2		1				1	2	1					2		21

Source: Authors

Statistical Analysis

Before the inferential analysis, data normality and homoscedasticity were tested using Shapiro-Wilk and Levene tests, respectively. A two-way repeated-measures ANOVA compared the performance variables and physiological responses at the pre and post-half season. When a significant F value was obtained, Bonferroni's post hoc was used. Independent Student T-Tests were performed to compare %change in the pre and post-half-season performance variables. Pearson's correlation coefficient measured the correlation between the sum of psychophysiological responses and %change performance variables. The correlation magnitude was classified from the value of r, with values <0.3 considered small, 0.3 - 0.5 moderate, 0.5 - 0.7 high, and> 0.7 very high[19,20]. A significance level was set at 5% for all inferential analyzes. Data were analyzed and plotted using the statistical package Graph Pad Prism™ (version 8.0, GraphPad Software, San Diego, CA, USA).

Results

SJFT throws showed a main group effect, once the $SJFT_H$ showed higher values ($F = 58.84$; $p < 0.0001$; Table 2). However, no statistically significant interactions (group x time) were observed ($F = 1.201$; $p = 0.27$). When compared the %change between groups (Figure 1E), no significant differences were observed ($SJFT_H$ %change = 0.1 ± 4.4%; $SJFT_L$ %change = 0.6 ± 7.1%; $p = 0.46$).

Table 2 - Performance Test

	$SJFT_H$		**$SJFT_L$**	
	PRE	**POST**	**PRE**	**POST**
SJFT Throws	31 ± 1.3*	30 ± 1.1	27 ± 0.9	27 ± 2.1
SJFT Index	10.73 ± 0.65*	11.10 ± 0.87	12.51 ± 0.68	12.40 ± 1.19
1RM load (kg)				
Curved Row	86 ± 17	91 ± 19	76 ± 24	83 ± 25
Bench Press	97 ± 28	100 ± 26	81 ± 32	90 ± 32
Back Squat	132 ± 35	133 ± 28	110 ± 27	117 ± 39
CMJ height (cm)	36.8 ± 4.6*	44.5 ± 6.9#	33.05 ± 4.47	36.85 ± 6.63

Notes: Denotes statistical group's main effect. # Denotes statistical difference in %change ($p<0.05$). SJFT: Special Judo Fitness Test. $SJFT_H$: High-level group. $SJFT_L$: Low-level group. 1RM: One maximum repetition. CMJ: Countermovement Jump.
Source: Authors.

Regarding the SJFT index (Table 2), a significant main group effect was observed, in which the $SJFT_H$ showed lower values ($F = 33.72$; $p < 0.0001$). However, no statistically significant interactions (group x time) were observed ($F = 0.823$; $p = 0.36$). When compared the %change between groups (Figure 1F), no significant differences were observed ($SJFT_H$ %change = 1.5 ± 6.3%; $SJFT_L$ %change = -2.3 ± 8.1%; $p = 0.33$).

The 1RM curved row showed no statistically significant interactions (group x time) along the half-season ($F = 0.023$; $p = 0.87$, Table 2). But when comparing the %change between groups (Figure 1A), a significant difference was observed, with higher changes for $SJFT_L$ ($SJFT_H$ %change = 4.3 ± 4.3%; $SJFT_L$ %change = 9.0 ± 5.6%; $p = 0.05$).

The 1RM bench press showed no statistically significant interactions (group x time) during the half-season ($F = 0.112$; $p = 0.73$, Table 2). But when comparing the %change between groups (Figure 1B), a significant difference was observed, showing higher changes for $SJFT_L$ ($SJFT_H$ %change = 4.3 ± 6.7%; $SJFT_L$ %change = 11.4 ± 12.0%; $p = 0.03$).

The 1RM back-squat showed no statistically significant interactions (group x time) during the study period ($F = 0.085$; $p = 0.77$, Table 2). Also, when compared the %change between groups (Figure 1C), no significant difference was observed ($SJFT_H$ %change = 2.6 ± 8.5%; $SJFT_L$ %change = 5.3 ± 9.0%; $p = 0.22$).

Regarding the CMJ a significant main group effect was observed, with the $SJFT_L$ showing lower values compared to $SJFT_H$ ($F = 12.54$; $p = 0.001$). However, no statistically significant interactions (group x time) were observed throughout the half-season ($F = 0.133$; $p = 0.25$, Table 2). When comparing the %change between groups (Figure 1D), a higher change was observed for the $SJFT_H$ ($SJFT_H$ %change = 19.5 ± 10.4%; $SJFT_L$ %change= 11.5 ± 12.4%; $p = 0.02$).

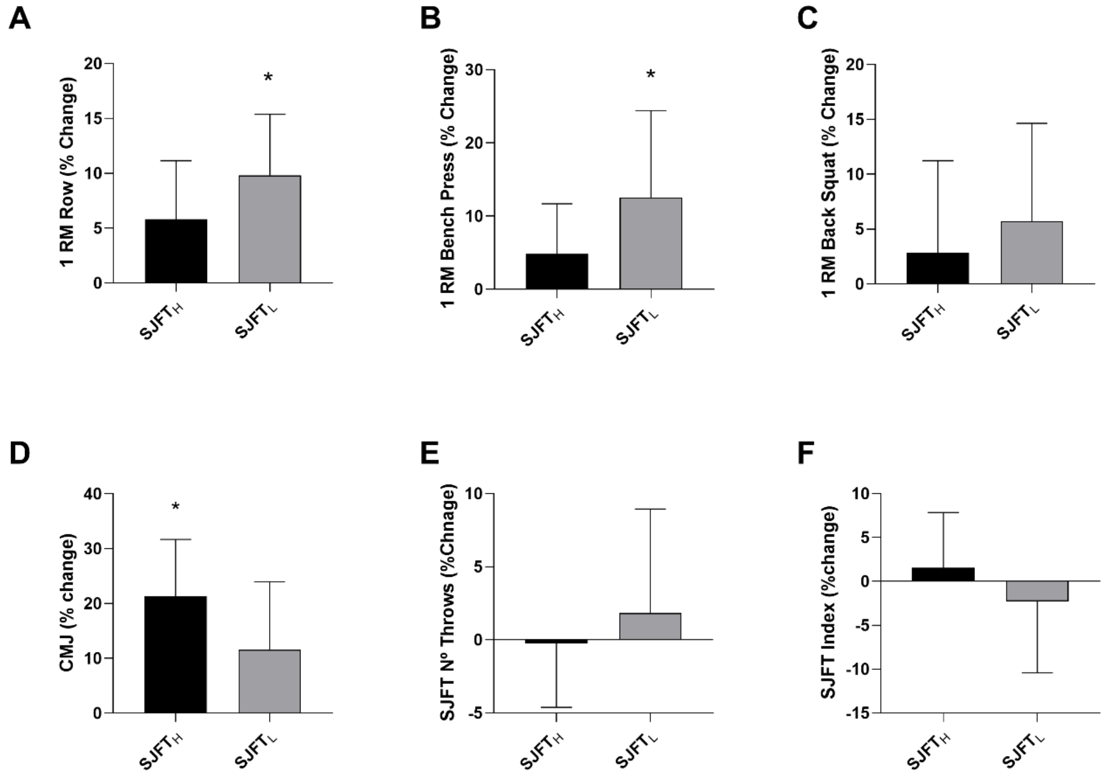

Figure 1: The percentual of change in 1RM loads for the Curved Row (A), Bench Press (B) and Back Squat exercises; (C), CMJ height; (D), SJFT throw number (E) and SJFT index (F), respective to the pre-mid-season. CMJ: countermovement jump, 1RM: one repetition maximal load, SJFT: Special Judo Fitness Test. *denotes statistical difference (p<0.05).
Source: Authors.

The psychophysiological response showed a main time effect, once the first month showed lower values for both groups (F = 23.10; p < 0.0001; Figure 2A). However, no statistically significant interactions (group x time) were observed (F = 0.466; p = 0.80). The Hooper Index showed no significant interactions (group x time) throughout the half-season (F = 0.150; p = 0.97; Figure 2B). For the correlations realized, 1RM curved row x psychophysiological response (r = -0.32; p = 0.07; Figure 2C), 1RM bench press x psychophysiological response (r = -0.09; p = 0.33; Figure 2D), 1 RM back squat x psychophysiological response (r = 0.16; p = 0.23; Figure 2E), only the CMJ x psychophysiological response showed a significant value (r = 0.47; p = 0.01; Figure 2F).

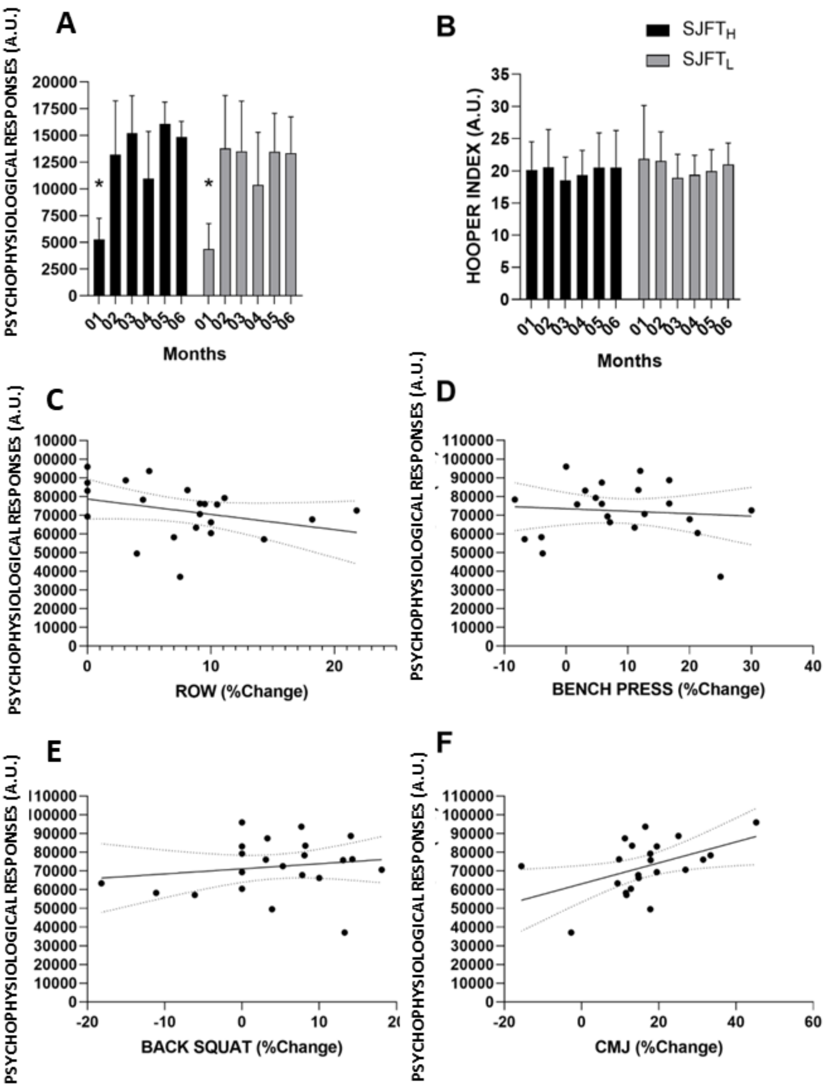

Figure 2: The comparison of psychophysiological responses (A), and Hooper Index throughout the pre-mid-season. Correlation between psychophysiological responses and respective change (%) to pre-mid-season of Row (C), Bench Press (D), Back Squat (E), CMJ (D). Note: A.U: arbitrary units, CMJ: countermovement jump, RM: maximal repetition, black bars: higher SJFT group, grey bars: lower SFJT group. *denotes statistical difference (p<0.05).

Source: Authors.

Discussion

The present study aimed to verify if the SJFT baseline score could differentiate the rate of evolution of strength and power performance in high-level judo athletes and if the performance change will also be affected by the psychophysiological response. We observed that for the $SJFT_L$ group, the % change of 1 RM for the upper limb had a significantly higher performance improvement than the $SJFT_H$ group. In contrast, only the $SJFT_H$ group showed a significantly greater performance improvement in the CMJ. In addition, the psychophysiological response showed a significant and positive association with the % change in CMJ over the half-season. However, there were no differences regarding the SJFT performance between groups, despite a significantly increase in upper limb's strength for the $SJFT_L$ group. The initial hypothesis was not confirmed by the results, since only the $SJFT_L$ group presented significant %changes in the generic tests, except for the CMJ height.

The result of our study shows that only the $SJFT_L$ presented statistically significant evolutions (%change) in the upper limb's strength compared to the higher one, which may be explained by the trainability window phenomenon. This phenomenon states that those people with the lowest strength levels are the ones that tend to have higher rates of evolution[21]. Furthermore, there were no baseline differences regarding upper limb's maximal strength between groups. The fact that the SJFT classification used divided both groups (i.e. High and Low-level group), reinforces that although there were no differences in generic tests, the use of a specific one might be advantageous to identify muscle weakness, guide training regimen and differentiate high to low-level athletes[22].

Regarding SJFT performance, there were no differences between groups for the SJFT index or number of throws at the end of the study. Another study with a similar training period and subjects also failed to show significant differences in SJFT after a specific periodization for judo, despite showing substantial evolution of muscle strength[23]. The SJFT encompasses a *nage-waza* (i.e. throwing technique) considered as an arm/shoulder technique (*ippon-seoi-nage*). However, although significant %change in the $SJFT_L$ group for the upper-limb maximum strength, it was not possible to see improvements in the test. Likewise, the $SJFT_H$ group, even though with a better baseline score, did not present any improvement in the SJFT performance along the study time. The SJFT is predominantly anaerobic and considering all the dynamic actions involved, an improvement in the total number of throws may be the result of increased maximal strength, speed, muscle power, agility and technical aspects[3,12]. In our study, the percentage of evolution in generic tests, despite close to that found in other studies[23-25], were not enough to improve the SJFT performance. Possibly, the training period was not enough to allow a transfer to specific performance improvement detectable by the SJFT, and/or the SJFT may not be sensitive enough to reproduce similar improvements in muscle strength as identified in generic tests. Moreover, technical aspects regarding the velocity of execution of the *ippon-seoi* technique should be target of attention during the training process of the athletes to improve the technique skill of the movement[26].

In addition, only the $SJFT_H$ group demonstrated improvements in the %change of CMJ performance. We hypothesized that the lack of improvement in the $SJFT_L$ might relate to the specific low levels of performance in the SJFT prior to the study, as the magnitude of adaptations might be assigned to the neuromuscular status of the athletes[27]. It's known that athletes must apply high force and power production in a short time during applications of throwing techniques[28]. Thus, the use of a specific ballistic training approach aiming to contribute to power development is crucial to the modality, especially related to the improvements in specific tasks such as the SJFT.

Furthermore, both groups showed a comparable psychophysiological response and Hooper index, showing that the training stimuli were perceived similarly by the subjects. The appropriate training load monitoring is an important factor contributing to performance enhancement, since it allows for better visualization of an athlete's response to the training program and thus acts potentially at reducing injury risk and functional overreaching[29]. In addition, the CMJ %change was positively related to the psychophysiological response. Considering different monitoring tools, it's possible that the CMJ was the most sensitive measure related to the employed training load during the half-season when compared to bench press, row, and back squat[30]. This is evidenced in other studies where the force evaluated by 1RM bench press and back squat did not show improvements in-season of rugby players[31]. This fact can be related to both a lack of sufficient stimuli during in-season training, which in turn could optimize the force-velocity characteristics or to a less sensitive testing approach regarding psychophysiological responses.

We state for future studies that a longitudinal investigation reporting competitive performance (e.g. wins or losses) related to the values of fitness tests over a season could be of great interest to coaches and athletes. Also, we reinforce that the total sample used in the study was completely composed of high-level athletes. In addition, the study was carried out during a competitive period, thus allowing a great ecological validity to similar environments of coaches and athletes during competitions. Finally, our study highlights the importance of evaluation and load control throughout a half-season to better identify the weakness of the athletes and to perceive the relationship between fatigue and recovery, allowing a good management of the training time in an individualized manner. Therefore, this approach might help to raise coaches and trainers' ability to predict the rate of adaptations in generic and specific tests to assess physical fitness of judo athletes.

Conclusion

We conclude that gains in muscle strength in generic tests may not directly reflect a SJFT performance improvement. Therefore, although specific tests such as the SJFT may detect competitive levels (e.g. high to low-level athletes), in our study it was not possible to detect performance change over time even with upper limb's muscle strength occurred. Moreover, a better baseline score of the SJFT does not represent an indicator of a greater improvement throughout the season in generic tests, reinforcing that even with high-level athletes, there must have an attention regarding both physical and technical aspects during the athlete's preparation and training routines. In addition, the CMJ performance may be useful to monitor neuromuscular function along a half-competitive season in judo athletes.

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