Original Article

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# The variability of strength production capacities during a judo contest

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

## Abstract

*Background.* The muscular response of athletes in a judo contest is one of the most important aspect to measure with precision. *Objective.* Our purpose was to obtain and analyse the variability of strength associated to muscular performance parameters during a judo contest. *Methods.* Thirty-five men performed five 5-minute bouts with 15 minutes of passive rest. Immediately after each bout, muscular performance parameters were tested: countermovement jump (CMJ), maximal dynamic strength capacities (mean power velocity (MPV), mean strength (MS), maximum strength (MXS), mean power (MP) and maximum power (MXP)) in upper body, dominant (DHS) and non-dominant handgrip isometric strength (NDHS). ANOVA to compare baseline test data and successive bouts was used. *Results.* ANOVA revealed significant differences in NDHS ($p<0.001$), DHS ($p<0.001$), CMJ ($p<0.001$), MPV ($p<0.001$), MXS ($p<0.001$), MP ($p<0.001$) and MXP ($p<0.001$). No significant differences in MS ($p = 0.008$) were found. Some significant correlations between NDHS and ΔPMX ($r=0.368$, $p=0.050$), MPV and ΔMXS ($r=0.528$, $p=0.001$) and ΔMXP ($r=0.683$, $p<0.001$), MPX and ΔMXS ($r=0.528$, $p=0.001$) and ΔMP ($r=0.877$, $p<0.001$) were found. *Conclusion.* Due to judo contest can be considered a high intensity exercise, it produces an amount of muscular fatigue and therefore significant loss strength that it cannot be recovery during rest-times between successive bouts. For this reason, it was a high variability in strength production capacities, which are modified during a judo contest.

**Keywords:** muscular performance parameters, muscular fatigue, judo contest, strength, strength variability

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# INTRODUCTION

An analysis of the specific demands of each sport is an indispensable starting point to establish and design intervention lines in training [1]. Specifically in judo, the underlying idea is the possibility of defeating opponents with greater physical strength [2]. With this theory, technical excellence means using strength, inertia and body balance abilities of the opponent against themselves [3-5]. In developing of grappling fight, one must unbalance the opponent, and in executing throwing judo techniques, high levels of muscular strength and endurance are required, involving the upper and lower limbs [6]. Throwing techniques are explosive actions that earn scores during the match and demand both lower- and upper-body power [1]. Therefore, professional preparation for judo matches calls for the development of force and the dynamic and explosive strength necessary for performing throws [7].

Analysing the specific leg actions in a judo match, constant explosive eccentric-concentric contractions (stretch-shortening cycle-SSC) [6] are observed. This kind of action generates a high mechanical load, producing great stress in muscle structures [8]. In addition, judo matches may induce fatigue in the lower limbs, which could probably be determined by a test involving SSC, such as a countermovement jump (CMJ) [9,10]. Thus, most of the match-time is spent in grip disputes, requiring high levels of isometric and dynamic strength-endurance, especially in the forearms [11]. Specifically, the grappling disputes during the match are maintained through forearm strength endurance [7], the high intensity technical actions executed to throw the opponent are related to lower-body muscle power [7,12], and immobilising movements involve whole-body maximal strength [13]. Thus, judo athletes need to develop a wide range of strength abilities to execute the technical actions needed to score during a match [2,7].

According with handgrip strength, one study [12] investigated the influence of 4 successive judo bouts of 5 minutes each one. In this study, a significant decrease in maximal isometric strength was found in both hands after the third and fourth matches, compared with baseline values. Another study of three 5-min simulated judo contests showed that a reduction in strength occurs from the second match onward, which indicated that strength and endurance are potential predictors of judo performance [14,15]. Besides, some authors [16] determine the evolution of muscular performance parameters during a judo contest, obtaining a loss strength percentage of 5.30% between the baseline test and postmatch 1 test in maximal power of upper limbs. Subsequently, in an official competition, it was obtained significant differences between prematch, postmatch 1 and 2 with postmatch 3 [7,12].

It is said that CMJ can be considered as an absolute indicator of lower limb muscle power [17] due to independency with the body size characteristics. Related to this capacity, results of assessment in Greek junior national athletes, as an indicator of this capacity in judoist of high level, show 26.0 ± 4.2 cm in a CMJ [18]. Besides, some authors [6] found a 3.6% (after $2^{nd}$ bout) and 3.2% (after bout $3^{rd}$) of decrease in CMJ values during successive judo bouts.

Several judo actions involved to maximum dynamic strength (MDS) on judo contest [7,12,19]. This capacity refers to move, with a high demand of velocity, an external load. In a comparison between Olympic and Paralympic judo players, Olympic athletes showed a higher value in MDS [20]. Specifically in a simulated judo contest [1], it was found a decrease after only a single judo bout in a comparison with the baseline test. Also, it was obtained that training programs of 8 weeks with linear and undulating protocols induced similar decrease in MDS during a simulated judo contest with 3 matches [16].

Taking into account some previous considerations [8], there are many actions with important strength implications, which take place in unfavourable metabolic conditions. This is one example of the high physical demands of a judo match. For this reason, the problem statement of this study is the necessity of knows with accuracy the evolution of strength capacities during a judo contest. Thus, the novelty of this study was the measurement of muscular performance parameters during an entire judo contest and further processing of data focused on finding differences. The main purpose of the current study was to obtain the variability of strength capacities values associated with muscular performance parameters during a judo contest, showing the percentages of loss and the effects on force production capacity. The hypothesis is that a judo contest will cause muscular fatigue and impair strength production in both the upper and lower limbs, producing variability in these capacities.

# METHODS

*Experimental approach to the problem*

The current study consists of a simulated judo contest with five 5-min successive matches, and 15-min of passive rest between each one. When an ippon was scored, the match continued until the end of match-time, taking into account other simulated judo contest protocols [16]. The simulated contest took place at the end of the mesocycle immediately before (approx. 2 weeks) an important tournament (such as the National Championship, European Cup, etc.). After familiarisation with the physical fitness test, subjects were submitted to a muscular performance test immediately after each match (at rest-time), consisting of maximal dynamic strength (MDS), handgrip isometric strength (HS) and countermovement jump (CMJ).

*Participants*

Thirty-five male judo athletes (age: 22.35±3.19 years; weight: 76.23±6.22 kg; height: 173.7±3.4 cm; body mass index (BMI): 23.41 ±1.89 kg/m$^2$; body fat: 10.47± 4.98%; muscle mass: 64.03±5.83%) voluntarily participated in this study. After receiving detailed information on the objectives and procedures, participants provided informed consent in accordance with the ethical standards established in the Declaration of Helsinki (2013). Subjects younger than 18 years old had to provide this informed consent signed by their parents. The study was approved by the local ethics committee and was conducted according to the European Community's guidelines for good clinical practice (111/3976/88; July 1990) and the Spanish legal framework for clinical research on humans (Real Decreto 561/1993 on clinical trials). For develop the simulated judo contest, groups of 6 judoist were established in a randomized way and taking into account that there could not be a difference greater than 10% in body weight between the judokas of the same group.

All participants were medalists in the National Championship in several age categories, and had at least 10 years of experience of judo and 4 years' experience of judo competitions. As an inclusion criteria, participants trained at least 8 hours per week, being national medalist in the 2 years previous to this study. On the contrary, as exclusion criteria, participants had not been injured for more than one week in the 3 months before the study. None were involved with any program for weight loss according to official weight category This fact could interfere with the result not only of the contest, but also of all test.

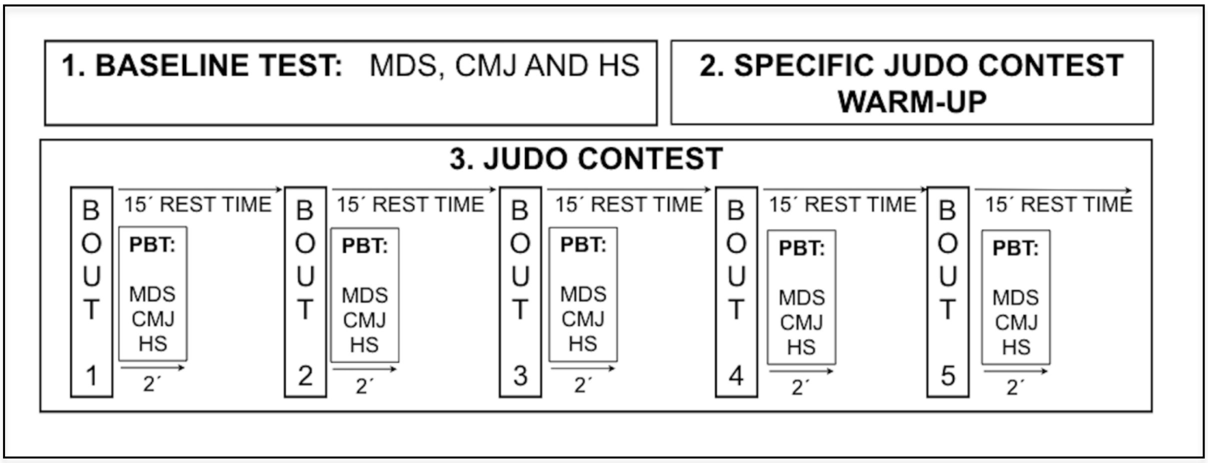


Figure 1. Planning of measures and test procedures in data collection; PBT: post-bout test; MDS: maximum dynamic strength; CMJ: counter movement jump; HS: handgrip strength; HR: heart rate; RPE: rate of perceived exertion; LAC: lactate.

*Procedures*

The current study was a repeated measures research (figure 1). In order to obtain the muscular performance impact, some strength parameters were assessed immediately after each match (MDS, CMJ and HS). Judo athletes were divided into weight groups so that there was a difference in body mass of less than 10% between athletes in a group [1,21]. Participants performed all physical tests one month before the simulated judo contest in order to become familiar with the test procedures. Also, on the day of the simulated contests they completed all the test of this study as a baseline reference. The protocol used was replicated in an official contest (weighing, warm-up time, rest-time, etc.).

Participants performed a CMJ [1,21] in which they were required to flex their knees at a 90° angle, with both hands on their waist and their legs shoulder-width apart. Three attempts were performed, separated by 15 seconds of recovery. The best of them was selected. The CMJ was recorded using the OptoGait system (Microgate, Bolzano, Italy), which has been used in similar studies [11,14,16,22,23].

A bench press exercise was used to calculate the mean power velocity (MPV), mean strength (MS), maximum strength (MXS), mean power (MP) and maximum power (MXP) for the upper limbs. The exercise was performed only once after each match to minimise fatigue for participants. Bench press is familiar to participants due to it is frequently used in physical training for combat sports [24]. Participants were required to achieve an execution speed of at least 1 m/s (60% of 1RM) [25-27] to determine the load for the next repetitions [28]. The T-Force Dynamic Measurement System (Ergotech, Murcia, Spain) was used to quantify bench press capacity, as in similar studies [29-31]. It is a dynamic system for assessing and training muscle strength and enables one to obtain a direct estimate of load shift velocity in each repetition. The system automatically recognises an eccentric-concentric phase as a repetition.

The recommendations for the HS measurement from previous studies were considered in this study [14,29,32-34]. A digital hand dynamometer (TKK 5101 Grip D; Takey, Tokyo, Japan) was used to record HS in kg. Optimum grip was adjusted according to the calibration formula given in previous studies [35-37]. Participants were encouraged to achieve maximum handgrip strength. Three 5s HS trials were performed with each hand (dominant and non-dominant), separated by 15 seconds of recovery; the best result was selected.

*Statistical Analysis*

The data were analysed using SPSS version 19.0 for Windows (SPSS, Inc., Chicago, IL, USA) and the significance level was set at $p<0.05$. The data are presented as means and SDs. Levene's test and the Shapiro-Wilk test were used to confirm that the data were normally distributed. A one-way repeated measures analysis of variance (ANOVA) was used to compare data between pre- and post-test. Bonferroni's test was used for post hoc assessments of pairwise differences. Ordinal data—RPE—were assessed using the nonparametric Friedman and Wilcoxon contrast test. Additionally, a Pearson correlation analysis was conducted. Increases in all variables with the difference between results in postmatch 5 and basal results were calculated (Δ).

# RESULTS

Table 1 summarises the results of repeated measures ANOVA for muscular performance parameters and significant leves showed by p-values and effect size. parameters. Significant differences in NDHS and DHS were revealed. Post hoc analysis confirmed significant decreases in NDHS and DHS (Figure 2). In percentages, NDHS decreased in 13.14% (Figure 1) in relation to the baseline test, and DHS decreases in 11.29% respect to baseline data. The Pearson test revealed significant correlations between NDHS and ΔPMX ($r=0.368$, $p=0.050$).

Table 1. Muscular capacities results and significant level.

| Cap | NDHS (kgf) | DHS (kgf) | CMJ (cm) | MPV (m/s) | MS (N) | MXS (N) | MP (W) | MXP (W) |
|---|---|---|---|---|---|---|---|---|
| Baseline Mean (SD) Post hoc (a) | 46.18 (5,59) b,c,d,e,f | 48.27 (6.41) c,d,e,f | 34.78 (4.50) c,d,e,f | 0.95 (0.08) c.d.e.f | 429.28 (67.96) | 735.57 (140.10) f | 403.75 (67.67) c,d,e,f, | 789.35 (129.58) c,d,e,f |
| Post-bout 1 Mean (SD) Post hoc (b) | 44.03 (5.64) a,d,e,f | 46.42 (6.24) e,f | 33.95 (4.58) d,e,f | 0.91 (0.11) e,f | 432.22 (70.79) | 720.74 (148.95) | 390.77 (75.63) e,f | 764.84 (137.74) e,f |
| Post-bout 2 Mean (SD) Post hoc (c) | 43.20 (6.19) a,d,f | 45.11 (0.84) a,f | 33.39 (4.87) a,d,f | 0.89 (0.11) a,e,f | 432.25 (70.83) | 710.39 (143.19) | 379.28 (70.65) a,f | 733.16 (135.48) a,b |
| Post-bout 3 Mean (SD) Post hoc (d) | 41.46 (5.82) a,c | 44.95 (6.87) a,e,f | 32.23 (5.01) a,b,c,e,f | 0.88 (0.13) a,e,f | 432.20 (70.71) | 709.36 (145.45) | 377.70 (77.43) a,f | 736.55 (155.64) a,f |
| Post-bout 4 Mean (SD) Post hoc (e) | 40.03 (8.65) a,b | 43.77 (6.95) a,b,d, | 31.54 (4.91) a,b,d,f | 0.85 (0.12) a,b,c,d, | 431.95 (70.59) | 701.34 (151.82) | 366.96 (74.32) a,b,f | 719.38 (136.19) a,b,f |
| Post-bout 5 Mean (SD) Post hoc (f) | 40.11 (6.75) a,b,c | 42.82 (6.44) a,b,c,d | 30.35 (4.71) a,b,c,d,e | 0.83 (0.13) a,b,c,d,e | 438.72 (68.33) | 688.32 (127.43) a | 352.16 (73.70) a,b,c,d,e | 707.24 (131.75) a,b |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | 0.08 | 0.001 | <0.001 | <0.001 |
| ES | 0.672 | 0.725 | 0.848 | 0.567 | 0.267 | 0.502 | 0.607 | 0.598 |

ES: effect size; NDHS: no-dominant hand isometric strength; kgf: kilogram-force; DHS: dominant hand isometric strength; CMJ: counter movement jump; MPV: mean propulsive velocity; MS: medium strength; MXS: maximum strength; MP: medium power; MXP: maximum power. Post hoc: The same letter in different columns indicates significant differences. All of them are bellow of $p<0.05$.

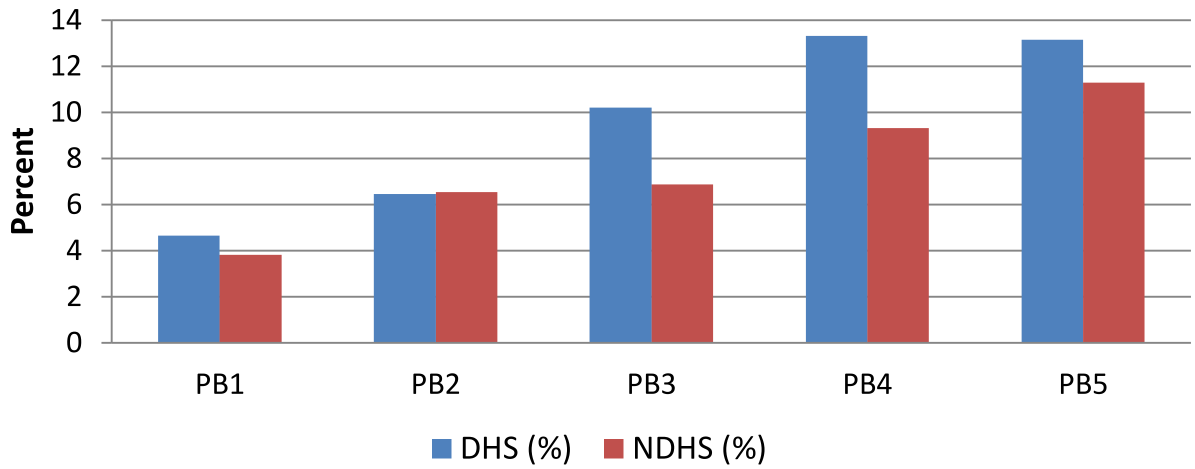


Figure 2. Handgrip strength percentages (%); DHS: dominant hand isometric strength; NDHS: no-dominant hand isometric strength; PB: postbout measure (measure obtained immediately after each bout).

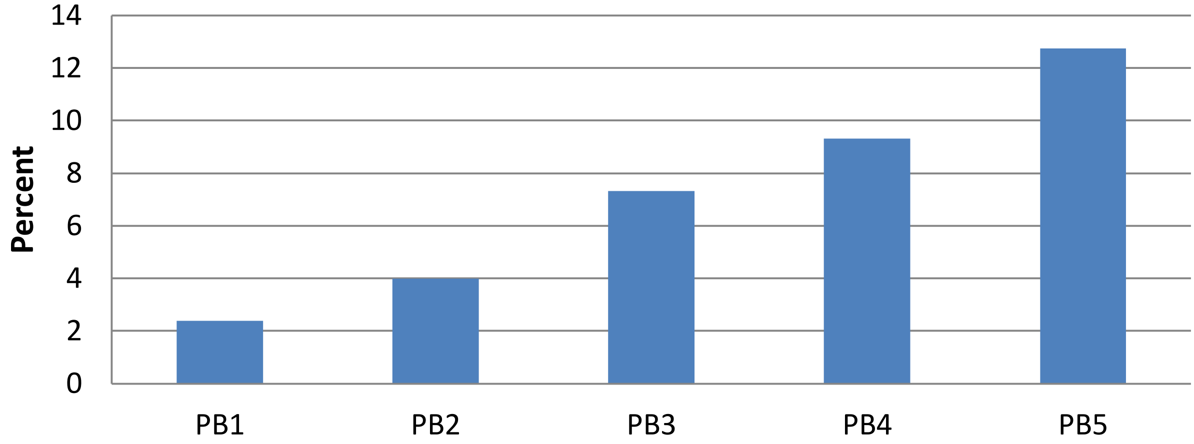


Figure 3. Countermovement Jump (CMJ) percentages (%); PB: postbout measure (measure obtained immediately after each bout).

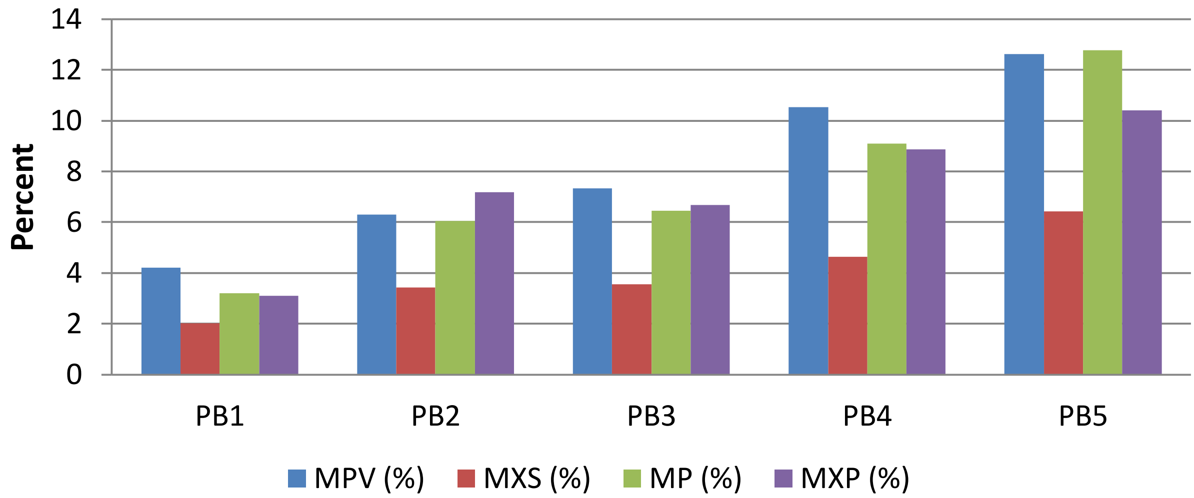


Figure 4. Maximal Dynamic Strength (MDS) values. MPV: Mean Propulsive Velocity; MXS: Maximal Strength; MP: Mean Power; MXP: Maximal Power; PB: postbout measure.

According to the obtained CMJ data, significant differences ($p<0.001$) were found for all measures compared with baseline data. This fact shows that from the baseline test to postmatch 5, CMJ data decreased in 12.74% (Figure 3).

With regard to MDS results, significant differences in MPV, MXS, MP and MXP ($p<0.001$ for all of them) were found. P value for MS was 0.08, decreasing in 12.63% (Figure 3) during successive matches. The Pearson test revealed significant correlations between MPV and ΔMXS ($r=0.528$, $p=0.001$) and between MPV and ΔMXP ($r=0.683$, $p<0.001$). A decrease of 12.78% in MP was obtained. In MXS, there was a decrease of 6.42%. In MXP, a decrease of 10.40% was obtained. MPV decreased 12.63%, correlating significantly with ΔMXS ($r=0.528$, $p=0.001$) and ΔMP ($r=0.877$, $p<0.001$).

# DISCUSSION

The purpose of the current study was to obtain the strength capacity values associated with muscular performance parameters during a judo contest, showing percentages of possible loss and the effects on the capacity for the production of force. The main finding was obtaining the variability of strength production capacities associated to muscular performance parameters, which showed that there was a considerable decline during a judo contest. With this finding, it can be said that only 15 min of rest-time is not enough to recover 100% of these capacities. The hypothesis was corroborated since the judo contests caused muscular fatigue and impaired strength production in both the upper and lower limbs, obtaining a high variability during successive judo matches.

Analysing previous studies about HS, one [35] reported a decrease of 12.7% in handgrip strength of the dominant hand after one judo match and a 15% after four judo matches. In other study a decrease of a 5% was reported in HS after the first match and 15% after second match [1]. In other study [14], it was obtained a decrease of 12.57% in the dominant hand in the first match and 14.80% in the second match for the same hand, while the non-dominant hand decreased the values a 10.25% and 13.11% respectively, arguing that the non-dominant hand recovered less between matches than the dominant hand. It can be argued that HS is more specific for judo than maximal strength, because judo players have to maintain their grip for a long time [38]. On the contrary, another study [34] obtained correlations between HS and MS-MXS, and argued that athletes with higher values of HS develop a high quantity of MS and MXS, and the non-correlation between DHS and NDHS shows that both hands work differently, making a different effort. Along the same lines, in the current study similar loss percentages (13.14% in the dominant hand and 11.29% in the non-dominant hand) between the baseline test and successive judo matches were obtained. Correlations show that judo athletes with the highest values in the non-dominant hand were those who developed the highest peaks power and strength. This can be explained by the specific actions done by this hand. With these considerations, it seems obvious that a judo contest demands a high isometric effort, accumulating fatigue in the upper limbs due to the isometric effort during successive judo bouts.

According to our results, judo contests cause fatigue in the lower limbs, as shown by the decline in CMJ values (12.74% after bout 5 when compared with the baseline test). Some authors [8,11] justify similar decreases due to the high load (eccentric-concentric) in specific judo actions on the lower limbs. The results of the current study contrast with others that found no difference in this capacity after only one bout [8] and after 2 bouts [1]. Only one study [18] was found an increase of 1.62% in CMJ values after a judo match. Another study [11] obtained a lower decrease in this capacity after matches of 0.93%, 3.62% and 3.20% in postbout 1, 2 and 3, respectively. Along the lines of the current study, correlations between muscular performance parameters show that judo is a complete sport that develops not only upper limbs but also lower limbs [35]. In lower limbs, although judo actions that affect them are more intermittent than for upper limbs, the high number of these actions, their energy cost and the explosive conditions demanded of them also causes a loss in muscular performance. According to these results, it can be deduced that successive judo bouts have an important effect on the muscular performance response of lower limbs, with effects not only in power production but also in subsequent recovery.

Similar to our results, another study [8] obtained loss percentages in MDS parameters, specifically in MP (3.21% in the current study versus 6.20%, taking into account an only bout). After this study [35], it was obtained a 5.30% decrease in MXP values between the baseline test and postbout 1. This decrease in strength capacity is found in some muscular performance parameters from bout 1 until bout 5 (12.63% in MPV, 10.40% in MXP and 6.42% in MXP). Correlations show the validity of execution velocity as an indicator for peak power and strength, according to some authors [21]. As is highlighted by some authors [2,7] when well-trained judo athletes are studied, it is frequently found that they have highly developed dynamic strength and muscular endurance. Even with these considerations, judo athletes experience a decrease in strength production, showing significant muscular fatigue during successive bouts.

# CONCLUSION

Our study highlights that a judo contest modified the strength capacities due to the significant variability obtained in these capacities, which becomes greater as the successive matches unfold. Judo athletes have to start a bout with signs of muscular fatigue produced in previous bouts, suggesting that 15 minutes of rest-time is not enough to recover 100% of the muscular performance capacity.

# PRACTICAL APPLICATIONS

Compared to baseline tests results, in this study, it can see that the loss of muscular performance capacity takes place throughout the entire judo contest. It is known that strength capacity is one of the most important aspects of judo performance. Therefore, physical trainers and coaches can have valuable information about the evolution of this capacity in a judo contest to design judo specific training and competition programmes. Also, a high quantity of feedback will be proportionated as measure of training at each moment.

With the aim of maintaining high levels of muscular performance parameters during a judo contest, strength endurance training programmes for upper limbs are recommended. This should be developed by some judo specific actions on judogi: maintaining grip with opposition, different types of trawls fellow (lying, resisting, pulling, etc.), and actions involving the most muscle groups as possible. It is essential to blend this kind of action with explosive movements whose execution is carried out as fast as possible, as in a real competition. This last consideration can also be used for lower limbs, with a plyometric stimulus that provides potentiation with a improve in power production capacity.

Taking into account the high percentages of loss in muscular performance capacity, further studies could be conducted on the possibility of using recovery methods during a judo contest at rest-time between each match, with the aim of maintaining or decreasing the percentages of strength loss between matches. This way, future research could investigate the effect of different methods of recovery: passive or active, with specific judo movements and low loads.

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