

# Maximal isometric handgrip strength: comparison between weight categories and classificatory table for adult judo athletes

Emerson Franchini<sup>1,2,\*</sup>, Juliano Schwartz<sup>1,3</sup>, Monica Yuri Takito<sup>4,5</sup>

<sup>1</sup>Martial Arts and Combat Sports Research Group, Sport Department, School of Physical Education and Sport, University of Sao Paulo, Sao Paulo, Brazil

<sup>2</sup>Combat Centre, Australian Institute of Sport, Canberra, Australia

<sup>3</sup>University of British Columbia, Vancouver, Canada

<sup>4</sup>Human Movement Pedagogy Department, School of Physical Education and Sport, University of Sao Paulo, Sao Paulo, Brazil

<sup>5</sup>University of Canberra, Canberra, Australia

The aims of this study were to compare the maximal isometric handgrip strength of judo athletes from different weight categories and to create a classificatory table for this test. A total of 406 athletes had their maximal isometric handgrip strength measured, following standardized recommendations. Absolute and relative values were calculated for each hand and for the sum of both hands. Weight categories were compared through a one-way analysis of variance, followed by Tukey test. The effect size was determined by partial eta squared, and the relationship between variables was determined using Pearson correlation coefficient. There was a large effect of weight category in absolute handgrip strength for each hand and for the sum of both hands, with lower values for the lighter categories. Conversely, when the relative strength was considered higher values were found for the lighter categories

( $P < 0.001$ ). Very large and significant positive correlations ( $P < 0.001$ ) were found between right and left for absolute ( $r = 0.886$ ) and relative ( $r = 0.883$ ) handgrip values. Overall, there was an increase in absolute and a decrease in relative handgrip strength across weight categories. These differences found in grip strength in weight categories are probably linked to differences in muscle mass between them. There was a high correlation between each hand for absolute and relative values, which suggests that assessing only one hand may be enough, and therefore a faster way of evaluation. Finally, the normative classificatory table created may serve as a reference for different purposes.

**Keywords:** Tests, Combat sports, Sports performance, Martial arts

## INTRODUCTION

Judo is a grappling Olympic combat sport disputed in seven weight categories for both male and females. To be successful in this sport, athletes need to develop several physical capacities, including anaerobic power and capacity, aerobic power and capacity, maximal isometric and dynamic strength, muscle power and strength-endurance (Franchini et al., 2011). Each of these capacities has a specific contribution to a given phase of the judo match (Franchini et al., 2013), but all scoring actions in judo depend on a grip in the opponent's judogi (judo uniform) (Calmet et al.,

2010; Courel-Ibáñez et al., 2014). The physical component of the grip involves both maximal isometric strength and strength-endurance (Bonitch-Góngora et al., 2012; Franchini et al., 2011b), although the exact contribution of each of them remains to be determined. The grip dispute is especially important due to the fact that it represents around 50% of the judo match time (Franchini et al., 2013; Marcon et al., 2010). Moreover, maximal isometric handgrip strength is relevant for judo athletes as it was observed a decrease values across simulated (Bonitch-Góngora et al., 2012) and official judo matches (Kons et al., 2018), suggesting that the actions executed during the match negatively affect this ability

\*Corresponding author: Emerson Franchini  <https://orcid.org/0000-0002-0769-8398>  
School of Physical Education and Sport, University of São Paulo (USP), Av. Prof. Mello Morais, 65 Butantã, São Paulo, SP 05508-030, Brazil  
Tel: +55-11-3091-8793, Fax: +55-11-3091-3135  
E-mail: emersonfranchini@hotmail.com

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and a lower decrease across the tournament could represent an advantage for the judo athlete.

However, the discriminant ability of isometric maximal and strength-endurance performance in tasks involving either handgrip or gripping the judogi is controversial (Bonitch-Góngora et al., 2013). These authors reported that national level adolescent judo athletes achieved higher maximal and strength-endurance handgrip values compared to regional level judo athletes, whereas Franchini et al. (2005) did not report any difference between elite and nonelite adult judo athletes for maximal isometric handgrip strength, and Franchini et al. (2011b) did not observe any difference in strength-endurance in the isometric version of the chin-up test gripping the judogi between international level judo athletes compared to state level judo athletes. The ability of maximal and strength-endurance isometric handgrip tests to discriminate properly between judo athletes from different competitive levels probably depends on the weight category, combat style and the interaction with other physical characteristics of the athlete. Judo is disputed in seven weight categories, but no study compared the maximal isometric handgrip strength between these weight categories (Franchini et al., 2011), with two studies (Claessens et al., 1984; Farnosi, 1980) only grouping athletes from weight categories lighter and heavier than 71 kg, using sample sizes smaller than 13 athletes per group.

Given the relevance of grip dispute in judo, classificatory tables were developed for both isometric strength-endurance and maximal strength (Agostinho et al., 2018; Branco et al., 2017; Branco et al., 2018). Strength-endurance classificatory tables were developed for adult male (Branco et al., 2017), cadet and junior male and female judo athletes (Agostinho et al., 2018), using a chin-up test gripping the judogi. However, only one study proposed a classificatory table for maximal isometric handgrip in adult judo athletes (Branco et al., 2018), but reported only the absolute and relative value for the sum of the two hands. Additionally, the need for large samples when evaluating combat sports athletes using specific tests has been emphasized (Chaabene et al., 2018), but it also applies to nonspecific tests as the maximal isometric handgrip test. Furthermore, the use of simple tests that can provide relevant information, spending short periods of time and human resources is important in the athletes' evaluation process (Cronin et al., 2017). The knowledge of an athlete classification in a given test is relevant for coaches, strength and conditioning professionals and physiotherapists, as these professionals can compare the athletes with a large sample and control their evolution across training phases and injury recovery processes. Thus, the aims of the present

study were to compare the maximal isometric handgrip strength of athletes from different weight categories and to create a maximal isometric handgrip strength classificatory table for adult male judo athletes.

## MATERIALS AND METHODS

### Design

This was a cross-sectional, descriptive and comparative study conducted with adult male judo athletes, who performed the maximal isometric handgrip strength test using right and left hands. They executed this test 3 times with each hand, with 1-min intervals between attempts. Athletes were evaluated during their competitive period, after 2 hr rest and before the beginning of any weight loss procedure.

### Subjects

Four-hundred and six male judo athletes (age,  $24.8 \pm 4.9$  years; body mass,  $79.7 \pm 17.8$  kg; height,  $174.6 \pm 7.8$  cm) were evaluated. Athletes were included if they presented the following characteristics: (a) age between 18 and 35 years old, (b) competing in the month the measurement was taken, (c) more than 6 months of uninterrupted judo training, and (d) free of hand injuries that could affect their performance. Competitive level varied from regional to Olympic, and athletes from all weight categories were measured. All athletes gave their informed consent to take part in the evaluation process. All procedures were approved by the Brazilian-located University Research Ethics Committee (approval number: 2009/48).

### Body mass and height

Body mass was measured in a calibrated Filizola scale (Filizola, Sao Paulo, Brazil), with 0.1 kg accuracy and height was measured using a portable stadiometer (Seca 222, New York, NY, USA), with 1 mm accuracy, in accordance with Heyward (1997).

### Maximal isometric handgrip strength

The maximal isometric handgrip strength was measured three times on each side, alternately, with a 1-min interval between attempts, and, in each one, the athlete was instructed to generate the greatest possible force during 3–5 sec, in a standing position, with fully extended elbow and self-selected wrist positions. Measurements were conducted using a Jamar dynamometer (Jamar, Lafayette, CA, USA), with a 1 kilogram-force (kgf) accuracy. The highest value for each side was used in the present analysis. Addi-

tionally, the sum of the greatest value of each side was calculated, as well as the relative (i.e., dividing by the athlete's body mass) values for each side and for the sum of both sides. The dynamometer was set according to each athlete's hand length, following the recommendations of the American Society of Hand Therapy (Mathiowetz et al., 1984).

**Statistics**

Data were analyzed using Statistica ver. 8 (Statsoft, Tulsa, OK, USA). The homogeneity of variances and the normality of the sample were confirmed using Levene test and the Kolmogorov–Smirnov test, respectively. After confirming these assumptions for the parametric statistics, data were described using mean and standard deviation. Weight categories were compared using a one-way analysis of variance, followed by the Tukey test for unequal samples when a difference was found in the analysis of variance. Partial eta squared ( $\eta_p^2$ ) was calculated to determine the effect size, using the 0.0099, 0.0588, and 0.1379 considered as small, medium, and large effect sizes (Richardson, 2011). Pearson correlation coefficient was calculated to determine the relationship between variables and classified according to Hopkins (2018). To develop a classificatory table for each maximal isometric handgrip strength variables, percentile values were adopted to establish the following categories, as used in previous publications with judo athletes (Agostinho et al., 2018; Sterkowicz-Przybycień and Fukuda, 2014): excellent, highest 5%; good, next 15%; regular, middle 60%; poor, next lowest 15%; very poor, lowest 5%.

**RESULTS**

Table 1 presents the absolute and relative maximal isometric

handgrip strength of judo athletes from different weight categories.

There was an effect of weight category for the right absolute maximal isometric handgrip strength ( $F[6, 399] = 29.53, P < 0.001, \eta_p^2 = 0.308$ , large), with lower values for the 60 kg weight category compared to 66 kg ( $P = 0.016$ ), 73, 81, 90, 100, and over 100 kg weight categories ( $P < 0.001$  for these five comparisons), lower values for the 66 kg compared to 81, 90, 100, and over 100 kg weight categories ( $P < 0.001$  for all comparisons), lower values for the 73 kg compared to the 90 kg ( $P = 0.011$ ) and over 100 kg weight categories ( $P < 0.001$ ), and lower values for the 81 kg weight category compared to the over 100 kg ( $P < 0.001$ ). There was also an effect of weight category for the left absolute maximal isometric handgrip strength ( $F[6, 399] = 27.65, P < 0.001, \eta_p^2 = 0.294$ , large), with lower values for the 60 kg weight category compared to 66 kg ( $P = 0.001$ ), 73, 81, 90, 100, and over 100 kg weight categories ( $P < 0.001$  for these five comparisons), lower values for the 66 kg compared to 81 kg ( $P = 0.004$ ), 90 kg ( $P < 0.001$ ), 100 kg ( $P = 0.024$ ), and over 100 kg weight categories ( $P < 0.001$ ), lower values for the 73 kg compared to the 90 kg ( $P = 0.007$ ) and over 100 kg weight categories ( $P < 0.001$ ), lower values for the 81 kg weight category compared to the over 100 kg ( $P = 0.002$ ), and lower values for the 100 kg weight category compared to the over 100 kg ( $P = 0.042$ ). For the sum of both hands, a similar difference was found ( $F[6, 399] = 30.96, P < 0.001, \eta_p^2 = 0.312$ , large): lower values for the 60 kg weight category compared to 66 kg ( $P = 0.003$ ), 73, 81, 90, 100, and over 100 kg weight categories ( $P < 0.001$  for these five comparisons), lower values for the 66 kg compared to 81 kg ( $P < 0.001$ ), 90 kg ( $P < 0.001$ ), 100 kg ( $P = 0.002$ ), and over 100 kg weight categories ( $P < 0.001$ ), lower values for the 73 kg compared to the 90 kg ( $P = 0.005$ ) and over 100 kg

**Table 1.** Absolute and relative maximal isometric handgrip strength in adult judo athletes (n=406)

Weight	Right hand		Left hand		Sum	
	Absolute (kgf)	Relative (kgf/kg)	Absolute (kgf)	Relative (kgf/kg)	Absolute (kgf)	Relative (kgf/kg)
60 kg (n=69)	43 ± 7 <sup>a,b,c,d,e,f</sup>	0.73 ± 0.12 <sup>c,d,e,f</sup>	42 ± 8 <sup>a,b,c,d,e,f</sup>	0.70 ± 0.13 <sup>c,d,e,f</sup>	85 ± 15 <sup>a,b,c,d,e,f</sup>	1.43 ± 0.24 <sup>c,d,e,f</sup>
66 kg (n=73)	48 ± 6 <sup>c,d,e,f</sup>	0.71 ± 0.09 <sup>c,d,e,f</sup>	47 ± 6 <sup>c,d,e,f</sup>	0.70 ± 0.09 <sup>c,d,e,f</sup>	95 ± 11 <sup>c,d,e,f</sup>	1.41 ± 0.17 <sup>c,d,e,f</sup>
73 kg (n=83)	51 ± 8 <sup>d,f</sup>	0.68 ± 0.11 <sup>d,e,f</sup>	50 ± 8 <sup>d,f</sup>	0.66 ± 0.11 <sup>e,f</sup>	101 ± 16 <sup>d,f</sup>	1.34 ± 0.22 <sup>d,e,f</sup>
81 kg (n=70)	54 ± 7 <sup>f</sup>	0.65 ± 0.09 <sup>e,f</sup>	52 ± 7 <sup>f</sup>	0.64 ± 0.08 <sup>e,f</sup>	106 ± 13 <sup>f</sup>	1.29 ± 0.16 <sup>e,f</sup>
90 kg (n=52)	56 ± 8	0.62 ± 0.09 <sup>f</sup>	55 ± 9	0.61 ± 0.10 <sup>f</sup>	111 ± 17	1.23 ± 0.19 <sup>f</sup>
100 kg (n=29)	56 ± 8	0.56 ± 0.08	54 ± 8 <sup>f</sup>	0.54 ± 0.08	110 ± 15	1.10 ± 0.15
Over 100 kg (n=30)	61 ± 11	0.49 ± 0.09	60 ± 11	0.49 ± 0.09	121 ± 20	0.98 ± 0.17

Values are presented as mean ± standard deviation.

kgf, kilogram-force.

<sup>a</sup>Different from 66 kg ( $P < 0.05$ ). <sup>b</sup>Different from 73 kg ( $P < 0.05$ ). <sup>c</sup>Different from 81 kg ( $P < 0.05$ ). <sup>d</sup>Different from 90 kg ( $P < 0.05$ ). <sup>e</sup>Different from 100 kg ( $P < 0.05$ ). <sup>f</sup>Different from +100 kg ( $P < 0.05$ ).

**Table 2.** Classification of maximal isometric handgrip strength according to percentiles in adult judo athletes (n = 406)

Classification	Right hand		Left hand		Sum	
	Absolute (kgf)	Relative (kgf/kg)	Absolute (kgf)	Relative (kgf/kg)	Absolute (kgf)	Relative (kgf/kg)
Excellent	>66	>0.84	>66	>0.85	>132	>1.68
Good	59–66	0.76–0.84	58–66	0.74–0.85	116–132	1.49–1.68
Regular	44–58	0.56–0.75	42–57	0.55–0.73	86–115	1.11–1.48
Poor	36–43	0.47–0.55	36–41	0.45–0.54	71–85	0.92–1.10
Very poor	<36	<0.47	<36	<0.45	<71	<0.92

kgf, kilogram-force; Excellent, 95th percentile and higher; Good, more than 80th to 94th percentiles; Regular, 20th to 80th percentiles; Poor, more than 5th to 19th percentiles; Very poor, 5th percentile and below.

weight categories ( $P < 0.001$ ), and lower values for the 81 kg weight category compared to the over 100 kg ( $P = 0.001$ ).

There was an effect of weight category for the right relative maximal isometric handgrip strength ( $F[6, 399] = 29.53, P < 0.001, \eta_p^2 = 0.308$ , large), with higher values for the 60 kg compared to the 81 kg, 90 kg, 100 kg, and over 100 kg weight categories ( $P < 0.001$  for all comparisons), higher values for the 66 kg compared to the 81 kg ( $P = 0.018$ ), 90 kg, 100 kg, and over 100 kg weight categories ( $P < 0.001$  for these three comparisons), higher values for the 73 kg compared to the 90 kg ( $P = 0.018$ ), 100 kg, and over 100 kg weight categories ( $P < 0.001$  for both comparisons), higher values for the 81 kg compared to the 100 kg ( $P = 0.009$ ) and over 100 kg weight categories ( $P < 0.001$ ), and higher values for the 90 kg compared to the over 100 kg weight category ( $P < 0.001$ ). There was also an effect of weight category for the left relative maximal isometric handgrip strength ( $F[6, 399] = 26.17, P < 0.001, \eta_p^2 = 0.282$ , large), with higher values for the 60 kg compared to the 81 kg ( $P = 0.004$ ), 90 kg, 100 kg, and over 100 kg weight categories ( $P < 0.001$  for these three comparisons), higher values for the 66 kg compared to the 81 kg ( $P = 0.003$ ), 90 kg, 100 kg, and over 100 kg weight categories ( $P < 0.001$  for these three comparisons), higher values for the 73 kg compared to the 100 kg and over 100 kg weight categories ( $P < 0.001$  for both comparisons), higher values for the 81 kg compared to the 100 kg ( $P = 0.005$ ) and over 100 kg weight categories ( $P < 0.001$ ), and higher values for the 90 kg compared to the over 100 kg weight category ( $P < 0.001$ ). For the sum of both hands, a similar difference was found ( $F[6, 399] = 30.29, P < 0.001, \eta_p^2 = 0.313$ , large): higher values for the 60 kg compared to the 81, 90, 100, and over 100 kg weight categories ( $P < 0.001$  for all comparisons), higher values for the 66 kg compared to the 81 kg ( $P = 0.004$ ), 90 kg, 100 kg, and over 100 kg weight categories ( $P < 0.001$  for these three comparisons), higher values for the 73 kg compared to the 90 kg ( $P = 0.027$ ), 100 kg and over 100 kg weight categories ( $P < 0.001$  for both

comparisons), higher values for the 81 kg compared to the 100 kg ( $P = 0.004$ ) and over 100 kg weight categories ( $P < 0.001$ ), and higher values for the 90 kg compared to the over 100 kg weight category ( $P < 0.001$ ).

Significant positive correlations were found between right and left absolute handgrip values ( $r = 0.886, P < 0.001$ , very large); right and left relative handgrip values ( $r = 0.883, P < 0.001$ , very large).

Table 2 presents the absolute and relative maximal isometric handgrip strength classificatory table for adult judo athletes.

## DISCUSSION

The main findings of the present study were: (a) absolute maximal isometric handgrip strength increased across the weight categories, although subsequent weight categories did not differ between them (except for the 60 kg and 66 kg weight categories), indicating that athletes from successive weight categories can be paired when this variable is considered; (b) an opposite direction was observed for the relative maximal isometric strength, i.e., lighter weight categories had higher values compared to the heavier ones; (c) absolute and relative performances in the right and left hands were highly correlated, suggesting that testing a single side can be effective for proper classification of judo athletes; (d) a classificatory table was created for absolute and relative maximal isometric handgrip strength for right and left hands, and the sum of both hands.

The differences between weight categories in absolute maximal isometric strength are likely related to differences in muscle mass between them, especially because an opposite direction was observed when relative values were compared. The lower relative physical fitness of heavier judo athletes compared to lighter ones has been reported (Franchini et al., 2011), and is probably due to the higher body fat observed in heavier judo athletes (Franchini et

al., 2014). However, as the grip dispute is a very relevant factor to judo success (Calmet et al., 2010) and its physical component involves both handgrip maximal strength and strength-endurance (Bonitch-Góngora et al., 2012; Franchini et al., 2011b), the common practice of putting judo athletes from successive weight categories to train together was confirmed by our results. Additionally, as judo athletes execute the grip dispute using both hands, the high correlation between hands observed in our study suggests that a similar development is achieved on each of them. Thus, evaluating a single hand can provide enough information concerning the maximal isometric handgrip strength of judo athletes, which can make the test application even faster.

In a recent review, Cronin et al. (2017) reported that subjects normally achieved higher maximal isometric handgrip strength values in their dominant hand (mean difference of 0.1% to 16.5%) compared to their nondominant hand. Bohannon (2003) observed a slightly lower difference (0.1% to 10.7%) between the dominant and nondominant hands, reporting that the dominant hand superiority was more likely to be found in right-handed individuals, while for left-handed subjects the results were equivocal. Additionally, one problem reported by Bohannon (2003) was that the studies did not make clear the criteria used to define dominance. During the grip dispute in judo, the dominant hand is normally gripping the opponent's lapel (tsurite), while the nondominant hand controls the opponent's sleeve (hikite) (Courel-Ibáñez et al., 2014). Although the different functions performed by each hand, only a few studies compared the maximal isometric handgrip strength in the dominant versus non-dominant hands in judo athletes (Ache Dias et al., 2012; Gutierrez-Sanchez et al., 2011; Zaggelidis, 2016). Ache Dias et al. (2012) did not find any significant difference between hands, while Zaggelidis (2016) and Gutierrez-Sanchez et al. (2011) reported higher values in the dominant hand (3.2% and 4.1%, respectively) compared to the nondominant hand. Thus, the lack of information concerning the dominant hand in the present study is a limitation, and future studies should add the information about hand dominance.

In conclusion, our study provided normative data using a very high sample size ( $n=406$ ), and the results of judo athletes can now be evaluated using a five-grade scale. These values can be used as a reference to guide judo athletes' physical training and can be relevant for goal setting concerning maximal strength performance either peaking for a specific competition or during different phases of the rehabilitation process. The response to different periodization training programs can also be monitored using this table as a reference, as proposed for other tests (Agostinho et

al., 2018; Branco et al., 2017; Branco et al., 2018). Future studies should focus on table development for female judo athletes and to athletes from different age categories.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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