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KINESIOLOGY

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Vertical jump performance in judo and Brazilian jiu-jitsu athletes: an approach with different training levels

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Abstract

Background. Judo and Brazilian jiu-jitsu (BJJ) are grappling sports, in which the athletes of both modalities require a combination of powerful actions in the upper and lower limbs. In the lower limbs, power actions are observed in several judo throwing techniques, and the guard passes, sweeps, takedowns in the BJJ matches.

Aim. To compare the kinetic parameters of vertical jump performance between judo and BJJ athletes, and to compare these parameters between novices and advanced athletes.

Methods. Twenty judo male athletes (twelve novices and eight advanced) and twenty male BJJ athletes (twelve novices and eight advanced) participated in this study. They performed a countermovement jump (CMJ) on a force platform. The following variables were analyzed: jump height, mean power, peak power, maximum force, and peak velocity. An independent samples *t*-test was used with the level of significance set at $p \leq 0.05$ and the effect size was calculated to verify the effect magnitude.

Results. The main results showed that only peak velocity was higher in judo than BJJ athletes ($p = 0.02$). Also, advanced BJJ athletes showed higher peak velocity ($p = 0.03$) and jump height ($p = 0.05$) than novice athletes. Advanced judokas presented higher peak velocity ($p = 0.03$) and maximum force than novice athletes ($p = 0.02$).

Conclusions: We conclude that judo athletes are able to apply higher velocity during the jump take-off compared to BJJ athletes. In general, advanced athletes in both combat sports seem to present higher performance in CMJ parameters related to force and velocity.

Introduction

Judo and Brazilian *jiu-jitsu* (BJJ) are combat sports of domain actions, where the athletes of both modalities require a combination of physical fitness and technical–tactical abilities to attain better performance [Franchini *et al.* 2011; Andreato *et al.* 2017]. Judo and BJJ combat bouts are of a high-intensity intermittent nature with short periods of rest [Franchini *et al.* 2011; Andreato *et al.* 2013; Andreato *et al.* 2017]; however, these sports present different ratios of effort and pauses during the matches. In judo matches, the effort: pause ratio is close to 3:1 or 2:1 [Miarka *et al.* 2012], while in BJJ matches the ratio ranges from 6:1 to 13:1 [Andreato *et al.* 2015; Andreato *et al.* 2016].

In terms of physical condition, both judo and BJJ require a combination of strength and powerful actions in the upper and lower limbs [Ratamess, 2011; Franchini *et al.* 2013]. In the lower limbs, power actions are observed in several judo throwing techniques (*seoi-nage, o-goshi*) [Detanico *et al.* 2012], and guard passes, sweeps, and takedowns in BJJ matches [James 2014; Andreato *et al.* 2017]. One of the most reliable methods for estimating muscle power in the lower limbs is the countermovement jump (CMJ) [Markovic *et al.* 2004]. Several studies have used CMJ performance (jump height or power output) as an indicator of muscle power in judo athletes [Monteiro *et al.* 2011; Zaggelidis *et al.* 2012] and BJJ athletes [Silva *et al.* 2014; Andreato *et al.* 2015; Diaz-Lara *et al.* 2015]. Other parameters, such as the maximum force

in the concentric phase of the jump and peak velocity during the take-off, have also been studied. Athayde *et al*. [2017] found significant differences in these variables between judokas of different weight categories; however, no studies investigating CMJ variables in BJJ athletes have been reported. Understanding of the neuromuscular parameters in the lower limbs may aid in explaining the physical demands (training effects) of each sport.

Another important aspect in combat sports is that specific training (experience in the sport) seems to exert a positive influence on CMJ performance. Detanico *et al*. [2016] observed higher jump height and power output in advanced judo athletes (brown and black belts) compared to novice athletes (up to purple belt). Another study verified that advanced judo athletes demonstrate better ability to use the stretch-shortening cycle mechanism (SSC), optimizing power production during the vertical jump [Zaggelidis *et al*. 2012]. Diaz-Lara *et al*. [2014] reported that experienced BJJ athletes (from purple to black belts) presented better jump height, peak power, peak velocity, and mean power in CMJ compared to non-experienced athletes (white and blue belts). However, more studies are needed to understand particularities concerning muscle strength and power production in judo and BJJ athletes, bearing in mind the level of experience in the sport. This information may help coaches and physical trainers in both combat sports to discriminate or classify athletes at different training levels and delineate the load training for each.

Thus, this study aimed to compare the kinetic parameters of CMJ (height, power output, velocity, and force) between judo and BJJ athletes, and also to compare these variables between advanced and novice athletes. We hypothesized that BJJ athletes would show better performance in CMJ compared to judo athletes due to the greater intensity of the combat. Moreover, we supposed that advanced athletes would show higher performance in the major CMJ variables compared to novices.

Methods

Participants

Forty male athletes participated in this study, twenty judo athletes (age 20.5 ± 3.70 years, body mass 77.39 ± 6.31 kg, height 175.5 ± 3.53 cm, body fat 10.6 ± 4.11%) and twenty BJJ athletes (age 25.0 ± 4.75 years, body mass 79.23 ± 9.22 kg, height 175.79 ± 5.58 cm, body fat 13.63 ± 3.54%). No significant differences were found between judo and BJJ groups for body mass ($p = 0.29$), height ($p = 0.91$) and body fat ($p = 0.14$). The judo and BJJ athletes were divided two groups (novice and advanced). For this, we used the criterion of belt graduation level, considering brown and black belts to denote advanced judo athletes, and up to purple belt to denote novices. This same criterion was previously used by Del Vecchio *et al*. [2014] and Detanico *et al*. [2016]. In the BJJ group, a purple belt and above was considered advanced and blue belt novice [Diaz-Lara *et al*. 2014]. Thus, the judo novice group was composed of 12 athletes (experience of 5.0 ± 3.9 years) and the advanced group was composed of 8 athletes (experience of 12 ± 2.6 years). For BJJ, the novice group was also composed of 12 athletes (experience of 3.2 ± 1.2 years) and the advanced group 8 athletes (experience of 7.4 ± 3.4 years). All groups showed significant differences in the experience time ($p < 0.01$). Considering the weight categories, we excluded the heavy and ultra-heavy weight (judo and BJJ, respectively).

All athletes were training regularly (physical, technical, and tactical training) 4–5 times a week during the evaluation period, and competed at the state and national level. Participants were selected based on the following criteria: no reported musculoskeletal disorder or injury that would influence their maximal physical performance. All participants were older than 18 years, and received a detailed verbal explanation of the purpose, methods, and potential risks/benefits of the study. They then signed a written informed consent form agreeing to participate of the study. This study was approved by the Research Ethics Committee of the local university (119.014 dated 08/10/2012), in accordance with the Declaration of Helsinki. Athletes were advised to eat at least one hour before the evaluations. The evaluations were undertaken in the afternoon, in the following order: i) anthropometric evaluation and, ii) vertical jump assessment.

Anthropometric assessment

Prior to data collection, the following anthropometric variables were examined: body mass, height, and skinfold thickness. We used the protocol proposed by Faulkner [1968] to calculate the percentage of body fat (%G), which considered the sum of four skinfold thicknesses (subscapular, triceps, abdomen, and suprailiac). Body weight was measured using a digital scale (0.1 kg accuracy) and height was assessed using a stadiometer scale with an accuracy of 0.1 cm.

Vertical jump assessment

The participants performed a familiarization/warm-up period involving 30 s hopping on a trampoline, three series of 10 hops on the ground, and five submaximal vertical countermovement jumps (CMJs). Then, participants performed the CMJ protocol, in which the athletes started from a static standing position and were instructed to perform a countermovement (descent phase) followed by a rapid and vigorous extension of the lower limb joints (ascent phase). During the jump, participants were asked to maintain their trunks as vertically as possible, keeping their hands on their hips (akimbo). The athletes were instructed to jump as high as possible. The vertical jumps

were performed on a piezoelectric force platform (model 9290AD, Kistler, Quattro Jump, Winterthur, Switzerland), which measures vertical ground reaction sampling at 500 Hz. Each participant performed three maximal jumps with a rest interval of 1 min between them. The average of the three jumps was taken for analysis. Based on the analysis of the ground reaction force (GRF), the following variables were analyzed, as defined in the literature[Lithorne, 2001]: jump height, calculated using the GRF dual integration method; peak power output: highest value of the curve obtained from the multiplication of the GRF by the velocity in the concentric phase of the jump, normalized by body mass; mean power output: mean value of the curve obtained from the multiplication of the GRF by the velocity in the concentric phase of the jump, normalized by body mass; maximum force, identified as the highest value obtained in the concentric phase of the jump, normalized by body mass; peak velocity, being the highest value of the vertical take-off velocity.

Statistical analysis

Data are reported as mean ± standard deviation (SD). The Shapiro–Wilk test was performed to verify data normality. The *t*-test for independent samples was used to compare the CMJ variables for the judo and BJJ groups, and the novice and advanced groups. The statistical analyses were performed in the Statistical Package for Social Sciences (v. 17.0, SPSS Inc., Chicago, IL, USA) and the level of significance was set at 5%. In addition, the effect size (ES) was calculated and the classification of effect magnitude used was that proposed by Cohen [1988] (< 0.4 small, 0.41–0.7 moderate, > 0.7 large).

Results

Table 1 shows the comparison of CMJ variables for the judo and BJJ groups. Peak velocity was significantly higher in judo athletes compared to BJJ athletes (large effect). No significant differences for the other variables were reported, but the maximum force presents a moderate effect (higher in judo athletes than in BJJ athletes).

Table 2 presents the CMJ variables for the novice judo and BJJ athletes. Peak velocity was significantly higher in judo novice compared to BJJ athletes (large effect). No significant differences for the other variables were reported.

Table 3 presents the CMJ variables for the advanced judo and BJJ athletes. Peak velocity was significantly higher in judo novice compared to BJJ athletes (large

Table 1. Comparison of CMJ variables for judo and BJJ athletes.

	Judo (n = 20)	BJJ (n = 20)	p	ES
Jump height (cm)	46.56 ± 3.92	45.33 ± 6.60	0.48	0.21
Maximum force (N.kg^{-1})	24.75 ± 2.49	23.43 ± 2.46	0.10	0.53
Mean power (W.kg^{-1})	28.66 ± 3.03	27.87 ± 3.28	0.42	0.33
Peak power (W.kg^{-1})	49.97 ± 4.29	50.34 ± 5.01	0.80	0.22
Peak velocity (m.s^{-1})	2.79 ± 0.14*	2.64 ± 0.24	0.02	0.76

* $p < 0.05$

Table 2. Comparison of CMJ variables for novice judo and BJJ athletes.

	Novice BJJ (n = 12)	Novice judo (n = 12)	p	ES
Jump height (cm)	43.25 ± 7.00	45.32 ± 4.12	0.39	0.36
Maximum force (N.kg^{-1})	22.99 ± 2.06	23.76 ± 2.07	0.37	0.37
Mean power (W.kg^{-1})	27.32 ± 3.80	27.80 ± 3.15	0.73	0.13
Peak power (W.kg^{-1})	49.32 ± 5.70	48.69 ± 4.28	0.76	0.12
Peak velocity (m.s^{-1})	2.56 ± 0.27	2.73 ± 0.14*	0.05	0.79

* $p < 0.05$

Table 3. Comparison of CMJ variables for advanced judo and BJJ athletes.

	Advanced BJJ (n = 8)	Advanced judo (n = 8)	p	ES
Jump height (cm)	48.44 ± 4.76	48.41 ± 2.90	0.98	0.07
Maximum force (N.kg^{-1})	24.09 ± 2.97	26.22 ± 2.41	0.13	0.78
Mean power (W.kg^{-1})	28.62 ± 2.30	29.93 ± 2.51	0.29	0.54
Peak power (W.kg^{-1})	51.87 ± 3.54	51.88 ± 3.75	0.99	0.02
Peak velocity (m.s^{-1})	2.76 ± 0.10	2.87 ± 0.14*	0.04	0.90

* $p < 0.05$

effect). No significant differences for the other variables were verified, but the maximum force presented a large effect, and mean power showed a moderate effect (higher in advanced judo athletes).

Table 4 shows the comparison of CMJ variables for the advanced and novice groups of BJJ athletes. The advanced athletes presented higher values for jump height (large effect) and peak velocity (large effect) compared to novices. The maximum force and peak power show a moderate effect, i.e., higher in advanced athletes than in novices, but with no significant difference ($p > 0.05$).

Table 5 presents the CMJ variables for the advanced and novice judo athletes. The maximum force and the peak velocity were higher for advanced judokas (large effect). Jump height, peak power, and mean power also show also large effects, but no significant differences ($p > 0.05$).

Discussion

The goals of this study were to compare the kinetic parameters of CMJ (height, power output, velocity, and force) between judo and BJJ athletes, and between advanced and novice athletes. Considering the first objective, we reject the hypothesis, as the peak velocity was higher in judo athletes than in BJJ athletes. Peak velocity is the highest value identified in the v-*t* curve in the last contact with the ground (jump take-off). Although BJJ combat exhibits greater intensity than judo combat (regarding the effort: pause ratio) [Franchini *et al.* 2011; Miarka *et al.* 2012; Franchini *et al.* 2013; Andreato *et al.* 2015; Andreato *et al.* 2016; Andreato *et al.* 2017], there is no indication if this intensity is higher in the upper or lower limbs. The highest velocity during the jump take-off was confirmed in the judo athletes. This may be explained by the predominance of standing combat in judo compared BJJ, in which the combat is predominantly on the ground [Ratamess 2011; Jones, Ledford 2012]. In addition, in judo there are several throwing techniques, especially leg actions (for example, *o-soto-gari*, *de-ashi-barai*), performed at high velocity. These techniques (*ashi-waza*) are widely used during judo competitions, comprising as much as 40% of the total number of techniques in a Judo World Championship [Adam *et al.* 2011].

In this investigation, the peak and mean power output and maximum force obtained in the two sports did not differ from each other, although there was a moderate effect for force in the case of judo athletes. Maximum force refers to the highest value obtained in the concentric phase of the jump, while the power output is determined by the product of force and velocity ($P = F \times V$) [Knudson 2009]. In other words, although the velocity was higher for judo athletes than BJJ athletes, the force did not differ between them. The power output during the jump seems to have been influenced rather more by the force than the velocity. Therefore, it can be suggested that these neuromuscular capacities (force and power) are widely required during training and combat in both judo and BJJ, taking into account the characteristics of sports.

Moreover, jump height, considered the best indicator of muscle power in the lower limbs [Markovic *et al.* 2004], was similar in judo and BJJ athletes (close to 45 cm). Previous studies have shown similar values in judo athletes [Monteiro *et al.* 2011; Detanico *et al.* 2012; Papacosta *et al.* 2013; Detanico *et al.* 2015; Athayde *et al.* 2017] but lower values in BJJ athletes [Diaz-Lara *et al.* 2015; Diaz-Lara *et al.* 2014] compared to those in this

Table 4. Comparison of CMJ variables for advanced and novice BJJ athletes.

	Novice (n = 12)	Advanced (n = 8)	p	ES
Jump height (cm)	43.25 ± 7.00	48.44 ± 4.76*	0.05	0.86
Maximum force ($N.kg^{-1}$)	22.99 ± 2.06	24.09 ± 2.97	0.38	0.43
Mean power ($W.kg^{-1}$)	27.32 ± 3.80	28.62 ± 2.30	0.40	0.39
Peak power ($W.kg^{-1}$)	49.32 ± 5.70	51.87 ± 3.54	0.23	0.48
Peak velocity ($m.s^{-1}$)	2.56 ± 0.27	2.76 ± 0.13*	0.03	0.94

* $p < 0.05$

Table 5. Comparison of CMJ variables for advanced and novice judo athletes.

	Novice (n = 12)	Advanced (n = 8)	p	ES
Jump height (cm)	45.32 ± 4.12	48.41 ± 2.90	0.08	0.94
Maximum force ($N.kg^{-1}$)	23.76 ± 2.07	26.23 ± 2.41*	0.02	1.50
Mean power ($W.kg^{-1}$)	27.80 ± 3.15	29.93 ± 2.51	0.13	0.78
Peak power ($W.kg^{-1}$)	48.69 ± 4.28	51.88 ± 3.75	0.11	0.84
Peak velocity ($m.s^{-1}$)	2.73 ± 0.14	2.87 ± 0.10*	0.03	1.15

* $p < 0.05$

study. This demonstrates that the judo and BJJ athletes in this study exhibited important levels of force and power in the lower limbs. Technical actions in the combat sports, such as the throwing techniques or groundwork situations (guard passes, sweeps, takedowns, etc.), present during training and combat, require high levels of muscle power in the lower limbs [Franchini *et al*. 2013; James 2014; Diaz-Lara *et al*. 2015]

Considering the second objective, which was to compare the kinetic parameters of CMJ between novices and advanced athletes, we accept the hypothesis because there were significant differences in three variables and the others showed moderate to large effect magnitude. Also, the peak velocity was higher in the judo novice athletes compared to novice BJJ, as well as higher in judo advanced compared to BJJ advanced. Considering the BJJ athletes group, we found higher values for jump height and peak velocity in the advanced group of BJJ athletes than in the novice group. A previous study also verified better performance in terms of jump height, and peak and mean power output in experienced BJJ athletes compared to beginners [Diaz-Lara *et al*. 2014]. The higher performance in jump height supports the idea that athletes with greater experience in the sport present better storage and reuse of elastic energy (SSC optimization) during the vertical jump [Zaggelidis *et al*. 2012]. No significant differences in the maximum force and power output (mean and peak) were recorded, suggesting that novices and advanced athletes can apply similar levels of force and power in the concentric phase of the jump.

Among the judo athletes, higher values of maximum force and peak velocity were found in the advanced group than the novice group, i.e., the experienced judo athletes were able to apply more force and velocity in the jump take-off. The peak power and mean power showed a large effect, but no significant differences. Peak velocity and maximum force have been strongly correlated with jump height [Yamauchi *et al.* 2007], which also showed a large effect. Previous studies have found that advanced judokas present better performance in the CMJ (jump height and power output) compared to novice athletes due to the better SSC optimization in this type of action [Zaggelidis *et al*. 2012; Detanico *et al.* 2016]. In addition, jump height is considered the variable that best discriminates beginner and advanced judokas, and can be used as a reference to classify the level of training novice or advanced [Detanico *et al.* 2016].

Finally, it is important to highlight that although the CMJ is the best indicator of muscle power in the lower limbs [Markovic *et al*. 2004], care should be taken in the direct transfer of capacities such as strength, velocity, and power (identified through the CMJ) to performance during combat bouts as the analysis was based on a generic test. On the other hand, the findings of this study can contribute to coaches and physical trainers to identify different characteristics in the muscle power production, particularly regarding the velocity. Also, vertical jump performance can be interesting method for muscle power assessment in the lower limbs and possibly classifying the power level in judo and BJJ athletes.

Conclusions

We conclude that the judo athletes (both novice and advanced) were able to apply higher velocity during the jump take-off compared to BJJ athletes. However, the CMJ performance (jump height) was similar in judo and BJJ athletes. In general, advanced athletes in both combat sports (judo and BJJ) seem to present higher performance in CMJ parameters related to force and velocity than novices. More studies are needed to investigate possible differences between judo and BJJ athletes in the force and power parameters of the upper limbs. Although the two combat sports show similarities (intermittent nature, domain actions, etc.), there are several specificities, particularly in the terms of the force and velocity utilization during the actions.

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Wyniki skoków pionowych zawodników judo i brazylijskiego jiu-jitsu: w ujęciu z różnymi poziomami szkoleniowymi

Słowa kluczowe: sporty walki, moc mięśni, cykl skracania rozciągania, kończyny dolne

Abstrakt

Tło. Judo i brazylijskie jiu-jitsu (BJJ) są rodzajem sportu wykorzystującym techniki chwytów, w którym obie formy wymagają kombinacji działań siłowych z użyciem górnych i dolnych kończyn. Zastosowanie kończyn dolnych w działaniach siłowych jest obserwowane w judo w kilku technikach rzucania, gardach, obezwładnieniach i rzutach na matę.

Cel. Porównanie parametrów kinetycznych wydajności skoku pionowego między zawodnikami judo i BJJ oraz porównanie tych parametrów pomiędzy nowicjuszami a zaawansowanymi sportowcami.

Metody. W badaniu wzięło udział 20 sportowców judo (12 początkujących i 8 zaawansowanych) oraz 20 zawodników jiu-jitsu (12 początkujących i 8 zaawansowanych). Wykonali oni skok z obrotem (*counter-movement jump*) na platformie

mierzącej siłę. Zanalizowano następujące zmienne: wysokość skoku, średnią moc, moc szczytową, maksymalną siłę i prędkość szczytową. Zastosowano niezależny t-test przy poziomie istotności $p \leq 0,05$ i obliczono wielkość efektu w celu sprawdzenia wielkości rezultatu.

Wyniki. Główne wyniki wykazały, że w judo tylko szczytowa prędkość była większa niż w przypadku sportowców BJJ ($p = 0,02$). Ponadto zaawansowani sportowcy BJJ wykazywali wyższą prędkość szczytową ($p = 0,03$) i wysokość skoku ($p = 0,05$) niż początkujący sportowcy. Zaawansowani judocy wykazywali wyższą prędkość szczytową ($p = 0,03$) i maksymalną siłę niż początkujący sportowcy ($p = 0,02$).

Wnioski. Z badań wynika, że sportowcy judo potrafią zastosować większą prędkość podczas wybicia się do skoku w porównaniu z sportowcami BJJ. Ogólnie rzecz biorąc, zaawansowani sportowcy w obu sportach walki wydają się prezentować wyższe parametry w skokach z obrotem związane z siłą i prędkością.