applied sciences

MDPI

Article

Neuromuscular Performance of World-Class Judo Athletes on Bench Press, Prone Row and Repeated Jump Tests

Luís Monteiro [1,2,3], Luís Miguel Massuça [1,3,4,*], Sérgio Ramos [1] and José Garcia-Garcia [2]

1 CIDEFES, Lusófona University, 1749-024 Lisbon, Portugal
2 Faculty of Sport Science, Castilla-La Mancha University, 45071 Toledo, Spain
3 ICPOL, Higher Institute of Police Sciences and Internal Security, 1300-663 Lisbon, Portugal
4 CIFI2D, Faculty of Sport, University of Porto, 4200-450 Porto, Portugal
* Correspondence: luis.massuca@gmail.com or luis.massuca@ulusofona.pt

Abstract: Judo is a sport that requires multiple high-intensity moments during the fight and high neuromuscular performance. Although not often, the explosive actions of the lower limbs can be decisive to winning in combat. This study aims to identify the differences in the neuromuscular features of the range of movements of the upper and lower limbs between the top-elite and elite male judo athletes. This cross-sectional study included 63 high-level male judo athletes, who were classified into two level groups: (i) top-elite (n = 30; age: 23.5 ± 3.2 years) and (ii) elite (n = 33; age: 22.6 ± 2.9 years). All the participants went to the laboratory for neuromuscular evaluations in the bench press (BP), prone row (PR), and repeated jump in 30 s (RJ30) tests. The results show that the top-elite judo athletes are superior in all the upper-body neuromuscular attributes studied. These differences were significantly superior in (i) BP peak velocity ($p < 0.01$), maximum load 1RM, power (peak and mean), force (peak and mean), force mean to peak power, and rate of force development (RFD) (all, $p < 0.001$); and (ii) RP maximum load 1RM ($p < 0.01$), power load (kg, $p < 0.001$; % 1RM, $p < 0.05$), peak power ($p = 0.010$), power mean (absolute, $p < 0.01$; relative, $p < 0.05$), force mean ($p < 0.05$), force mean to peak power (absolute, $p < 0.05$) and RFD ($p < 0.001$). However, no significant differences were observed in the BP and PR time to peak force, time to peak power, and time between peaks (power and force). In the RJ30, it was observed that the initial contact time (T1) of top-elite athletes is significantly lower than that of elite athletes ($p < 0.05$) and that power at 15 (T2) and 30 (T3) seconds is significantly higher in top-elite athletes (T2, $p < 0.05$; T3, $p < 0.01$). The main effect of the performance group was significant in contact time ($p < 0.05$), and the main effect of time was statistically significant in jump height ($p < 0.001$), power ($p < 0.001$), force ($p < 0.001$) and velocity ($p < 0.01$). In addition, jump height ($p < 0.01$; $\eta^2_p = 0.088$) and power ($p < 0.05$; $\eta^2_p = 0.068$) showed a significant interaction between time and performance group. These results suggested that the observed superiority of the top-elite judo athletes in neuromuscular attributes can determine success in judo competitions. This observation reinforces that neural and metabolic profiles must be considered to increase the effectiveness of maximal power training for the upper and lower body.

Keywords: combat sports; force; performance; power; rate of force development; strength; velocity

check for updates

Citation: Monteiro, L.; Massuça, L.M.; Ramos, S.; Garcia-Garcia, J. Neuromuscular Performance of World-Class Judo Athletes on Bench Press, Prone Row and Repeated Jump Tests. *Appl. Sci.* **2024**, *14*, 2904. https://doi.org/10.3390/app14072904

Academic Editors: Nikolaos Zaras and Marios Hadjicharalambous

Received: 2 March 2024
Revised: 24 March 2024
Accepted: 27 March 2024
Published: 29 March 2024

1. Introduction

The bases that determine the performance of a winning judoka define him as a judoka with a great capacity to perform many attacks, great combat activity, high technical-tactical mastery, and high attack–defence efficiency [1,2], and to succeed in international judo competitions, judokas must achieve optimal physical fitness during training [3].

According to the literature, the main physical fitness attributes of judo performance are aerobic and anaerobic [3], muscle strength, and the power of the upper and lower limbs [4–6]. Aerobic power and capacity are essential to recovery from high-intensity efforts in short rest periods and to sustain the effort during the entire judo combat. Anaerobic power and capacity determine the actions that depend on powerful movements [5]. Furthermore, there is no doubt regarding the importance of explosive strength and power in the training and competition of high-performance judokas (particularly during the grip and throw phases). Nevertheless, the functions of the upper and lower trunk muscles may differ because of the nature of the movements used and the metabolic demands of some offensive and defensive movements in judo bouts [7].

During a fight, the upper body's muscles are usually the most involved with the continuous performance of muscular contractions, resulting in more significant energy expenditure during combat, and the lower body has a punctual presence of explosive actions during projection actions (consequently, less energy expenditure) [7]. Although not often, the explosive actions of the lower limbs during the throw can be decisive in a sport where the result can be decided only through effort (Ippon—maximum advantage, with which you can immediately win the fight).

The muscle-elastic components, including the short-stretch muscular cycle (SSC), are essential in generating optimal lower body muscle power [8]. Recent studies demonstrated that the best-ranked athletes performed better in the countermovement jump and continuous vertical jump test, lasting 15 s longer than their lower-ranked counterparts [4], and had higher neuromuscular performance (i.e., handgrip strength and vertical jump performance) than the lower-ranked athletes [4,9]. Furthermore, the judokas with higher muscle power (i.e., countermovement jump performance) showed a more effective time in the combat bouts [4,10].

Throwing judo techniques requires explosive strength, power, speed, and synchronisation of the ankle, knee, and hip joints. A judoka must execute these techniques as quickly as possible to develop the technique effectiveness necessary to defeat the opponent during a fight [11]. In judo, the rapid transition between the eccentric and concentric phases occurs mainly in actions of an explosive nature, such as the technical actions to throw the opponent, in which an eccentric action precedes a concentric action [12]. The ability to resist the initial muscular stretch and invert the direction of the displacement of the gravity centre results in the mechanical, nervous, and metabolic aspects associated with muscular work and rate force. It is known that the movements involving muscular contraction on SSC are characterised by producing a mechanical power higher than the one produced only in pure concentric movements. At this point, it is also understandable that repeated stretching loads cause neuromuscular fatigue, which reduces the stretching tolerance because of the increased time work and the time of transition between the short-stretching contractions [8,13].

Although it is well known that maximum explosive force is vital to compete successfully in judo, the truth is that there needs to be more information about its evaluation in top-elite judokas. A comparison of top-level and high-level athletes can provide relevant information that enables the development of model indicators of sports mastery in judo and the optimisation of training at the highest level. Following this, this study aims to identify differences in the neuromuscular features of the range of movements of the upper and lower limbs between the top-elite and elite male judo athletes.

2. Methods

2.1. Participants

Sixty-three high-level adult male judo athletes from five National Judo National Teams (Portugal, Tunisia, Brazil, France, and Spain) participated in this cross-sectional study. Despite having different performance levels, weight categories, and ages, a minimum level of competition was ensured by establishing, as a selection criterion, having been a part of each country's national team. The participants (undergoing 8–10 h/week of judo-specific training volume) were divided into two groups of highly trained athletes: (i) top-elite (n = 30), which were medal-winning athletes in the Continental Championships, Grand Prix, Grand Slam, World Championships or Olympic Games; and (ii) elite (n = 33), which were athletes who had participated but did not win medals in the international competitions (i.e., Continental Championships, Grand Prix, Grand Slam, World Championships or Olympic Games). They voluntarily participated in this study (previously received information on its objective, extent, and tests and accepted the pre-established protocols and methodology) and provided written informed consent before participation. The Faculty of Sport Science, Castilla La Mancha University (Toledo, Spain) Ethics Committee approved this study (Approval code 45006232; Date: 11 October 2013), and all procedures and the study protocol were conducted following the Declaration of Helsinki.

2.2. Neuromuscular Evaluations

Muscular strength in judo athletes has been characterised using free weight exercises [14] and vertical jump tests [15,16]. Accordingly, the judo athletes (top-elite and elite) performed two upper-body strength tests (bench press and prone row) and one vertical jump test (repeated jump 30 s). Participants had been familiar with the testing procedures as they customarily performed them as part of their regular training/evaluation routines. They only participated in prolonged exercise within 24 h of testing onset.

The subject performed a general warm-up of 3–5 min light activity. After the general warm-up, the subject performed a specific warm-up of 8 repetitions at approximately 50% of his 1RM, followed by another set of 3 repetitions at 70% close to 1RM [17].

Bench press (BP) (Figure 1) is one of the tests with the highest validity in predicting the competitive level in judo [18]. The test was performed in the laboratory following the recommended procedures of the American Society of Exercise Physiologists [17]. It was developed by applying progressive loads, with three repetitions being performed with each load until reaching the maximum load. The system was mounted with an encoder of 200 cm and 2 N of resistance in the vertical plane of the bar displacement. The load discs used were previously calibrated using a tensiometric cell suspended from a horizontal beam, with the weights that did not have a deviation greater than 0.5% being considered valid. The first load, the athlete, had to overcome was a 0.200 kg plastic bar to obtain the maximum execution speed. The loads had to be overcome concentrically, without the help of countermovement, for which a device had been adjusted in the Isocontrol system (Isocontrol 5.1. plus system, Quasar Control, Madrid, Spain) that timed each of the repetitions to avoid said action. The loads increased by 5, 10 or 20 kg depending on the 1RM of each athlete and the speed with which they moved the previous weight. The rest between sets was 3 to 5 min, with a greater rest as we approached the value of 1RM.

Figure 1. Bench press exercise using the Isocontrol Dynamic 5.1 (Quasar Control, Madrid, Spain).

The prone row test (PR) (Figure 2) was carried out in the laboratory. It was developed through progressive loads, with three repetitions being performed with each load until reaching the maximum load, a load with which only one repetition would be completed at a speed close to 0.30 m/s. The most crucial point of the evaluation was that the encoder (Isocontrol 5.1. plus system, Quasar Control, Madrid, Spain), marked by the yellow circle in Figure 2, was always below the bar and perpendicular to its movement. The first load the athlete had to overcome was a barbell with 20 kg. The loads had to be overcome concentrically, without countermovement aid. The loads increased by 5, 10, or 20 kg depending on the 1RM of each athlete. When the execution speed dropped below 0.30 m/s, he was told to perform a single repetition since the normal speed in executing the 1RM in experienced athletes is usually approximately 0.30 m/s. The rest between sets was 3 to 5 min, with more rest as we approached the 1RM value.

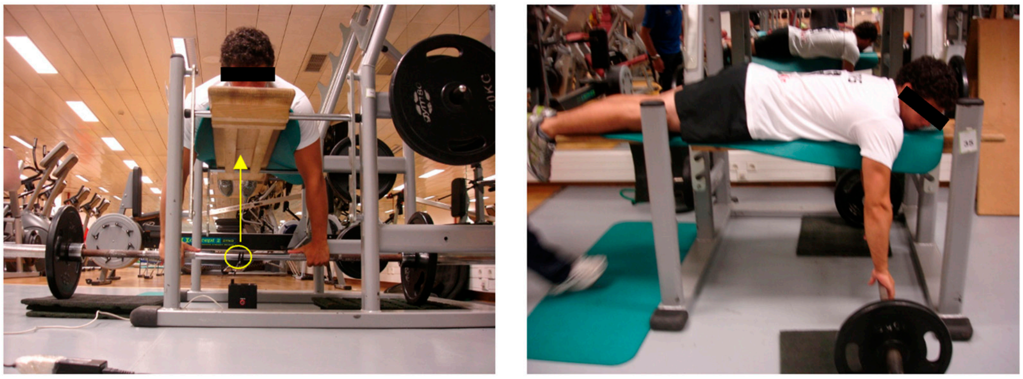

Figure 2. Prone row exercise using the Isocontrol Dynamic 5.1 (Quasar Control, Madrid, Spain).

The repeated jump test in 30 s (RJ30) evaluated the resistance to explosive leg strength. The participant had to perform maximum repetitions in 30 **s** on a portable force platform (ISONET 500, J.L.M.L. R&D, Madrid, Spain) validated by the National Institute of Applied Technologies (I.N.T.A. Torrejón de Ardoz, Madrid, Spain), which concluded that the product has excellent concurrent criterion validity [12]. Participants initiated the test by standing and crouching immediately following a jump to maximum height [19]. Each subject held the bar (mass, 0.200 kg) for the entire test duration, so bar–shoulder contact was always maintained for RJ30. The right side of the rod was attached to a linear position transducer (LPT) (Aurki, Fagor Corporation, Mondragón, Spain) with a retraction tension of 2.4 N, and the maximum acceleration that could be measured was 150 m/s^2. Analogue signals from the force platform and LPT were collected in all the tests at 1000 Hz, with a BNC-2010 interface box with an analogue-to-digital card (Crossbow Technology DMU VGX Rev, B.01, serial number 9711987, San Jose, CA, USA). The data collection methodology was previously validated [20,21], the same experienced investigator obtained all the measurements, and the CV for all the variables in these measurements was <10% [22] for each measure.

2.3. Statistical Analysis

Results are expressed using means and standard deviations (mean ± SD) for all the dependent variables. The Kolmogorov–Smirnov and Levene tests were used to evaluate the normality and homogeneity of the two groups under study (top-elite vs. elite). The age, body size, and neuromuscular attributes (upper-body strength and vertical jump tests) were analysed using a *t*-test for independent samples, in which the level of performance (top-elite vs. elite) was the between-participant variable. The significance evolution in RJ30 attributes was evaluated with repeated measures ANOVA across three time periods, namely T1 (highest initial value between the 1st and 3rd jump), T2 (jump value in 15 s), and T3 (the value of the jump in 30 s) and, when appropriate, the Bonferroni post hoc test was applied. The level of significance for each analysis was set at p-value < 0.05. All calculations were performed using the Statistical Package for the Social Sciences (SPSS Inc, version 20.0, Chicago, IL, USA).

3. Results

No significant differences were observed between the elite and top-elite judo athletes in age (top-elite, 23.5 ± 3.2 years; elite, 22.6 ± 2.9 years; p = 0.269), stature (top-elite, 1.77 ± 0.06 m; elite, 1.76 ± 0.07 m; $p = 0.628$) and body mass (top-elite, 79.17 ± 15.08 kg; elite, 73.27 ± 9.09 kg; $p = 0.062$).

The bench press (BP) exercise results show that the top-elite judokas were significantly superior to elite judokas (Table 1). However, no significant differences were observed in power load (% of 1RM), the time to peak force, time to peak power and time between peaks (power and force). In the prone row (PR), top-elite judo athletes were superior in all attributes studied (Table 1), i.e., statistical significant in maximum load (1RM), power load (kg and % 1RM), peak power, power mean, force mean to peak power force mean, and rate of force development (RFD). As in the BP, no significant differences were observed in the time to peak force, time to peak power, and time between peaks (power and force).

Table 1. Mean values and standard deviation (M ± SD) of the strength variables, resulting from the execution of the bench press and prone row in top-elite and elite judo athletes.

Dependent Variables	Bench Press			Prone Row		
	Top-Elite	Elite	*p*-Value	Top-Elite	Elite	*p*-Value
Peak velocity (m/s) [A]	5.48 ± 0.67	5.08 ± 0.54	**<0.01**	2.94 ± 1.00	2.76 ± 0.75	0.420
Maximum load 1RM (kg)	114.03 ± 19.45	82.42 ± 19.65	**<0.001**	105.27 ± 17.95	93.33 ± 14.67	**0.005**
Power load (kg)	57.57 ± 10.81	41.15 ± 12.16	**<0.001**	58.57 ± 10.43	48.24 ± 10.35	**<0.001**
Power load (% of 1RM)	50.72 ± 6.70	49.87 ± 7.35	0.634	56.02 ± 7.40	51.70 ± 7.23	**0.023**
Peak power (W)	1107.16 ± 323.76	757.56 ± 207.47	**<0.001**	1191.18 ± 318.63	986.60 ± 291.29	**0.010**
Relative peak power (W/kg)	14.14 ± 4.01	10.76 ± 2.89	**<0.001**	15.17 ± 3.63	13.48 ± 3.64	0.070
Power mean (W)	709.10 ± 151.39	504.68 ± 122.90	**<0.001**	804.28 ± 174.15	681.09 ± 186.38	**0.009**
Relative power mean (W/kg)	9.05 ± 1.76	7.13 ± 1.60	**<0.001**	10.29 ± 1.94	9.25 ± 1.96	**0.040**
Peak force (N)	2062.47 ± 597.40	1290.31 ± 373.88	**<0.001**	1677.48 ± 496.07	1556.95 ± 384.79	0.283
Relative peak force (N/kg)	26.11 ± 5.96	18.28 ± 4.91	**<0.001**	21.55 ± 6.54	21.19 ± 4.21	0.797
Force mean to peak power (N)	932.42 ± 289.98	607.86 ± 161.92	**<0.001**	805.66 ± 162.89	716.34 ± 154.65	**0.029**
Relative force mean to peak power (N/kg)	11.97 ± 3.73	8.64 ± 2.23	**<0.001**	10.32 ± 1.87	9.78 ± 1.70	0.238
Force mean (N)	1146.54 ± 248.02	866.72 ± 224.19	**<0.001**	1149.66 ± 238.64	1015.96 ± 167.18	**0.012**
Rate of force development (N/s)	103224.20 ± 16379.57	65605.15 ± 22515.31	**<0.001**	94887.10 ± 26779.61	67327.05 ± 20171.80	**<0.001**
Relative rate of force development (N/s/kg)	1335.08 ± 273.93	944.08 ± 355.64	**<0.001**	1219.68 ± 360.31	918.90 ± 264.97	**<0.001**
Time to peak force (ms)	22.60 ± 5.67	25.30 ± 10.93	0.230	24.00 ± 9.14	28.58 ± 12.43	0.099
Time to peak power (ms)	311.70 ± 48.62	305.33 ± 66.71	0.669	211.97 ± 52.71	199.06 ± 66.39	0.399
Time between peaks (power and force) (ms)	289.10 ± 48.97	280.03 ± 67.09	0.546	187.97 ± 50.75	170.48 ± 71.24	0.271

Key: [A], Peak velocity (m/s) for bench press without loads and prone row with 20 kg.

In the repeated jump test (RJ30), the initial contact time (T1) of the top-elite athletes was significantly lower than that of elite athletes, and power at 15 (T2) and 30 (T3) seconds were significantly higher in top-elite athletes (Table 2).

The main effect of the performance group was significant in contact time ($p = 0.048$), and the main effect of time was statistically significant in terms of jump height (p-value < 0.001), power ($p < 0.001$), force ($p < 0.001$) and velocity ($p = 0.002$). Repeated measures ANOVA results for contact time ($F(1.337, 81.560) = 0.211$, $p = 0.718$; $\eta^2_p = 0.003$; Power = 0.077), force ($F(2, 122) = 1.981$, $p = 0.142$; $\eta^2_p = 0.031$; Power = 0.403) and velocity ($F(1.713, 104.518) = 2.231$, $p = 0.120$; $\eta^2_p = 0.035$; Power = 0.412) failed to show a significant interaction of period versus performance level (all, Greenhouse–Geisser corrected model). In addition, jump height ($F(1.683, 102.679) = 5.898$, $p = 0.006$; $\eta^2_p = 0.088$; Power = 0.822) and power ($F(1.782, 108.721) = 4.418$, $p = 0.018$; $\eta^2_p = 0.068$; Power = 0.715) showed a significant interaction between time and performance group. The Bonferroni post hoc test results showed that height jump and power significantly decreased at 15 s (T2) and 30 s (T3) (Figure 3).

Table 2. Mean values and standard deviation (M ± SD) in jump height, contact time, power, force, and velocity, resulting from the execution of the repeated jump test, RJ30 (T1, initial; T2, 15 s; T3, 30 s) in top-elite and elite judo athletes.

Dependent Variables	Periods	Top-Elite	Elite	*p*-Value
Number of jumps (n)	All	29.93 ± 3.90	29.36 ± 2.85	0.508
Jump height (cm)	T1	32.48 ± 4.66	34.75 ± 6.22	0.110
	T2	30.46 ± 4.74	30.98 ± 5.91	0.702
	T3	28.06 ± 5.38	27.41 ± 5.09	0.625
Contact time (ms)	T1	533.37 ± 97.42	593.55 ± 118.99	**0.033**
	T2	533.77 ± 106.42	578.91 ± 117.99	0.117
	T3	545.70 ± 140.07	598.97 ± 113.45	0.101
Power (W)	T1	2061.55 ± 477.93	2008.21 ± 415.99	0.638
	T2	2079.09 ± 482.78	1846.77 ± 402.74	**0.042**
	T3	1901.85 ± 431.45	1621.92 ± 344.68	**0.006**
Force (N)	T1	1795.82 ± 654.22	1871.98 ± 501.05	0.604
	T2	1905.17 ± 688.43	1722.68 ± 422.01	0.216
	T3	1570.86 ± 476.38	1488.96 ± 391.35	0.457
Velocity (m/s)	T1	2.73 ± 0.33	2.85 ± 0.36	0.175
	T2	2.73 ± 0.30	2.73 ± 0.36	0.995
	T3	2.66 ± 0.43	2.63 ± 0.42	0.758

Key: T1: highest initial value (between the first and third jump); T2 (15 s): jump value in 15 s; T3 (30 s): the value of the jump in 30 s.

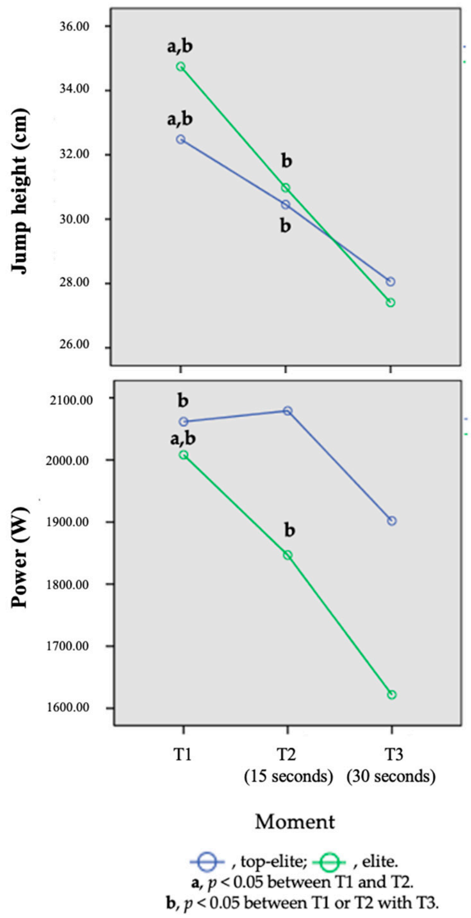

Figure 3. Time course changes in elite and top-elite judo athletes, in jump height and power, during the repeated jump test across 30 s for the RJ30 (moments: T1, initial; T2, 15 s; T3, 30 s).

4. Discussion

This study aims to identify the differences between the top-elite and elite male judo athletes' neuromuscular attributes of their upper and lower limb movements. The following was observed: (i) top-elite judokas were significantly superior in all upper body neuromuscular attributes (except for time to peak force, to peak power, and between peaks); (ii) top-elite athletes significantly decreased jump height, power, and force during the execution of the RJ30 (but elite athletes also decreased velocity); and (iii) top-elite athletes' initial contact time in the RJ30 was significantly lower than that of the elite athletes, and the power at 15 and 30 s was significantly higher in top-elite athletes.

The results of this study suggest that the peak velocity, maximum load (1RM), power load, peak power, power (peak and mean), force (peak), force mean to peak power, and rate of force development in the bench press (BP) test differentiate the top-elite male judokas from the elite ones. However, although the prone row (PR) does not reflect statistically significant differences in the relative peak power, peak force, and relative force mean to peak power, this exercise still tends to differentiate the top-elite from the elite judokas.

Concerning arm power, it is known that judokas have a more robust profile than other athletes. Studies in the literature [12,23] highlight the importance of strength and power of the arms in a judo performance, observing that the athletes with the most remarkable sporting success were the ones who presented higher values of arm power [3,12]. The results of our study support the conclusion that there are differences in strength and power capabilities between the top-elite and elite athletes, as observed by Almeida and colleagues [24]. The power levels that the judoka must develop, at a minimum, must be sufficient to overcome the resistance of the opponent's body weight in the shortest possible time to achieve his imbalance (Kuzushi) and end the throw.

The average 1RM of the top-elite judokas in the BP test was significantly higher than that of the elite judokas (Table 1), and then judokas of the Canadian national team [15], and Finnish judokas of the international and national level [14], but lower than observed in judokas of the Italian Olympic team [25]. Regarding the PR and the average 1RM of the judokas in our study (Table 1), the literature shows higher values in the regular and reserve athletes of the Brazilian National Team [26]. As we can see, the top-elite group is stronger than the elite group in PR and BP. Despite this, the differences in maximum load (1RM) may be associated with weight categories, so comparisons across different judoka studies should be cautiously conducted. It is recommended that the data be presented by weight categories, given that the strength profiles seem to differ from one to another [23]. However, Franchini et al. [3,26] considered strength a discriminatory component between groups of different competitive levels.

We observed that in the BP test, there were no significant differences between the top-elite and elite at the level of the power load (% of 1RM), contrary to what was observed in the PR test. In judo, due to the resistance that the athlete must overcome, the power load must be achieved, with a relatively significant percentage of 1RM (50–60% of 1RM), with a load like his body weight. Considering that some researchers [27] indicate that the influence of maximum force on power production decreases when the external load decreases, there is high power in judo since the external load that the judoka must overcome is high (the opponent's weight plus the resistance he offers). In conclusion, the judokas in our study consider the optimal load (% of 1RM with which they develop maximum power) of the arms in the profile of power athletes.

Concerning time to peak force, time to peak power, and the difference between peaks (power and force), no significant differences are observed between the two performance groups. However, the load where the maximum power is manifested differs in the two groups (the load is much greater on top-elite judokas). In the top-elite judokas, the time to peak power value recorded in the PR (~200 ms) is lower than that of the BP (~300 ms), and the time between peaks (peak power until the peak force) recorded in non-PR (~190 ms) is also lower than that of the BP (290 ms). The time until the acquisition of peak force also shows no significant difference between the top-elite and elite athletes. Although the differences observed were not significant, most top-elite judokas still manifested peak force in a shorter time than the judokas of the elite group (Table 1). In this variable, associated with the behaviour of type IIb muscle fibres, there is no real difference in the time necessary to manifest the maximum dynamic force. No significant differences are observed between the two performance groups; however, the load displayed with maximum power differs in the two groups (the load is greater in top-elite judokas).

Of all the strength manifestations analysed, the rate of force development (RFD) in BP and PR is the one that shows the most pronounced differences between the top-elite group and the elite group (Table 1). It is widely accepted that the RFD constitutes a primary variable to describe performance during explosive muscle contractions and in the BP and PR exercises evaluated in our study. The data from our research show that top-elite athletes can manifest significantly higher values in maximum explosive strength than elite judokas. An explanation for these data could be that more experienced judokas mobilise FT IIb fibres more selectively and have higher neural activation. The experience of working with sub-maximal and maximum loads at high speed is one of the possible reasons for the difference between top-elite and elite athletes in this context. Physiologically, it could be attributed to a more remarkable development of intramuscular coordination, based mainly on a better ability to recruit FT IIb muscle fibres and the possibility of having a greater stimulation frequency when performing maximum effort. Both values are critical in judo since a judoka can express his best RFD against a below maximum resistance or his maximum strength against a maximum resistance in the shortest possible time. For example, if the rival judoka does not offer great resistance, we cannot manifest our maximum dynamic strength. Still, we can display a great maximum explosive force since this is independent of the resistance to be overcome. It must be remembered that RFD rarely manifests itself at maximum resistance. However, there is a concept of relative explosive force where the values at maximum loads usually represent 40% to 60% of the RFD. Hence, the two values and their training for high competition are essential. In our study, the time for its manifestation ranged between 200 ms in the PR and 300 ms in the BP, and the RFD values exceeded 90,000 N/s.

The vertical jump tests do not correspond to the motor patterns of specific manifestations of strength in the lower limbs. Still, the impossibility of quantitatively evaluating the explosive strength of the lower limb with precise combat movements makes it necessary to use a test. The use of the repeated jump test in 30 s (RJ30) as a field test allows us to observe whether the average height of the jumps performed by the top-elite athletes (30.33 cm) is like those performed by the elite athletes (31.05 cm). However, the height of the jumps decreased almost linearly, showing a more accentuated decrease in the elite group relative to the top-elite. Although few studies have evaluated the response of the jump ability in judo athletes, Chaouachi et al. [28] showed median values of the athletes' jump heights in RJ30, which were higher than the ones our study showed (38.1 $\pm$ 3.6 cm and 32.07 cm, respectively).

Top-elite athletes have an average contact time of 0.536 ms to 105.191 ms less than the contact of elite athletes. However, the increase in contact time is proportionally higher from the first moment (T1) until the third (T3). These results suggest an increase in the stance phase duration associated with the changes in angular behaviour because of a muscular dynamic from which the deterioration of stiffness and muscular power begins in fatigue situations. The high load the muscles are exposed to during the eccentric phase is an important feature associated with maximum impulse movements. According to Komi [29], the ability to resist that load suggests a high level of muscular stiffness in this phase of the short-stretch muscular cycle (SSC). The same author details that the flight time presents intense electric activity before the contact, which allows a tension level during the eccentric phase of the muscular contraction.

In this way, the reduced stretching involving the movement is associated with muscular pre-activation, which results from pre-proclamation of the nervous central system [30], preparing the muscle to resist the impact loads through the union of some crossed points between the contractile proteins. On the other hand, according to Komi and Nicol [8], in fatigue conditions, the neuromuscular system changes the regulation of muscular stiffness, reducing the sensibility of stretching [30]. Therefore, although there were no significant changes recorded in the dimension of the stretched muscle with the installation of the fatigue, the truth is that the times of the eccentric action increased, which suggests a decrease in the mechanic power of the extensor muscles of the inferior limb, which probably results from a change in the muscular stiffness.

In short, the results verified that the initial contact (T1) time in the top-elite group is inferior to the elite group (i.e., −60.18 ms), and the power at the 15 s and 30 s mark is greater. It has also been observed that the power values present a more marked descent in the elite group in the middle (T2) and the final test (T3). However, there was no significant difference between the several moments on the record. The results suggest that the power of the jump depends on the judo athletes' performance group, being more pronounced in the elite athletes in both intervals (T1–T2 and T2–T3) and in the top-elite athletes only in the second half of the test (i.e., T2–T3). In other words, the top-elite judo athletes, being more powerful than the elite athletes, also present a smaller and later break during the 30 s of the test. In fact, both the evolution of mechanical power developed through all the jumps and contact time are precious sources of information on the characteristics of judo athletes.

This study allows us to discover that strength does not depend on the performance group and, in resemblance to what was verified for power, the effect of the length of the exercise is more pronounced in elite athletes. The strength applied tends to be higher in the initial part of the test (first repetitions) but leans to be progressively smaller as the repetitions increase, verifying an accentuated decrease in the elite group compared to the top-elite group. Also, the jump velocity (like what was observed for the power and strength) does not depend on the performance group. In every conditional aspect resulting from the jump evaluation, it can be observed that in every case, the decrease is noticed more in the elite athletes (top-elite, T2–T3; elite, T1–T2 and T2–T3).

According to the literature [7,30], the musculature of the lower limbs has an important galactic explosive role in judo, with punctual needs for high peaks of explosive strength for the projections and blockage/dodge of the opponent's attack. Aerobic base work supports these intermittent peaks, allowing recovery between them. However, the results suggest that limb power and fatigue endurance in short-term actions (breakdown after 15 s) are characteristics of the top-elite athletes as opposed to elite athletes (i.e., non-medallist athletes in international competitions). In fact, according to Monteiro and colleagues [12], the judoka does not jump a lot, nor does he need to (he must have a quick flexion/extension, i.e., be fast in the SSC). These results highlight the importance of training/development of maximal neuromuscular power in the lower limbs of judo athletes, and the studies presented by Cormie and colleagues [31,32] can also be a valuable scientific basis for judo coaches.

5. Conclusions

This study showed that (i) top-elite judokas were significantly superior in all upper-body neuromuscular attributes (except for time to peak force, to peak power, and between peaks); (ii) top-elite athletes significantly decrease jump height, power, and force during the execution of the RJ30 (but elite athletes also decrease velocity); and (iii) top-elite athletes' initial contact time in RJ30 is significantly lower than that of elite athletes, and the power at 15 and 30 s is significantly higher in top-elite athletes.

The observed superiority of top-elite judo athletes in neuromuscular attributes can determine their success in judo competitions. It reinforces that neural and metabolic profiles must be considered to increase the effectiveness of maximal power training for the upper and lower body. In this sense, various training methods are proposed to improve explosive actions, such as jumps, accelerations, throws, and hits, such as judo throws. The coach must know the different options presented to him and plan the training accurately, using other possibilities depending on the specific needs of his athletes and the part of the season they are in, to contribute to optimising sports performance.

These findings have implications for sports science in helping Olympic coaches select the appropriate neuromuscular and fitness training strategies to increase the competitive level of their elite judo athletes (overvaluing the RFD and glycolytic methods as they are the determining neuromuscular and metabolic components in judo performance). Strength and conditioning coaches working with Judo athletes are encouraged to think constructively about the information presented in these results and develop individual methods of incorporating some of these ideas within their training environments.

Author Contributions: Conceptualisation, methodology, investigation, resources, L.M. and J.G.-G.; formal analysis, data curation, L.M. and L.M.M.; writing—original draft preparation, L.M. and L.M.M.; writing—review and editing, L.M., L.M.M., S.R. and J.G.-G.; supervision, J.G.-G.; project administration, L.M.; funding acquisition, L.M. and L.M.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted following the Declaration of Helsinki and was approved by the Institutional Review Board of the Faculty of Sport Science, Castilla La Mancha University, Toledo, Spain (Approval code 45006232; Approval Date: October 11, 2013).

Informed Consent Statement: Informed consent was obtained from all the subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

Acknowledgments: The authors thank the judo athletes who participated in the study.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Serrano-Huete, V.; Latorre-Román, P.; García-Pinillos, F.; Morcillo Losa, J.; Moreno-Del Castillo, R.; Párraga-Montilla, J. Acute effect of a judo contest on muscular performance parameters and physiological response. *Int. J. Kinesiol. Sports Sci.* **2016**, *4*, 24–31. [CrossRef]
2. Ren, M.; Tian, Y.; McNeill, C.; Lenetsky, S.; Uthoff, A. The Role and Development of Strength for Elite Judo Athletes. *Strength Cond. J.* **2023**, *45*, 663–673. [CrossRef]
3. Franchini, E.; Del Vecchio, F.B.; Matsushigue, K.A.; Artioli, G.G. Physiological Profiles of Elite Judo Athletes. *Sports Med.* **2011**, *41*, 147–166. [CrossRef]
4. Kons, R.; Franchini, E.; Detanico, D. Neuromuscular and judo-specific tests: Can they predict judo athletes' ranking performance? *Kinesiol. Coach.* **2020**, *20*, 15–23.
5. Franchini, E.; Artioli, G.G.; Brito, C.J. Judo combat: Time-motion analysis and physiology. *Int. J. Perform. Anal. Sport* **2013**, *13*, 624–641. [CrossRef]
6. Marcos, S.U.; Rodríguez-Rodríguez, R.; Alfaro-Saiz, J.-J.; Carballeira, E.; Marcos, M.U. Improving on Half-Lightweight Male Judokas' High Performance by the Application of the Analytic Network Process. *Front. Psychol.* **2021**, *12*, 621454. [CrossRef] [PubMed]
7. Bonitch-Domínguez, J.; Bonitch-Góngora, J.; Padial, P.; Feriche, B. Changes in peak leg power induced by successive judo bouts and their relationship to lactate production. *J. Sports Sci.* **2010**, *28*, 1527–1534. [CrossRef]
8. Komi, P.V.; Nicol, C. Stretch-Shortening Cycle Fatigue. In *Biomechanics and Biology of Movement*; McIntosh, B., Nigg, B., Eds.; Human Kinetics Publication: Champaign, IL, USA, 2000.
9. Kostrzewa, M.; Laskowski, R.; Wilk, M.; Błach, W.; Ignatjeva, A.; Nitychoruk, M. Significant Predictors of Sports Performance in Elite Men Judo Athletes Based on Multidimensional Regression Models. *Int. J. Environ. Res. Public Health* **2020**, *17*, 8192. [CrossRef]
10. Ceylan, B.; Šimenko, J.; Balcı, S.S. Which Performance Tests Best Define the Special Judo Fitness Test Classification in Elite Judo Athletes? *J. Funct. Morphol. Kinesiol.* **2022**, *7*, 101. [CrossRef]
11. Narazaki, N.; Narazaki, K.; Atergiou, N. Kinetic and Kinematic analysis of a judo throwing technique: Osoto-gari. *Bull. Assoc. Sci. Stud. Judo* **2007**, *11*, 19–31.
12. Monteiro, L.F.; Massuça, L.M.; García, J.G.; Carratala, V.; Proença, J. Plyometric muscular action tests in judo- and non-judo athletes. *Isokinet. Exerc. Sci.* **2011**, *1*, 287–293. [CrossRef]

13. Gollhofer, A.; Komi, P.V.; Miyashita, M.; Aura, O. Fatigue During Stretch-Shortening Cycle Exercises: Changes in Mechanical Performance of Human Skeletal Muscle. *Int. J. Sports Med.* **1987**, *8*, 71–78. [CrossRef]
14. Fagerlund, R.; Hakkinen, H. Strength profile of Finnish judoist, measurement and evaluation. *Biol. Sport* **1991**, *8*, 143–149.
15. Thomas, S.G.; Cox, M.H.; LeGal, Y.M.; Verde, T.J.; Smith, H.K. Physiological profiles of the Canadian National Judo Team. *Can. J. Sport Sci.* **1989**, *13*, 142–147.
16. Claessens, A.M.; Beunen, G.; Lefevre, J. Body Structure, Somatotype, and Motor Fitness of Top-Class Belgian Judoists. In *Perspectives in Kinanthropometry*; Day, J.A.P., Ed.; Human Kinetics: Champaign, IL, USA, 1984; pp. 155–163.
17. Brown, L.; Weir, S. ASEP Procedures Recommendation I: Accurate Assessment of Muscular Strength and Power. *J. Exerc. Physiol.* **2001**, *4*, 1–21.
18. Lucic, J. Prognostic Validity of some Situation Motor Test for Judo. *Fiz. Kult.* **1989**, *23*, 147–152.
19. Bosco, C.; Luhtanen, P.; Komi, P.V. A Simple Method for Measurement of Mechanical Power in Jumping. *Eur. J. Appl. Physiol. Occup. Physiol.* **1983**, *50*, 273–282. [CrossRef]
20. Cormie, P.; McBride, J.M.; McCaulley, G.O. Power-Time, Force-Time, and Velocity-Time Curve Analysis of the Countermovement Jump: Impact of Training. *J. Strength Cond. Res.* **2009**, *23*, 177–186. [CrossRef]
21. González-Badillo, J.J.; Marques, M.C. Relationship between Kinematic Factors and Countermovement Jump Height in Trained Track and Field Athletes. *J. Strength Cond. Res.* **2010**, *24*, 3443–3447. [CrossRef]
22. Hopkins, W.G. Measures of Reliability in Sports Medicine and Science. *Sports Med.* **2000**, *30*, 1–15. [CrossRef]
23. Callister, R.; Callister, R.J.; Staron, R.S.; Fleck, S.J.; Tesch, P.; Dudley, G.A. Physiological characteristics of elite judo athletes. *Int. J. Sports Med.* **1991**, *2*, 196–203. [CrossRef]
24. Almeida, F.; Padial, P.; Bonitch-Góngora, J.; de la Fuente, B.; Schoenfeld, B.J.; Morales-Artacho, A.J.; Benavente, C.; Feriche, B. Effects of Power-Oriented Resistance Training During an Altitude Camp on Strength and Technical Performance of Elite Judokas. *Front. Physiol.* **2021**, *12*, 606191. [CrossRef]
25. Sbriccoli, P.; Bazzucchi, I.; DI Mario, A.; Marzattinocci, G.; Felici, F. Assessment of maximal cardiorespiratory performance and muscle power in the Italian Olympic judoka. *J. Strength Cond. Res.* **2007**, *21*, 738–744. [CrossRef]
26. Franchini, E.; Nunes, A.V.; Moraes, J.M.; Del Vecchio, F.B. Physical Fitness and Anthropometrical Profile of the Brazilian Male Judo Team. *J. Physiol. Anthr.* **2007**, *26*, 59–67. [CrossRef]
27. Moss, B.M.; Refsnes, P.E.; Abildgaard, A.; Nicolaysen, K.; Jensen, J. Effects of maximal effort strength training with different loads on dynamic strength, cross-sectional area, load-power and load-velocity relationships. *Eur. J. Appl. Physiol.* **1997**, *75*, 193–199. [CrossRef]
28. Chaouachi, A.; Coutts, A.J.; Chamari, K.; Wong, D.P.; Chaouachi, M.; Chtara, M.; Roky, R.; Amri, M. Effect of Ramadan Intermittent Fasting on Aerobic and Anaerobic Performance and Perception of Fatigue in Male Elite Judo Athletes. *J. Strength Cond. Res.* **2009**, *23*, 2702–2709. [CrossRef]
29. Komi, P.V. Stretch-Shortening Cycle. In *Strength and Power in Sport*; Komi, P.V., Ed.; Blackwell Science: Oxford, UK, 2003; pp. 184–202.
30. Dietz, V.; North, J.; Berger, W. Interaction between pre-activity and stretch reflex in human triceps brachii during landing from forwards falls. *J. Physiol.* **1981**, *311*, 113–125. [CrossRef]
31. Cormie, P.; McGuigan, M.; Newton, R. Developing Maximal Neuromuscular Power: Part 1—Biological Basis of Maximal Power Production. *Sports Med.* **2011**, *41*, 17–38. [CrossRef]
32. Cormie, P.; McGuigan, M.; Newton, R. Developing Maximal Neuromuscular Power: Part 2—Training Considerations for Improving Maximal Power Production. *Sports Med.* **2011**, *41*, 125–146. [CrossRef]