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The Effect of Lactate Concentration on the Handgrip Strength during Judo Bouts

AU2 **Juan G. Bonitch-Góngora, Juan G. Bonitch-Domínguez, Paulino Padial, and Belen Feriche**

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Abstract

Bonitch-Góngora, JG, Bonitch-Domínguez, JG, Padial, P, and Feriche, B. The effect of lactate concentration on the handgrip strength during judo bouts. *J Strength Cond Res* XX(X): 000–000, 2011—Judo is a combat sport in which the athletes attempt to hold and control their adversary through gripping techniques (kumi-kata) to apply opportune throwing techniques (nage-waza). Twelve male judo athletes, representing national teams, were recruited to investigate the changes in the maximal isometric strength in both hands before (pre) and after (post) 4 judo bouts and its relationship with the maximal blood lactic acid concentration. The subjects performed a maximal isometric contraction with each hand immediately before and after each bout. A blood sample was taken at 1, 3, and 14 minutes after each bout, and the lactic acid concentration was determined. An overall effect of the successive bouts on the maximal isometric handgrip strength of prebouts was observed for both hands ($p < 0.05$) but not in that of postbouts ($p > 0.05$). The dominant hand showed an overall decrease in the maximal isometric strength because of the bout, with the decrease being significant for the first, third, and fourth bouts ($p < 0.05$). The nondominant hand only showed a significant decrease in the first prebout and postbout ($p < 0.05$). We observed an inverse relationship between the maximal isometric handgrip strength of postbouts and maximum lactic acid concentration (Lacmax), and between the maximal isometric handgrip strength of postbouts and the lactic acid concentration at minute 14 of the recovery period (Lac14) ($p < 0.05$). These results show that successive judo bouts significantly reduce the maximal isometric strength of both hands and may suggest that fatigue of each hand depends on different factors. An enhanced understanding of the behavior of the isometric handgrip strength, and the factors that affect grip fatigue during judo bouts in the dominant and nondominant hands, can aid coaches in developing optimal training and exercise interventions that are aimed at mitigating decreases in the capacity of judo athletes to perform a grip.

Key Words hand strength, maximal isometric force, fatigue, judo, kumi-kata

Introduction

Handgrip strength is a general term used in clinical (28,46,55) and occupational (16,32,43,59) settings and by strength athletes (9,38). It refers to the muscular strength and force that can be generated by the hands. The strength of a handgrip is the result of the maximum force that the subject is able to exert under normal biokinetic conditions through the voluntary flexion of all finger joints, thumbs, and wrists (36). Factors that are considered during these activities include the absolute level of strength necessary to perform the tasks and the fatigue experienced by the muscles responsible for these movements (4).

Several sporting activities require the maintenance of adequate levels of handgrip strength to maximize control and task performance and decrease injury risk (4). Judo is a sport in which handgrip strength is essential. During the bout, a judo athlete grips the opponent's uniform (*judogi*), which provides the basis for the execution of the throwing techniques (*nage-waza*) (2). This results in a high physiological demand on the upper body (6,23,45). Although the fight situation in judo is quite complex and the outcome is defined by >1 variable (21), the gripping method (*kumi-kata*) is the first contact between 2 judo athletes and may determine the result of the bout (17,25,39).

Given its importance, the isometric handgrip peak strength in different groups of judo athletes is well documented in the literature (14,17,20,21,39,42). After reviewing research published to date, Franchini et al. (22) concluded that high-level male and female judoka differ less between themselves with respect to isometric handgrip strength than do less competitive level judo athletes, particularly when the data are expressed relative to body weight. These authors also note the absence of significant differences in the levels of isometric handgrip strength of high-level judo athletes in their 60s (42).

On the other hand, the evaluation protocol used in these investigations (a single maximal isometric contraction of between 5- and 10-second duration) does not correspond to

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the reality of combat. In a combat situation, judo athletes repeat this action at least 15 or 20 times per bout (26,53) for a median time of almost 8 minutes that a combat can last. It therefore consumes 51 ± 11% of the time during the struggle for grip (41). This typical time structure of a judo bout, with between 15 and 30 seconds of activity alternating with between 5 and 10 seconds of interval periods (13,48,57), is characterized by the important participation of anaerobic metabolism that produces lactic acid. Lactic acid concentrations found after bouts between experienced judo athletes range from 13 to 18 $mmol \cdot L^{-1}$ (11,12,24,27,45,47,49,56). This intensity is confirmed by mean heart rates during bouts in simulated contests recorded at between 180 and 185 $b \cdot min^{-1}$, which correspond to effort intensities above the respiratory compensation point for metabolic acidosis (VT2) (6,7,11,45). The negative effects of high hydrogen ion (H^+) concentrations on sporting muscular performance have been well documented (1,5,30,33,35,60,62). However, depending on the intensity of the isometric contraction, it has been observed that changes in lactic acid production are 2–3 times greater at 25–60% than at 90–95% of maximal isometric force (44). Acidosis could therefore be considered to be one of the main causes of loss of grip strength at these intensities (10,33,52). In addition, it has been observed that the performance of an intermittent gripping task, such as that during judo combat, increases the endurance time and reduces the recovery time relative to a continuous exercise (50).

These observations therefore highlight the importance of endurance of the isometric handgrip strength as a major determining factor of success in judo (22). In line with this, some authors claim that the isometric peak grip strength value for the hand during a judo bout is less important for a successful grip than the endurance because of the loss of grip strength, because the athletes perform a near continuous grip during a judo bout and the maximal strength is not maintained for a long period (8,22). Yet few studies to date have analyzed the isometric grip strength endurance in judo athletes. Bonitch-Góngora et al. (8) found losses of 39% of maximum isometric hand grip strength in national-level judo athletes during a test interval of 10 repetitions of 10 seconds alternated by 10 seconds of recovery. Only one investigation (31) has analyzed the effect of the fighting on the maximal isometric handgrip strength (2 judo bouts of 5 minute duration with 15 minutes of passive recovery between each). This study found that maximal isometric handgrip strength decreases for both hands by >5% in the first postbout and by 15% in the second postbout.

These studies demonstrate the fatigability of the gripping muscles of the forearms of judo athletes. However, more research is needed to better understand the behavior of the maximum isometric handgrip strength and to analyze in depth the causes of their decline in real combat situations, because high-level judo athletes can participate in between 5 and 7 fights on the same day to get a place among the top 5 competitors (24). The key aim of this study is therefore to analyze changes to the maximal isometric handgrip strength in the hands because of a bout, or series of bouts, and its relationship with the observed lactic acid levels.

Methods

Experimental Approach to the Problem

This study followed a repeated measures intragroup protocol whereby each subject participated in a simulated judo contest consisting of 4 bouts (4 levels of the independent variable) separated by a passive recovery period. The bout and recovery times were established beforehand. The resulting maximal isometric strength of both hands, prebout and postbouts, was measured, and blood samples were taken during the recovery period to determine the maximal lactate concentration and lactate clearance between bouts.

Subjects

Twelve male judo-athlete volunteers from different weight categories were recruited (Table 1). Ten of the athletes were, or had been, medalists in national championships in Spain and France in different age categories; the remaining 2 had won medals in regional competitions in Andalusia (Spain). All the subjects had been practicing judo for >10 years, training for between 12 and 18 $h \cdot wk^{-1}$, and had technical levels ranging from first to third Dan. Informed consent was obtained from each participant according to the Institutional Review Board of the University of Granada, and the evaluation protocol was approved. T1

All of the subjects were tested during the competitive period. During this period, the subjects were training in judo specific tasks (6–8 judo sessions per week, 2 hours per session) and were strength training (1–3 times per week) to develop the power of different muscle groups.

Procedures

Preliminary Test. The subjects performed a training session with the grip test to familiarize themselves with the instrumentation and the maximal isometric handgrip strength measurement protocol, for which we used a digital dynamometer (Psymtéc TKK-5101). As recommended by Watanabe et al. (59), the subjects made various attempts with both hands, noting the most comfortable distance to the handle when gripping the dynamometer, and this distance AU4

Table 1. Description of the study population.*

	Age (y)	Weight (kg)	Height (cm)	% Fat
Mean	22.00	76.3	176.4	15.34
SD	3.24	12.7	6.53	4.73

*% Fat: Durnin and Womersley, 1974. AU10

was maintained during all subsequent tests. Each subject was instructed to maintain maximal isometric contraction during each measurement for between 3 and 6 seconds (15,40). Contractions were made with each hand with both feet on the floor, the shoulder bent by 90°, and the elbow completely extended (Figure 1).

Experimental Test. Each subject participated in a simulated judo contest. This contest consisted of four 5-minute bouts (actual combat time) separated by 15 minutes of passive recovery (6,15,19,24). Each bout took place on a regulation tatami judo mat installed in the School of Exercise and Sports Science of the University of Granada and was controlled by referees and timekeepers from the Andalusian Judo Federation and Associated Disciplines. To ensure that all the bouts in this study lasted for the officially allotted time, the official regulation that specifies "a contest will end when one contestant has achieved ippon or equivalent" (article 19 of the International Judo Federation's Referee Rules) was modified. This resulted in victory being decided only at the end of the bout by totaling all the points scored (yuko = 5 points, waza-ari = 7 points, ippon = 10 points and the summation of shido with its equivalence to yuko, waza-ari, or ippon).

All the contests were performed in the morning (10:00–14:00), and the temperature of the room ranged from 16 to 20°C.

To generate a demanding competitive environment, the subjects were divided into pairs of the same weight (difference of <10%) and similar ranking as published by the Andalusian Judo Federation and Associated Disciplines (24) and were paid for each victory achieved.

The testing apparatus was set up, in duplicate, at a distance of 4 m from the tatami's safety zone. The judo athlete performed the manual dynamometry test in the 30 seconds immediately before (pre) and after (post) each bout according to the instructions provided in the familiarization session. The test was first performed with the dominant hand and then with the nondominant one. A single measurement was taken for each hand to obtain the maximal isometric handgrip strength values of prebouts and postbouts.

A 10-μL blood sample was taken from the fingertip at 1, 3, and 14 minutes after each bout, and the lactic acid concentration was determined using a photoenzymatic apparatus (Dr. Lange, LP 20 plus) (18). The highest lactic acid concentration reached between bouts was taken as the maximal value. The percentage of lactic acid clearance between bouts was determined from the difference between Lacmax and Lac14.

This protocol more closely reproduced judo combat activity (e.g., temporal structure) and therefore physiological responses (e.g., blood lactate concentration) as described in the literature (7,24,47). To ensure that the temporal structure of the contests was as close as possible to competition conditions, the entire experimental phase was recorded with a Sony DCR-TRV14OE digital camera. The mean effort and rest periods, and the number of attacks, were calculated for each bout. The reliability of this method has been established previously (13,15,27).

Statistical Analyses

All results are quoted as mean ± *SD*. The Shapiro-Wilk test was used to analyze the frequency distribution. The overall effect of the independent variable on the measurements taken before and after each bout was determined by analysis of variance (ANOVA) using repeat measures with bout number (1, 2, 3, or 4) as an intrasubject factor. A variance analysis was performed by applying a Greenhouse-Geisser or Huynh-Feldt correction if the Mauchly sphericity test was significant. In the event of a significant ANOVA, the Sidac test was applied for between-pair comparisons. Variables with a nonnormal distribution were analyzed using the Friedman and Wilcoxon test ($\alpha < 0.05/4$). The comparisons between measurements of

Figure 1. Position of the arm during measurement of the maximal isometric handgrip strength.

Table 2. Analysis of the maximal isometric handgrip strength for both hands during the bouts.*

	MIS-B (N)			MIS-A (N)		
Bout no.	Dominant	Nondominant	*P*1	Dominant	Nondominant	*P*1
1	575.85 ± 69.14	554.26 ± 74.20	0.147	502.52 ± 57.03	495.89 ± 63.90	0.590
2	525.24 ± 76.84	517.97 ± 73.45	0.596	489.76 ± 71.84	480.28 ± 67.50	0.494
3	528.35 ± 75.89†	494.83 ± 68.03†	**0.043**	484.04 ± 88.22	477.26 ± 62.47	0.735
4	527.29 ± 92.38‡	490.58 ± 75.70‡	**0.022**	489.27 ± 94.91	479.87 ± 59.78	0.652
P	**0.002**	**0.000**		0.529	0.216	

*MIS-B = Amaximal isometric strength before the bout; MIS-A = maximal isometric strength after the bout; *P* = overall effect of the bout; *P*1 = statistical difference between the dominant and nondominant hand for each measurement.
†Difference between bouts 1 and 3 ($p < 0.05$).
‡Difference between bouts 1 and 4 ($p < 0.05$).

prebouts and postbouts were achieved by performing a Student-*t* or Wilcoxon test for paired data. We used a Pearson or Spearman correlation analysis to analyze the intervariable relationships. A confidence interval of 95% was established in all cases.

Results

The mean times for the rest and effort phases during the bouts were 13.79 ± 9.47 and 13.95 ± 9.09 seconds, respectively, and the mean number of attacks during each bout was 10.5 ± 4.1.

The judo athletes tested had a mean maximal isometric handgrip strength of 0.78 ± 0.08 and 0.75 ± 0.11 $kg \cdot kg^{-1}$ when gripping with the dominant and nondominant hands, respectively.

The maximal isometric strength values for each hand for prebouts and postbouts are listed in Table 2. An overall effect of the successive bouts on the maximal isometric strength of prebouts was observed for both hands ($p = 0.002$ and $p = 0.000$ for the dominant and nondominant hands, respectively). The pair comparison showed a significant decrease in

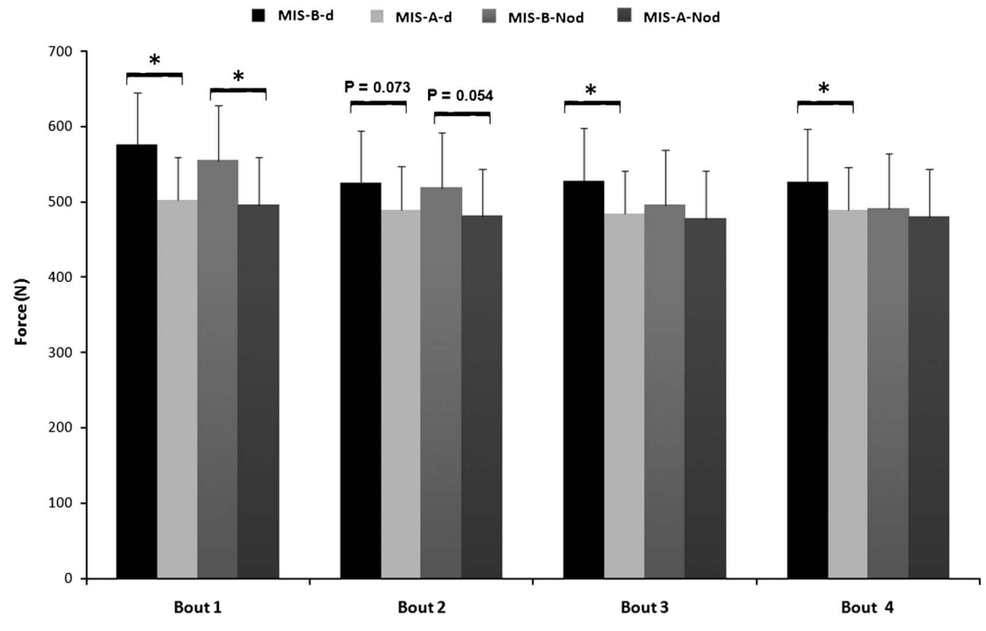

Figure 2. Comparison of the maximal isometric strength before (MIS-B) and after (MIS-A) each bout for the (d) and nondominant (Nod) hands. *Significance at $p < 0.05$.

Table 3. Blood lactate concentration by bout.*

Bout no.	Lacmax (mmol·L^{-1})	Lac14 (mmol·L^{-1})	%Lac clear
1	18.12 ± 4.40†	11.37 ± 3.92†	37.74 ± 15.51
2	16.95 ± 3.58†	12.73 ± 4.48†	26.89 ± 16.19
3	15.27 ± 4.47	10.03 ± 4.06	36.27 ± 13.08
4	14.58 ± 3.57	8.41 ± 2.71	42.54 ± 9.12
P	0.000	0.010	$p > 0.05$

*Lacmax = maximal blood lactate concentration; Lac14 = maximal blood lactate concentration 14 minutes after the bouts.
†Difference with respect to bout 4.

the maximal isometric handgrip strength of the third and fourth prebouts with respect to that found in the first prebout for both hands ($p < 0.05$). The maximal isometric strength recorded at the third and fourth prebouts was significantly higher for the dominant hand than for the nondominant hand. There were no significant changes in the maximal isometric strength of postbouts, and similar values were found for both hands (Table 2).

A comparative analysis of the maximal isometric strength values of prebouts and postbouts for both hands is shown in Figure 2. The dominant hand shows an overall decrease in maximal isometric handgrip strength because of the combat, with this decrease being significant for the first, third, and fourth bouts ($p < 0.05$). The nondominant hand shows a significant decrease in its maximal isometric handgrip strength only at the first prebouts and postbouts ($p < 0.05$), with no major changes during the rest of the contest.

The blood lactic acid concentrations during the recovery periods are shown in Table 3. A significant effect of successive combats on the Lacmax and the Lac14 ($p < 0.01$) can be seen. The pair-comparison analysis shows a significant drop in both values of the fourth bout compared with those of the first and second bouts ($p < 0.05$). The clearance follows a similar trend for all 4 bouts ($p > 0.05$).

Results of the correlation analysis are shown in Table 4, in which inverse relationships between maximal isometric handgrip strength, and the Lacmax and Lac14, are seen in all cases. The correlation between maximal isometric handgrip strength of postbouts and the Lacmax is significant

Table 4. Bilateral correlation and significance results for the maximal lactate concentration at minute 14 and recovery of the maximal isometric handgrip strength for both hands.*

			1		2		3		4	
Bout no.	Time	Hand	Lacmax	Lac14	Lacmax	Lac14	Lacmax	Lac14	Lacmax	Lac14
1	Before	d								
		Nod								
	After	d	−0.37	−0.73†						
		Nod	−0.26	−0.72†						
2	Before	d		−0.20						
		Nod		−0.36						
	After	d			−0.64†	−0.69†				
		Nod			−0.63†	−0.65†				
3	Before	d				−0.62†				
		Nod				−0.61†				
	After	d					−0.58†	−0.60†		
		Nod					−0.59†	−0.53		
4	Before	d						−0.70†		
		Nod						−0.38		
	After	d							−0.565	−0.64†
		Nod							−0.50	−0.49

*d = dominant hand; Nod = nondominant hand; Lacmax = maximal lactate concentration (moles per liter); Lac14 = lactate concentration at minute 14 of the recovery period (moles per liter).
†Significance level for correlation: 0.05 (bilateral).

for the second and fourth bouts ($p < 0.05$), and the correlation between maximal isometric handgrip strength of postbouts and Lac14 is significant for all 4 bouts ($p < 0.05$). From the second bout onward, there is also a strong relationship between Lac14 and the maximal isometric handgrip strength of the following prebout ($p > 0.05$). This relationship is most stable for the dominant hand in all cases.

Discussion

In this study on national-level judo athletes, it initially seemed plausible that high levels of peak force in a maximal isometric contraction in the hand grip could be developed by the athletes, because grip strength is vital to the development of attack and defense techniques in judo (17,21,25,39). The maximal isometric handgrip strength values observed in our study sample (575.85 ± 69.14 and 554.26 ± 74.20 N for the dominant and nondominant hands, respectively, in the first prebout) are similar to those found in other studies of judo athletes at similar competitive levels (17,39,54).

This study, however, demonstrates an effect of the bout on the maximal isometric handgrip strength (prebout vs. postbout) for both hands, with the progression of the tournament and the succession of bouts. It showed a decrease in starting maximal isometric handgrip strength for each bout. In addition, it demonstrated a lack of complete recovery between bouts that was greater for the nondominant than for the dominant hand, thus showing that each hand works in a different manner. The limit of maximal isometric handgrip strength loss appears to be stable throughout the contest as a whole and is related to the posteffort lactic acid concentration, particularly in the dominant hand. This shows that the judo athletes are unable to recover their initial levels of grip strength throughout the course of the tournament and, for the first time, suggests that fatigue of each hand depends on different factors.

According to Walker et al. (58), the percentage loss of grip strength during each bout could be related to the corresponding initial maximal isometric strength. For example, these authors reported that during prolonged isometric contraction, 50% of a higher maximal isometric strength was more effective in terms of resistance capacity than 50% of a lower initial maximal isometric strength. This suggests that, as indicated by our results, as the bouts progress and fatigue begins to accumulate, the drop in initial maximal isometric strength (<91.80% in the dominant hand and 89.87% in the nondominant hand) lowers the ability to resist isometric tensions during the bout. In line with this, Bonitch-Góngora et al. (8) analyzed the changes in gripping ability by measuring the effect of performing repeated maximal isometric contractions with the dominant hand performing 10 seconds of a maximal isometric contraction separated by a 10-second recovery period. They found a 39% decrease in maximal isometric handgrip strength ($p < 0.000$) in a group of 15 Austrian national-level judo athletes. The decrease in handgrip strength after the third repetition was found to be to <80% of the maximal isometric strength ($p < 0.05$), with no further major changes occurring after the seventh repetition. The results of this study show that the maximum grip strength for the bout does not fall <83% of the maximal isometric strength in any case. This smaller reduction of maximal isometric strength using our protocol, compared with that found using the above-mentioned intermittent protocols, could be because of the grip strength during the bout being submaximal. This results in lower fatigue levels with respect to those generated during intermittent work in which each contraction is maximal. Similarly, Yamaji et al. (61) reported that the rate of grip strength loss increases when working at 100% of the maximal isometric strength. The intensity of the grip's maximal isometric strength when performing the kumi-kata in judo cannot be calculated precisely because of a ban on using any type of instrumentation during a contest. Furthermore, the intermittent nature of the bout, together with technical variations and other aspects which affect performance, means that the grip intensity of hands may vary. The variation in grip intensity affects the resistance and recovery times for this type of contraction (10,50). For these reasons, the specific nature of this research, reproducing the characteristics of a real judo competition, makes these data valuable for the understanding of the behavior of maximal isometric grip strength. With respect to the differences between both hands as a result of successive bouts observed in this study, the importance of the initial maximal isometric strength value may well be different for each hand, because each has a different role during the bout and their fatigability may also depend on different factors.

Only one previous investigation (31), which simulates a judo tournament with each bout separated by a 15-minute recovery period, similarly found a decrease in the first and second postbout maximal isometric handgrip strength for both hands. In its detailed analysis, maximal isometric handgrip strength was found to decrease for both hands by >5% in the first postbout and by 15% in the second postbout. In our research, the maximal isometric handgrip strength decrease per bout was 12.57 and 14.80% for the dominant hand and 10.25 and 13.11% for the nondominant hand in the first and second bouts, respectively. These decreases are significant for the dominant hand in all contests when considering the p value of 0.074 for the second bout as being a significant decrease. The nondominant hand only shows a significant drop in the first postbout, although it is close to being significant for the second ($p = 0.054$). This therefore indicates greater difficulty for the nondominant hand to recover between bouts than for the dominant hand. Furthermore, the nondominant hand shows a lower difference between values of prebout and postbout maximal isometric handgrip strength. As can be seen in Table 2, the maximal isometric handgrip strength of prebouts follows a different dynamic to that of postbouts. Where there appears to be a stable lower limit for the maximal isometric handgrip

strength of postbouts (83–87% of the maximal isometric strength; $p > 0.05$), the accumulated fatigue means that the maximal isometric handgrip strength of prebouts is progressively lower. This drop becomes significant for the third and fourth bouts with respect to the first bout for both hands, although more so for the nondominant hand.

With respect to other combat sports, Kraemer et al. (37) investigated the physiological responses and performance in a simulated freestyle wrestling tournament. These authors conducted a tournament of 2 days' duration, in which 5 matches in total were carried out (3 matches during the first day and 2 during the second). Immediately before and after the matches, the fighters performed a battery of tests including a test of grip strength using a dynamometer. All the values of grip strength were significantly lower than the initial reference value (baseline). In addition, values recorded after fights 1–3 were significantly lower than the corresponding values recorded before. In agreement with the findings of our study, these data show isometric grip force fatigability in a combat sport with grip with physiological and performance implications and characteristics of temporary structure and technical tactics that are very similar to those of judo.

Our study is novel in that it investigates the relationship of this decline in isometric grip force and the lactic acid concentration in blood and the different degree of influence it has in the fatigability of the dominant and nondominant hands. We recorded very high concentrations of blood lactate after the contests (18.12 ± 4.40 mmol·L^{-1}), which is within the range reported in other studies involving judo athletes of a similar level (between 13 and 18 mmol·L^{-1}) (6,11,12,24,49), demonstrating the eminently anaerobic nature of judo. Associated with the large increase in blood lactate concentration, there is a significant alteration in the acid-base balance of the body from each fight (6). This fact has been demonstrated to affect the contractile ability of the muscles. Therefore, although judo athletes may adapt through improvement of several mechanisms of intercellular and intracellular buffering (e.g., sodium bicarbonate) (24), our findings show an important relationship between the drop in maximal isometric handgrip strength of postbouts and the Lac14 values obtained after each bout (Table 4). This correlation can be seen for all cases when comparing maximal isometric handgrip strength of postbouts with the corresponding Lac14 value for the dominant hand and when comparing Lac14 and the maximal isometric handgrip strength of prebouts for the following bout for the same hand.

Our findings enable us to confirm for the first time the differences discussed above regarding the maximal isometric strength dynamics for each hand and their recovery and the reasons for fatigue. In the sample analyzed, the dominant hand shows a force resistance profile that appears to depend on peripheral muscle fatigue-related factors, such as metabolic acidosis (34). By contrast, the nondominant hand shows a profile that depends to a greater extent on the quality of the isometric contraction during the grip, which is less resistant, and also on neuromuscular activity (51). When this type of muscle contraction (>90–95% of the maximal isometric strength) is maintained for any length of time, the concentration of adenosine triphosphate and phosphocreatine in muscle drops to <30% (3) and the anaerobic lactic contribution decreases (44), because of the nature of its intensity-time relationship. By contrast, when the contraction is less intense allowing periodic increases in blood flow to the muscle, the increase in lactate concentration is greater (120 mmol·kg^{-1} dry muscle at 25–60 vs. 90–95% of the maximal isometric strength) (53) and its contribution to peripheral fatigue while gripping is more likely (10,33). AU5

Practical Applications

The results of this study suggest that a judo bout significantly reduces the maximal isometric strength of both hands. The fatigue resulting from 4 successive bouts affects the maximal gripping strength that each hand can generate differently, with the dominant hand being more resistant and recovering better than the nondominant one. There is an inverse and significant relationship between the maximal isometric handgrip strength of postbouts and the posteffort lactic acid concentrations, with this relationship being more stable for the dominant hand than for the nondominant one and the latter appearing to be less dependent on peripheral muscle fatigue-related factors.

These findings are the first to characterize sports-specific changes in grip strength that occur with several bouts of judo and relate them to the blood lactic acid levels, highlighting specific issues and providing additional information to coaches and trainers for the design of training regimens to improve judo performance. The gripping techniques in judo (kumi-kata) are very important tactical aspects, which often determine the result of the bout (17,25,39), and may depend on the peak grip strength and the endurance of a grip strength. Nevertheless, because elite judo athletes do not demonstrate peak grip strength values superior to those of nonelite judo athletes (20) or to those of nonjudo athletes (29), resistance to a loss of grip strength would seem to be more important for a successful grip during a judo bout or series of bouts (8,22). Therefore, given the importance of achieving kumi-kata in judo, it is recommended that the design of a training regime is directed for maximal isometric handgrip strength, and most importantly, for strength-resistance of the flexor muscles in the forearms. This will ultimately assist judo coaches to better understand forearm muscle physiology during successive judo bouts and to optimize results.

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