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High level performance in world judo circuit: Notational analyzes of combat phase by weight categories

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ABSTRACT

This study analysed the time dedicated in the different phases of combat in all male weight divisions. For this, we analysed 548 combats. This time-motion analysis was performed through a previously-validated protocol. The main results indicated a significant effect for approach ($p \leq 0.001$), where the Half-Middleweight division showed a higher frequency vs. the others, except Half-heavyweight. For attack, Half-Lightweight showed a higher frequency versus Heavyweight (5.7±4.8 vs. 4.6±3.5 attempts; $p=0.004$). Extra-Lightweight showed a lower frequency of defences vs Half-Lightweight and Lightweight (2.2±2.6 vs. 3.8±3.2 vs. 4.4±3.7 attempts; ($p \leq 0.047$). Extra-Lightweight also showed a lower frequency of standing to ground transition vs. Half-Lightweight, Lightweight, and Half-Middleweight ($p \leq 0.048$). For groundwork, Middleweight showed a lower frequency of actions vs. the other divisions, except Heavyweight ($p \leq 0.001$). for the pause the Heavyweight division showed a lower frequency vs. Lightweight and Half-Middleweight (6.7±4.2 vs. 9.9±6.2 vs. 10.2±6.3 times; $p \leq 0.019$). In conclusion, our results can be applied to planning and prescribing specific training for the different weight divisions, taking into account the specific frequencies obtained in the combat phases. For lighter fighters, we recommend training focused on approach speed and gripping. For heavier weights, the training should be differentiated for muscle power development and groundwork combat. **Key words**: MARTIAL ARTS, TIME MOTION STUDIES, ATHLETIC PERFORMANCE, TASK PERFORMANCE AND ANALYSIS.

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INTRODUCTION

Time-motion analysis is focused on identifying movement and time patterns in the judo combat environment, and monitoring competitive and training load to understand fatigue in athletes (Franchini, Brito, Fukuda, & Artioli, 2014). While muscle group precise torque production by weight has been well established in judo (Lech, Chwała, Ambroży, & Sterkowicz, 2015), a time-motion model to evaluate contextual information during judo competition by each weight division is needed. Over the years, there has been evolution in the physical preparation in judo (Torres-Luque, Hernández-García, Escobar-Molina, Garatachea, & Nikolaidis, 2016), thus it becomes more and more necessary to develop specific physical and technical-tactical preparation for world circuit and Olympic Games competitions (Miarka, Del Vecchio, et al., 2016). In addition, time-motion could guide training exercises, specifically preparing athletes for the competitive demands of weight divisions and gender (Miarka, Fukuda, Del Vecchio, & Franchini, 2016; Miarka, Fukuda, Heinisch, et al., 2016). Moreover, traumatic and atraumatic injuries are a common consequence of specific judo mechanisms, mostly associated with combat phases (*i.e.* attack/defence, grip attempts, and groundwork combat (Miarka et al., 2018)), which could be avoided by functional training programs based on specific effort time by weight divisions.

Primordially, studies have reported that judo combat could be analysed by phases according to the sequential actions (i.e. approach, gripping, attack/defence, groundwork combat and pause times) with significant differences between age classes in male (Miarka et al., 2012) and female athletes (Miarka et al., 2014). Approach and gripping times in high level athletes (Calmet, Miarka, & Franchini, 2010) are similar to those in the existing literature for sub-elite senior level competitors, with approaches between 5-8s and gripping between 6-13s (Miarka et al., 2014; Miarka et al., 2012). Although a previous study showed a difference in four large weight division groups (Sterkowicz-Przybycien, Miarka, & Fukuda, 2017), little is known about the specificity of each weight division for such combat phases.

Athletes in the lightest divisions have lower body fat percentage than those in the heavier weight (Sterkowicz-Przybycień & Almansba, 2011). In the heaviest divisions, athletes display the highest body fat percentages and the lowest relative strength when compared to lightweight (Sterkowicz-Przybycień & Almansba, 2011). Thus, phenotypes and physical potentials between athletes in the lowest and highest weight divisions may have precluded possible differences in gripping and attack time-motion analysis. Furthermore, 20% of all attack efforts in the 2012 Olympic Games happened during the transition to the groundwork combat phase (Miarka, Fukuda, Heinisch, et al., 2016). Recently, findings about female athletes have indicated that women in the lighter weight divisions anticipate their opponent's attack with *defensive* actions prior to quickly attacking in a strategic effort to engage in *groundwork* (Sterkowicz-Przybycien et al., 2017).

Regarding the relevance of time-motion analysis, studies have been carried out to determine behavioural aspects during competitions which can be used by coaches and athletes (Boguszewski, 2011; Calmet et al., 2010; Miarka et al., 2014; Miarka et al., 2018; Miarka, Del Vecchio, et al., 2016; Miarka, Fukuda, Del Vecchio, et al., 2016; Miarka, Fukuda, Heinisch, et al., 2016). Among the investigations already performed in world level judo athletes, studies have shown the influence of time-motion and technical-tactical analysis associated with the prevalence of injury (Miarka et al., 2018), home-advantage (Brito, Miarka, de Durana, & Fukuda, 2017), gripping (Calmet et al., 2010; Kajmovic & Radjo, 2014), defensive actions (Boguszewski, 2011) and throwing techniques (Franchini, Sterkowicz, Meira, Gomes, & Tani, 2008). However, there is a lack of studies which have investigated time-motion analysis (approach, gripping, attack, defence, standing-ground transition, ground combat and pause) in all the weight divisions. As judo athletes attempt to improve their performance, modifications in training load are required using specific knowledge about weight divisions, particularly increases in frequency, duration, and intensity according to the competitive time-motion patterns. Results on combat patterns by weight divisions could support developing training loads adjusted for combat phases according to the weight in order to either increase or decrease the time/effort in each phase depending on the weight division. Ensuring that combat effort is appropriately titrated by weight division is important for both adaptations to judo training as well as for competition performance. Therefore, the present study analysed the time dedicated in the different combat phases in all seven male weight divisions in world circuit competitions.

MATERIALS AND METHODOLOGY

Experimental approach

This study is characterized as transversal and descriptive employing time-motion analysis in order to approach the basic aspects of actions applied during a judo match. Thus, judo combat phases from international judo circuit competitions were analysed to determine relative and total frequency and duration of sequential combat actions performed by high level judo athletes. Sequential movements were classified as combat, with sub-phases of approach, gripping, attack, defence, groundwork, or pause phases according to previously-defined protocols (Miarka, Fukuda, Heinisch, et al., 2016). In an effort to support the requisite needs of analyses for training program development, the combat phases were compared by weight division.

Sample

The sample was composed of 548 analyses of athletes in combat performed by male athletes ranked for the 2012 Olympic Games distributed in seven divisions (Extra-lightweight, -60 kg: n=44; Half-lightweight, -66 kg: n=132; L Lightweight, -73 kg: n=71; Half-middleweight, -81 kg: n=152; Middleweight, -90 kg: n=42, Half-heavyweight, -100 kg: n=35 and Heavyweight, +100 kg: n=72). In order to guarantee ecological validity and to verify the elite status of the sample, the competitive bouts were analysed using several publically available judo video databases, including those provided by the International Judo Federation and the International Olympic Committee. Each video had to be of sufficient quality (standard definition 480/60i) in order to be included and taken from a landscape view of the entire competition area. While potential limitations exist due to these requirements, the utilized procedures reflect a method to observe critical events in combat performance, which could be quantified in a consistent and reliable manner. The competitive bouts were evaluated following previously-outlined protocols (Miarka et al., 2012) from International Judo Federation (IJF) competitions in 2011-12, including the following: Olympic Games (London, 2012), World Championship (Paris, 2011), five *Grand Slams* (Paris, 2011 and 2012; Tokyo, 2011; Rio de Janeiro, 2011 and Moscow, 2011) six *Grand Prix's* (Düsseldorf, 2011 and 2012; Qingdao, 2011; Amsterdam, 2011; Abu Dhabi, 2011), and 19 *World Cups* (Prague, 2012 and 2011; Oberwart, 2012 and 2011; Bucharest, 2012 and 2011; Jeju, 2012; Madrid, 2012 and 2011; Tbilisi, 2012 and 2011; Warsaw, 2011; Tallinn, 2012; Miami, 2012; San Salvador, 2012; Apia, 2012; Buenos Aires, 2012; Lisbon, 2012; and Sofia, 2012). The free computer version of VirtualDub Program 1.8.6 was used to fragment and edit images, and Frami® software was used to conduct the time-motion analysis; the study was previously approved by the local Ethics and Research Committee (protocol 1052010).

Judo time-motion combat analysis

The combat states were observed according to occurrence frequency and their time. All analyses were done using Frami software (Miarka, Hayashida, Julio, Calmet, & Franchini, 2011), following the respective previous protocol, which included the actions of approach, gripping (*kumi-kata*), attack, defence (*tae-sabaki*), groundwork combat and pause (Miarka, Branco, Vecchio, Camey, & Franchini, 2015). In order to verify possible differences between intra and inter-expert measurement of the protocol variables, comparisons of all variables were carried out by means of the Mann-Whitney U Test, and no differences were observed among intra and inter-expert. In addition, the correlation between measurements obtained for each model was verified by means of the Cohen Kappa coefficient (Miarka, Del Vecchio, et al., 2016; Miarka, Fukuda, Del Vecchio, et al., 2016; Miarka, Fukuda, Heinisch, et al., 2016) with an inter-agreement range between 0.45 and 1.00, classification of "Almost perfect" for all variables, and with a range between 0.82 and 1.00 for intra-expert analysis, along with a classification of "Almost perfect" for all ten variables. The significance level of $p \leq 0.05$ was used.

Statistical Analysis

All statistical tests were processed using SPSS software (version 20.0; SPSS, Inc., Chicago, IL, USA). Descriptive data are presented as mean and standard deviation (SD). The Kolmogorov-Smirnov test (K-S) was used to determine the normal distribution of the data. Time-motion comparisons between weight divisions were performed by one-way ANOVA followed by Bonferroni *post hoc* to verify the differences between weight divisions (Extra-lightweight vs. Half-lightweight vs. Lightweight vs. Half-middleweight vs. Middleweight vs. Half-heavyweight vs. Heavyweight). For analysis of variance, Eta squared (η^2) values were calculated to evaluate effect size and interpreted using the criteria: strong effect size (η^2>0.14), moderate effect size (0.06<η^2<0.14) and weak effect size (η^2<0.06). The 95% confidence intervals were calculated and a significance level of $P \leq 0.05$ was used for all analyses.

RESULTS

Table 1 shows the frequency in each combat phase (approach, gripping, attack, defence, standing-ground transition, ground combat and pause) obtained in the world circuit competitions separated by weight division.

The analysis showed a weight division effect for approach frequency (F=7.63, $p \leq 0.001$, η^2=0.78), in which the Middleweight showed a higher frequency when compared to all other weight divisions ($p \leq 0.014$), except Half-heavyweight. Also, there was an effect for the gripping frequency attempts (F=7.14, $p \leq 0.001$, η^2=0.74), in which the Half-middleweight demonstrated a higher frequency than the Lightweight and Half-lightweight. Additionally, the Heavyweight division showed a higher frequency than the Extra-lightweight division ($p \leq 0.001$ for all comparisons). There was a weight division effect for attack frequency (F=2.69, p=0.014, η^2=0.029) with higher attempts by the Half-lightweight division when compared to the Heavyweight division (p=0.004). Differences were also observed for defence (F=6.51, $p \leq 0.001$, η^2=0.068). The analysis showed that Extra-lightweight presented a lower frequency when compared to the Half-lightweight (p=0.047) and Lightweight (p=0.002) divisions, and Heavyweight also performed a lower number of defence actions when compared to Half-lightweight and Lightweight ($p \leq 0.001$ for all comparisons). In turn, Lightweight presented a higher frequency than Half-middleweight (p=0.007).

There was also a difference between the standing to ground transition (F=7.11, $p \leq 0.001$, η^2=0.073). For this action, Extra-lightweight showed a lower frequency when compared to half-lightweight (p=0.016), Lightweight (p=0.048) and Half-middleweight (p=0.016). Likewise, the Middleweight division showed a lower frequency than the Lightweight (p=0.024) and Middleweight (p=0.025). The Heavyweight division also obtained a lower frequency when compared with Half-lightweight ($p \leq 0.001$), Lightweight (p=0.003) and Half-middleweight ($p \leq 0.001$). There was a statistical difference for ground combat (F=10.5, $p \leq 0.001$, η^2=0.105), in which Middleweight showed a lower frequency than all other weight divisions (p = 0.011), except Heavyweight. In addition, Heavyweight presented a lower frequency when compared to all other weight divisions ($p \leq 0.003$), except Extra-lightweight. The pause time also presented significant differences (F=4.45, $p \leq 0.001$, η^2=0.047), in which the Heavyweight division showed a lower frequency than the Lightweight (p=0.019) and Half-middleweight ($p \leq 0.001$), as well as Half-middleweight showed a higher frequency than Extra-lightweight ($p=0.021$). Table 2 shows the descriptive data of the total time in each combat phase analysed by weight division.

Table 1. Frequency (µ±SD) of combat phase separated by weight division.

Weight division	Approach	Gripping	Attack	Defence	Transition	groundwork	Pause
Extra-lightweight	7.7±5.4	10.0±5.9	5.7±4.1	2.2±2.6[e]	0.8±1.1[h]	3.6±3.6	6.8±5.0
Half-lightweight	10.1±6.2	14.2±8.0	7.2±4.7	3.8±3.2	1.9±1.6	4.1±3.0	8.4±5.7
Lightweight	11.7±6.8	15.3±8.8	6.5±4.7	4.4±3.7[g]	1.9±2.3	4.5±3.6	9.9±6.2
Half-middleweight	18.0±22.1[a]	20.1±12.4[b]	6.5±4.8	2.9±2.5	1.9±2.2	4.3±3.0	10.2±6.3[n]
Middleweight	10.2±6.8	15.9±13.0	6.6±6.2	3.1±3.4	0.8 ±1.2[j]	1.4±2.4[k]	8.5±5.7
Half-heavyweight	11.8±5.6	16.1±10.6	5.5±4.3	3.2±2.9	1.0±1.5	4.3±3.1	9.9±5.5
Heavyweight	9.0±4.7	18.4±11.8[c]	4.6±3.5[d]	1.8±1.9[f]	0.7±1.0[i]	2.0±1.7[l]	6.7±4.2[m]

Notes: the data showed how mean (µ) and standard deviation (SD). [a] significant difference for Lightweight (*p=0.014*), Middleweight (*p=0.01*), Extra-lightweight, Half-lightweight and Heavyweight (*p≤0.001* for all comparisons); [b] difference for Extra-lightweight and Half-lightweight (*p≤0.001* for all comparisons); [c] difference for Extra-lightweight (*p≤0.001*); [d] difference for Half-lightweight (*p=0.004*); [e] difference for Half-lightweight (*p=0.047*) and Lightweight *(p=0.002*); [f] difference for Half-lightweight and Lightweight (*p≤0.001*for all comparisons); [g] difference for Half-middleweight (*p=0.007*); [h] difference for Half-lightweight (*p=0.016*), Lightweight (*p=0.048*) and Half-middleweight (*p=0.016*); [i] difference for Half-lightweight, Lightweight and Half-middleweight (*p≤0.005* for all comparisons); [j] difference for Half-lightweight (*p=0.024*) and Half-middleweight (*p=0.025*); [k] difference for Extra-lightweight (*p=0.011*), Half-lightweight, Lightweight, Half-middleweight e Half-heavyweight (*p≤0.001* for all comparisons); [l] difference for Half-lightweight, Lightweight, Half-middleweight and Half-heavyweight (*p≤0.005* for all comparisons); [m] difference for Lightweight (*p=0.019*) and Half-middleweight (*p≤0.001*); [n] difference for Extra-lightweight (*p=0.021*).

There was an effect of the weight division on the total approach time ($F=2.82$, $p=0.01$, $\eta^2=0.037$), where the Lightweight division spent more time in this phase when compared to Half-middleweight ($p=0.05$) and Extra-lightweight ($p=0.007$). The results also showed a significant weight division effect for gripping ($F=7.7$, $p \leq 0.001$, $\eta^2=0.084$), where Extra-lightweight showed a lower mean when compared to all weight divisions ($p \leq 0.009$), except Half-lightweight and Middleweight. Half-lightweight also presented a lower time when compared to Half-middleweight ($p=0.033$) and Heavyweight ($p \leq 0.001$). In turn, the Heavyweight division showed a longer time when compared to Middleweight ($p=0.022$).

The attack time did not present differences between the divisions. On the other hand, there was a significant effect for weight divisions for the total defence time ($F=3.45$, $p=0.002$, $\eta^2=0.039$), and Lightweight showed a longer defence time compared to Heavyweight ($p=0.008$) and Half-Middleweight ($p=0.003$). In the total standing to groundwork transition there was also a significant difference ($F=3.02$, $p=0.007$, $\eta^2=0.035$), with lower times for Heavyweight when compared to Half-Middleweight ($p=0.018$). Regarding ground combat ($F=3.9$, $p \leq 0.001$, $\eta^2=0.044$), there was a lower mean for Heavyweight when compared to the Lightweight ($p=0.011$) and Half-middleweight ($p=0.005$) divisions, while no effect of weight division was observed for total pause time ($p \geq 0.05$). In contrast, the total combat time presented significant differences ($F=4.39$, $p \leq 0.001$, $\eta^2=0.049$), with lower time in the Extra-Lightweight division when compared to all other weight divisions

($p \leq 0.019$), except Middleweight. Table 3 presents the descriptive data of the time relative to the combat cycle and pause in each of the phases.

Table 2. Total time (seconds) in each of the combat phases compared by weight division (μ±SD).

Weight Division	Approach	Gripping	Attack	Defence	Transition	Groundwork	Pause	Total
Extra-lightweight	83.8±71.5	60.4±52.3[b]	8.3± 10.9	4.3±13.0	5.1±16.2	36.6±46.3	82.2±77.3	198.6±147.4[h]
Half-lightweight	115.3±85.9	104.5±75.9[c]	11.9±15.8	9.1±18.7[e]	11.1±18.5	48.2±50.1	116.4±112.2	300.1±166.3
Lightweight	137.5±86.2[a]	125.9±95.8	12.7± 9.0	6.9±11.1	5.7± 9.9	56.2±64.2	128.0±113.7	344.4±191.6
Half-middleweight	96.5±57.6	142.2±102.2	10.4±16.7	3.0± 6.1	6.2±10.1	54.5±48.2	137.6±109.4	330.6±173.4
Middleweight	117.7±81.5	104.9±110.6	14.2±18.0	5.7±11.6	5.4±13.4	28.9±41.8	114.0±88.0	276.9±158.9
Half-heavyweight	111.5±72.7	150.9±112.6	9.8±14.3	6.4±12.1	4.1±8.4	41.1±32.8	134.3±101.4	323.9±145.3
Heavyweight	102.7±73.8	165.2±119.6[d]	8.1±11.9	2.6± 7.1	4.5±11.2[f]	27.6±45.3[g]	112.9±94.2	303.9±155.5

Notes: data showed how mean (μ) and standard deviation (SD). [a] difference for Half-middleweight (p=0.05) and Extra-lightweight (p=0.007); [b] difference for Lightweight (p=0.009), Half-middleweight, Half-heavyweight and Heavyweight (p≤0.001 for all comparisons); [c] difference for Half-middleweight (p=0.033) and Heavyweight (p≤0.001); [d] difference for Middleweight (p=0.022); [e] difference for Heavyweight (p=0.008) and Half-middleweight (p=0.003); [f] difference Half-lightweight (p=0.018); [g] difference for Lightweight (p=0.011) and Half-middleweight (p=0.005); [h] difference for Half-lightweight (p=0.009), Lightweight (p≤0.001), Half-middleweight (p≤0.001), Half-heavyweight (p=0.017) and Heavyweight (p=0.018).

The approach time per combat and pause cycle presented statistical differences (F=18.65, $p \leq 0.001$, $\eta^2=0.2$), in which the Middleweight division obtained a lower time than all other weight divisions ($p \leq 0.02$), except Half-heavyweight. On the other hand, Half-heavyweight also presented a lower time when compared to the other weight divisions ($p \leq 0.001$ for all comparisons), except for Middleweight. In addition, Half-middleweight also showed a lower time when compared to Heavyweight ($p \leq 0.001$) and Lightweight ($p=0.002$). The relative gripping time also had an effect (F=4.73, $p \leq 0.001$, $\eta^2=0.05$), with a higher time for Heavyweight when compared to Lightweight ($p=0.020$), Half-middleweight ($p=0.016$) and Middleweight ($p \leq 0.001$). The Middleweight division also presented a lower time than Lightweight ($p=0.019$). Regarding the relative attack, defence and transition times, the analysis of variance did not show differences between divisions. Regarding the relative groundwork combat, differences (F=5.1, $p \leq 0.001$, $\eta^2=0.05$) were observed among the weight divisions, where Middleweight spent more time than Half-lightweight ($p=0.019$), Half-middleweight ($p \leq 0.001$) and Half-heavyweight ($p=0.039$). The relative pause time also differed (F=2.7, $p=0.014$, $\eta^2=0.03$), with higher means for Heavyweight when compared to the Extra-lightweight ($p=0.024$), Half-lightweight ($p=0.028$) and Middleweight ($p=0.009$) divisions. Likewise, Heavyweight showed a higher relative combat time when compared to the other divisions ($p \leq 0.04$), except Half-heavyweight.

Table 3. Relative Time (seconds) to a combat and pause cycle (μ±SD), in each of the combat phases analysed by weight divisions.

Weight division	Approach	Gripping	Attack	Defence	Transition	Groundwork	Pause	Total
Extra-lightweight	10.5±5.4	6.1±5.1	1.2±1.3	1.1±2.2	2.0±5.1	7.2±6.8	10.9 ±7.2	28.7±15.4
Half-lightweight	11.8±5.3	7.3±4.1	1.5±1.5	1.6±2.5	4.2±6.7	10.7±10.1	12.2±7.3	35.8±18.9
Lightweight	13.5±6.6	7.6±3.5	1.5±1.7	1.8±5.6	1.8±2.3	10.0±8.6	12.6±10.2	35.5±18.7
Half-middleweight	9.5±5.6[c]	6.7±3.3	1.6±2.8	0.8±2.2	2.1±3.1	14.3±15.8	11.8±6.6	34.4±16.3
Middleweight	5.6±3.8[a]	5.0±5.0[e]	2.3±3.9	1.0±2.5	2.9±7.4	3.2±8.2[f]	12.7±8.7	37.2±23.6
Half-heavyweight	4.5±2.3[b]	7.6±5.0	1.5±2.0	2.3±7.2	2.5±7.4	12.0±16.8	12.3±6.8	38.4±32.9
Heavyweight	13.2±7.6	8.7±3.7[d]	1.7±2.6	1.03±.0	3.3±9.1	10.3±15.3	16.3±13.2[g]	48.8±28.1[h]

Notes: data showed how mean (μ) and standard deviation (SD). [a] difference for all weight divisions ($p \leq 0.02$) except Extra-lightweight; [b] difference for the others ($p \leq 0.001$), except Middleweight; [c] difference for Heavyweight ($p \leq 0.001$) and Lightweight ($p=0.002$); [d] difference for Extra-lightweight ($p=0.02$), Half-middleweight ($p=0.016$) and Middleweight ($p \leq 0.001$); [e] difference for Lightweight ($p=0.019$); [f] difference for Half-lightweight ($p=0.019$), Half-middleweight ($p \leq 0.001$) and Half-middleweight ($p=0.039$); [g] difference for Extra-lightweight ($p=0.024$), Half-lightweight ($p=0.028$) and Half-middleweight ($p=0.009$); h difference for all weight divisions ($p \leq 0.04$), except Half-Heavyweight.

DISCUSSION

Many aspects can determine high-performance in judo athletes (Franchini et al., 2014), thus time-motion analysis can help the coach in planning specific preparations for each weight division (Miarka et al., 2015). In this sense, the present study aimed to analyse the time dedicated in the different phases of combat in all seven male weight divisions. The main results indicated that lighter divisions (Extra-lightweight, Half-lightweight and Lightweight) are the most differentiated in the gripping domain, Lightweight spends more time in the approach, and Extra-lightweight spends less time on kimono gripping. Extra-lightweight also showed a lower frequency of defensive actions and combat time. The Heavyweight division had the least time dedicated to the transition to ground and groundwork combat. Heavyweight Judokas maintain the longest relative grip time. Other interesting data is the lower frequency of pause actions for Heavyweights, however with a longer relative pause time. Combat sports such as judo involve complex movements, both in high or low intensity actions (Miarka et al., 2015), because attack and defence actions occur at almost concomitant moments. In this sense, technical-tactical analysis can help in guiding loads and training volumes directed to the specific characteristics of their weight division (Calmet et al., 2010; Miarka et al., 2014; Miarka et al., 2015). This study conducted an analysis of the world circuit to understand the actions applied in judo high-level combat; this is important and represents the elite performance of the modality, so that a coach of any country can focus their training on real competitive demands, thus avoiding low volume or excessive training (Miarka et al., 2014; Miarka, Del Vecchio, et al., 2016; Miarka, Fukuda, Del Vecchio, et al., 2016).

In fact, estimating and measuring judo workloads is a challenge for coaches (Miarka et al., 2012), because judo is a sport where muscle power is a key determinant of performance (Franchini et al., 2014). This may lead coaches to erroneously calculate training volumes and intensities, and expose fighters to greater injury risk (Miarka et al., 2018). The present results can be applied in the practice of training directing the activities to strengthen athletes' qualities or reinforce points that are critical for their performance (Miarka et al., 2015).

In our results it was observed that athletes in the Extra-lightweight division must have good movement speed mainly directed to developing their gripping and consequent attack in order to be able to compete at a high level, since judokas of this division are experts in escaping from the grips of their opponent. Calmet et al. (2010) observed that high-level judokas tend to take less time between gripping and performing their attack when compared to beginners. In fact, the combination of approach, gripping and attack may be the defining factor for judokas winning in the world circuit (Courel, Franchini, Femia, Stankovic, & Escobar-Molina, 2014). Regarding the approach, our results are consistent with those presented by Miarka, Fukuda, Del Vecchio, et al. (2016), who noted that the strategy for this technical action is crucial to high-level performance in the middle-middleweight division.

The Heavyweight division presented a lower frequency of gripping and attack. Our results suggest training with a higher focus on muscle power for this weight division, since these judokas demonstrated that the attack after gripping tends to be in a sequential action, so the training for this weight division should be focused on the quality of the attack against the volume; in this, the gripping advantage will be essential. In fact, athletes with better physical training tend to dominate in gripping (Calmet et al., 2010; Courel et al., 2014). Another point to guide the training of heavyweights can be training for ground combat, because this division presented less time and actions dedicated to the transition to the ground and groundwork combat, thus heavyweight judokas can present differentiated strategy when focusing their tactics on this aspect and thus may surprise their opponents with a technical aspect that is poorly explored in world-class competitions in this division. It should be noted that this type of competitive strategy for Heavyweights is also repeated when only analysing the athletes who classified for the Olympic Games (Brito, Gomes Moreira, et al., 2017).

Regarding defence actions, our results demonstrated that Half-lightweight devotes more time to this technical action. In this sense, training athletes in this division can be focused on the development of *tae-sabaki* (dodging) speed; not only dodging, but these movements can be optimized with the addition of counterattacks, since defence movements followed by a counterattack can be definitive for the combat outcome (Boguszewski, 2011; Boguszewski & Boguszewska, 2006). In this sense, one strategy to apply may be the use of foot technique (ex. *De-ashi-harai*) speed (Boguszewski, 2011), since blocking gripping and hip defence may be inefficient (Boguszewski, 2009). On the other hand, (Brito, Gomes Moreira, et al., 2017) it is recommended that athletes of this weight division should develop higher technical variability in order to best their opponent's defensive strategies.

The present study used the most commonly used tool for providing this information, namely video-based time-motion analysis via notational methods. This method provides information on the type, frequency and duration of the different activities that judo athletes perform; however, a drawback of this notational method is its reliance on subjective interpretation to describe these judo athletes' activities. We verified the reliability with an inter-agreement range between 0.45 and 1.00 and a classification of "Almost perfect" for all variables. Moreover, we also verified a range between 0.82 and 1.00 for intra-expert analysis with a classification of "Almost perfect" for all ten variables. The present results provide normative data on the judo demands by weight divisions with a sample limited to male athletes, as time-motion in female judo athletes has particularities (Miarka et al., 2014) which indicates the need for future research on the seven weight divisions in females athletes. Quantification of the physical demands of judo combat is receiving increasing attention as the need for greater understanding of the work rate profiles of weight divisions has been recognized (Sterkowicz-Przybycien et al., 2017). The information gained from the present analyses can be used to provide feedback to high-level athletes and improve the specificity of conditioning programs as well as in research settings.

CONCLUSIONS

Based on the aims of the present study and applied methods, we can conclude that lighter athletes are the most differentiated in the gripping domain, as Lightweights spend more time in the approach, and Extra-lightweight spends less time with the judogi gripping. Extra-lightweights also showed a lower frequency of defensive actions and combat time. Training focused on approach speed and gripping is recommended for this group of fighters. The Heavyweight division had the least time dedicated to the transition to ground and groundwork combat. Heavyweight Judokas maintain longer relative grip time compared to other divisions. Other interesting Heavyweight data is their lower frequency of pause actions, however with a longer relative pause time. Thus, training for these athletes should be differentiated for power development and groundwork combat.

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