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Technical-tactical comparisons between weight divisions in elite judo athletes

KEYWORDS:

Motor control.

Task performance and analysis.

Martial arts. Statistics.

ABSTRACT

The purpose of the present study was to compare technical-tactical (T-T) aspects between weight divisions of elite judo athletes. We analyzed 154 male athletes. The T-T actions comprised the approach, gripping, attack, groundwork, defense, and pause phases. The main results indicated that athletes of half-middleweight division have more combat time with the right foot on forward position (p = .047) and middleweights perform a higher time in frontal foot position (p = .002). The light categories are those that most change the handgrip (p = .041), and extra-lightweight maintaining a lower handgrip time (p = .026). The half-middleweight are more defensive and that causes higher number of penalties to the opponent (p = .003). The heavyweight division dedicated lower time to groundwork combat (p = .013). Weight (W) and height (H) significantly correlate with frontal foot position (r = .223; p = .01 for W and r = .191; p = .03 for H), attempts to grip (r = -.188; p = .02 for W and r = -.213; p = .01 for H), gripping on the left back/sleeve (r = .332; p = .001 for W and r = .29; p = .001 for H) and gripping on left/ right sleeve (r = -.204; p = .01 for W and r = -.269; p = .001 for H). We can conclude that weight divisions would significantly affect T-T and biomechanical patterns during individual combat phases.

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Comparações técnico-táticas entre divisões de peso em judocas masculinos de elite

RESUMO

O presente estudo comparou aspectos técnico-táticos (T-T) em judocas de elite nas diferentes categorias de peso. Foram avaliados 154 atletas. As ações T-T foram analisadas quanto a aproximação, agarre, ataque, luta de solo, defesa e pausa. Os principais resultados indicaram que os atletas da categoria meio-médio lutam mais tempo com o pé direito à frente (p = .047) e médios ficam maior parte do tempo com um dos pés à frente (p = .002). As categorias mais leves são aquelas que trocam mais pegadas (p = .041), a superligeiro é aquela que mantém a pegada por menor tempo (p = .026). A categoria meio pesado é a mais defensiva e que impõe ao adversário maior quantidade de faltas (p = .003). A categoria pesado é a que dedica menor tempo em combate de solo (p = .013). A massa corporal (MC) e estatura (ES) foram correlacionadas à posição frontal do pé (r = .223; p = .01 para MC e r = .191; p=0,03 para ES), tentativa de pegada (r = -.188; p = .002 para MC e r = -.213; p = .001 para ES), pegada à esquerda costa/manga (r = .32; p = .001 para MC e r = .29; p = .001 para ES), pegada manga-manga (r = -.204; p = .01 para MC e r = -.269; p = .001 para ES). Nossos resultados permitem concluir que as ações T-T interferem nos padrões biomecânicos durante as fases de combate.

PALAVRAS CHAVE:

Controle motor. Análise de desempenho.
Artes marciais. Estatística.

INTRODUCTION

Coordinative action skills in judo refer to the ability of an athlete to achieve appropriate movement at the right moment while quickly adjusting to the constantly instable competitive situation (Miarka, Branco, Vecchio, Camey, & Franchini, 2015). Notational analysis is concerned with recognizing movement patterns, often mentioned to as 'performance indicators', in the championship environment (Woods, Joyce, & Robertson, 2016). While match demands have been well-described in judo using time-motion data and muscle group specific torque production (Lech, Chwała, AmbroÐy, & Sterkowicz, 2015), a technical-tactical (T-T) model (Sterkowicz, Sacripanti, & Sterkowicz-Przybycien, 2013), with accurate biomechanical and statistical analyses considering anthropometric aspects, is needed to evaluate contextual information between weight divisions. Indeed, considering the complex system of actions performed by athletes of different weight categories, the analysis of T-T movement patterns may contribute for a better understanding of these activities with inferences over physiological work profiles in judo.

Combat performance involves a multifaceted interaction of open and complex skills, purportedly presenting irregular activity and pause periods (Branco et al., 2013; Courel, Franchini, Femia, Stankovic, & Escobar-Molina, 2014; Franchini, Sterkowicz, Meira, Gomes, & Tani, 2008). During judo competition, combat actions and pause phases are highly diversified and the relationships between these variables collectively represent an athlete's system of attack or fighting style (Miarka et al., 2014). Previous research has shown specific parameters that influence T-T actions in combat sports, including expertise (Drid et al., 2015), competitive outcome (Escobar-Molina, Courel, Franchini, Femia, & Stankovic, 2014), competitive level (Pozo, Bastien, & Dierick, 2011) and weight categories (Tabben et al., 2015). Furthermore, age effects have been observed in the time dedicated to the approach, gripping, groundwork and pause phases during judo competition (Miarka et al., 2014; Miarka et al., 2012). Despite these time-motion analysis differences, the effects of T-T indicators during each combat phase have yet to be identified between weight divisions.

Judo is composed by seven weight categories ranging from extra-lightweight (-60 kg) to heavyweight (+100 kg). Besides different morphological characteristics contained within each category, it was suggested that the choice of the fighting technique also differs among weight divisions (Miarka et al., 2014; Sterkowicz et al., 2013). Sterkowicz et al. (2013) have investigated frequently used techniques during London Olympic Tournament dividing into four weight categories: (1) extra lightweight; (2) half lightweight, lightweight, half middleweight; (3) middleweight; half heavyweight; (4) heavy weight. The results showed differences in technical preferences between extra lightweight and heavy weight groups, especially those with physical lever applied with max arm, physical lever applied with variable arm, and couple of forces applied by trunk and legs, which can be justified by the biomechanics of throws, once couple techniques are energetically more convenient compared to lever tech-

niques. However, the authors did not investigate combat/pause phases, grip fighting characteristics and ground fighting which may add important information in order to understand T-T approach between weight categories. Recent T-T analysis reports displayed specific factors that affect judo performance and determine competitive success, such as the approach and grip attempts, gripping patterns (*kumi-kata*), and effective attacks in varying orientations (Calmet, Miarka, & Franchini, 2010; Sterkowicz, Lech, & Blecharz, 2010). Consequently, it is recommended that notational analysis in judo be conducted with consideration for weight divisions differences in each combat phase with a wide range of interconnected elements, such as the type of approach (Calmet et al., 2010), type of attacks (Sterkowicz et al., 2013), defensive actions (Boguszewski, 2011), and groundwork attempts (Miarka et al., 2015).

A sequential T-T analysis examining each combat phase in high level athletes is needed to evaluate the fighting style and movement pattern differences between weight divisions. This hypothesis is supported by the fact that physical (Sterkowicz-Przybycień, & Almansba, 2011; Sterkowicz-Przybycien & Franchini, 2013) and physiological (Sterkowicz-Przybycien & Fukuda, 2014) characteristics vary between and among these athletes. Therefore, the purpose of the current study was to: (1) quantify different T-T indicators in high level judo matches; (2) quantify specific actions employed among weight divisions during individual combat/pause phases; and (3) determine the extent to which anthropometric-based differences occur between Olympic level athletes.

METHODS

This is a cross-section and descriptive applied study, using time-motion analysis.

SAMPLE

The present study comprised 154 male judo athletes who qualified for the 2012 Olympic Games, from this amount, 53.403 sequential combat actions were analyzed separated by seven official categories: extra-lightweight (-60 kg; *n* = 4.908, from 18 athletes with 27 ± 2.4 yrs., 60.0 ± 0.4 kg and 155.9 ± 37.7 cm), half-lightweight (-66 kg; *n* = 10.681, from 23 athletes with 28.6 ± 4.0 yrs., 64.9 ± 2.3 kg and 168.5 ± 5.4 cm), lightweight (-73 kg; *n* = 8.203, from 20 athletes with 28.6 ± 2.6 yrs., 72.6 ± 1.6 kg and 172 ± 4.6 cm), half-middleweight (-81 kg; *n* = 10.896, from 28 athletes with 28.7 ± 4.0 yrs., 79.3 ± 4.2 kg and 177.4 ± 6.3 cm), middleweight (-90 kg; *n* = 7.292, from 24 athletes with 28.7 ± 4.1 yrs., 87.9 ± 4.7 kg and 179.4 ± 6.3 cm), half-heavyweight (-100 kg; *n* = 4.112, from 14 athletes with 28 ± 3 yrs., 100 ± 0.5 kg and 184 ± 6.9 cm) and heavyweight (+100 kg; *n* = 7.174, from 27 athletes with 29.3 ± 3.9 yrs., 121.1 ± 22.4 kg and 188 ± 12 cm). In order to guarantee ecological validity and to verify the elite status of the sample, the competitive bouts were analyzed using several publically available judo video databases, including those provided by the International Judo Federation and the International Olympic Committee. In order to be included, each video had to be of sufficient quality (standard definition 480/60i) and taken from a landscape view of the entire competition area. While potential limitations exist due to these requirements, the procedures utilized reflect a method to observe critical events in combat performance which can be quantified in a consistent and reliable manner (Del Vecchio, Hirata, & Franchini, 2011; Tabben et al., 2015). Furthermore, performance analysis systems were used to collect a large sample sufficient to define movement patterns 'norms' while subsequent evaluation was based upon the principles of technical-tactical modelling (Kempe, Grunz, & Memmert, 2015). The competitive bouts were evaluated following previously outlined protocols (Miarka et al., 2012), from 36 international competitions from International Judo Federation (IJF) in 2011-12, including the Olympic Games (London, 2012), World Championship (Paris, 2011), two editions of *World Masters* (Almaty, 2012; Baku, 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), three Continental Competitions (Asian, Uzbekistan, 2012; American, Montreal, 2012, and; European, Chelyabinsk, 2012) 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.

DETERMINATION OF MOVEMENT WITH BIOMECHANICAL AND TECHNICAL-TACTICAL PATTERNS

The approach phase of combat was subdivided into four categories according to the movement pattern performed, including a right foot forward stance (*migi-shizentai*), a left foot forward stance (*hidari-shizentai*), a frontal stance (*shizen-hontai*), and attempting to grip (Calmet et al., 2010). The gripping phase of combat was evaluated by the location of the placement of the hands on the opponent's judo uniform (*judogi*), such as the collar, sleeve or back, and lateral location, right or left, following a previously validated protocol (Miarka, Hayashida, Julio, Calmet, & Franchini, 2011).

The attack phase of combat was characterized by the direction of the throwing technique, as front/rear or right/ left, and according to the specific biomechanical principles utilized, which were identified by the type of force couple applied or the length and point of application of the moment arm, as outlined by Sterkowicz et al. (2013). Throwing techniques that employed a force couple were designated as using: an arm lever (i.e., *Kuchiki-taoshi, Kibisu-gaeshi, Kakato-gaeshi* and *Te-guruma)*, an arm/ leg lever (i.e., *De-ashi-harai, O-uchi-gari, Okuri-ashi-harai, Kosoto-gake, Ko-uchi-gari, Ko-soto-gari)*, trunk/leg lever (i.e., *O-soto-*

gari, Uchi-mata, Ko-uchi-makikomi, Haraí-makikomi, Haraí-goshi, Hane-goshi), or a trunk/arm lever (i.e., *Morote-gari variations*), while techniques described by the moment arm were designated as minimal length (applied at the opponent's waist, i.e., *O-guruma, Ura-nage, Soto-Makikomi, Makikomi, Sukui-nage, Ushiro-goshi, Utsuri-goshi*), medium length (applied at the opponent's knee, i.e., *Hiza-guruma, Ashi-guruma, Hizasoto-muso, Soto-kibisu-gaeshi*), variable length (below the opponent's waist, i.e. *Tsuri-komi-goshi, O-goshi, Sasae-tsuri-komi-goshi, Koshi-guruma, Seoi-nage, Morote-seoi-nage*) or maximal length (applied at the opponent's foot/ankle, i.e., *Uki-otoshi, Sumi-otoshi, Seoi-otoshi, Tani-otoshi, Tai-otoshi, Tomoe-nage, Sumigaeshi, Yoko-tomoe, Uki-waza, Sasae-tsuri-komi-ashi*) (Sacripanti, 2012).

The groundwork phase of combat was determined by the specific actions conducted, including immobilization/pinning techniques (*osae-waza*), chokes (*shime-waza*) and arm-locks (*kansetsu-waza*) (Sacripanti, 2012; Sterkowicz et al., 2013). The defense phase of combat was categorized by the manner in which the defending athlete changed his/her body position and orientation, right or left (*tae-sabaki*), in response to an attack and by the use of a counter-attack (Boguszewski, 2009, 2011). During the pause phase, determinant penalty scores or advantages were counted according to penalties received by the athlete, or given to the opposing athlete (Miarka et al., 2014), and further designated between the initial penalty that did not result in a score or subsequent penalties that did result in a score, as determined by the referee officiating the match (Escobar-Molina et al., 2014).

Data were collected through systematic observation, performed by 3 evaluators which were previously trained to perform this analysis. To guarantee internal validity and verify the objectivity of the analysis, the reliability measures were assessed through intra-observer and inter-observer testing procedures (Bland & Altman, 2007), with a agreement classified as 'Strong' and 'Almost Perfect' for Kappa values, with a mean of agreement of .77 and .93 through intra-observer and inter-observer tests previously, respectivly (Miarka et al., 2011).

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). Kolmogorov-Smirnov test (K-S) was used to determine data's normal distribution. T-T indicators comparisons between weight divisions were made by calculating the *Kruskal-Wallis* test, used to conduct analysis of variance by ranks, 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 ($\eta^2 > .14$), moderate effect size ($.06 < \eta^2 < .14$) and weak effect size ($\eta^2 < .06$). The 95% confidence intervals were calculated and a significance level of $p \leq .05$ was used for all analysis.

RESULTS

Table 1 presents a descriptive and inferential analysis of T-T indicator frequencies of elite judo athletes by weight divisions.

TABLE 1. Descriptive analysis of technical-tactical indicator (frequencies) of elite judo athletes by weight divisions.

	EXTRA-LIGHTWEIGHT			HALF-LIGHTWEIGHT			LIGHTWEIGHT			HALF-MIDDLEWEIGHT			MIDDLEWEIGHT			HALF-HEAVYWEIGHT			HEAVYWEIGHT		
	MD	Q1	Q3	MD	Q1	Q3	MD	Q1	Q3	MD	Q1	Q3	MD	Q1	Q3	MD	Q1	Q3	MD	Q1	Q3
APPROACH PHASE	12.5	9.0	21.5	26.0	21.0	34.0	27.0	15.5	36.0	19.5	12.3	29.5	21.0	9.3	30.0	20.0	13.3	28.5	15.0	7.0	27.0
Right foot forward position	0.5	0.0	2.3	1.0	0.0	12.0	0.0	0.0	4.8	4.0[a]	0.3	11.5	0.0	0.0	4.0	0.0	0.0	4.0	0.0	0.0	2.0
Left foot forward position	1.0	0.0	6.0	1.0	0.0	12.0	5.0	0.0	14.5	1.0	0.0	6.8	1.0	0.0	2.8	0.5	0.0	8.3	0.0	0.0	2.0
Frontal foot position	0.5	0.0	3.5	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	3.8	4.0[b]	1.0	13.0	3.5	0.0	12.3	1.0	0.0	6.0
Attempts to grip	7.0	4.0	13.8	15.0[c]	9.0	20.0	15.0[c]	8.0	23.0	6.5	5.0	11.0	8.0	4.3	13.8	7.5	3.8	13.0	5.0	3.0	11.0
GRIPPING PHASE	10.0[d]	6.5	21.5	18.0	13.0	25.0	20.0	11.3	28.0	17.0	9.0	24.8	19.5	9.3	29.8	27.5	23.0	34.0	16.0	7.0	29.0
Gripping on the right back	0.0	0.0	0.3	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Gripping on the right back/sleeve	0.0	0.0	2.3	0.0	0.0	2.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	1.0	0.5	0.0	4.3	0.0	0.0	1.0
Gripping on the left back	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	1.0	0.0	0.0	0.0
Gripping on the left back/sleeve	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	3.5	1.0	0.0	2.0	0.0	0.0	4.0
Gripping on the right collar/sleeve	1.0	0.0	2.5	1.0	0.0	3.0	1.0	0.0	2.8	3.0	0.0	5.0	1.5	0.0	4.0	5.0	0.8	8.5	1.0	0.0	4.0
Gripping on the right collar	0.0	0.0	2.3	1.0	0.0	2.0	0.5	0.0	2.8	1.0	0.0	2.8	0.5	0.0	2.0	2.5	0.0	8.0	0.0	0.0	4.0
Gripping on the left collar	0.5	0.0	2.3	2.0	0.0	5.0	2.0	1.0	5.8	1.0	0.0	3.0	2.0	0.0	5.0	1.5	0.8	3.5	1.0	0.0	2.0
Gripping on the left collar/sleeve	0.5	0.0	4.5	1.0	1.0	3.0	2.0	0.0	4.0	2.0	0.3	5.0	0.0	0.0	2.0	1.0	0.0	2.0	1.0	0.0	4.0
Gripping on the right/left collar	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	3.5	0.0	0.0	2.0
Gripping on the right sleeve	1.0	0.0	2.5	1.0	0.0	5.0	0.5	0.0	3.8	0.0	0.0	1.0	1.0	0.0	3.5	0.5	0.0	2.3	1.0	0.0	3.0
Gripping on the left sleeve	0.0	0.0	1.3	0.0	0.0	2.0	1.5	0.0	4.0	1.0	0.0	2.0	1.5	0.0	6.0	1.0	0.0	4.0	0.0	0.0	1.0
Gripping on the right/left sleeve	0.0	0.0	1.0	0.0	0.0	3.0	1.0	0.0	2.0	1.0	0.0	3.0	0.0	0.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0
ATTACK PHASE	3.5	2.0	8.5	8.0	3.0	13.0	5.5	2.5	11.0	6.0	3.0	9.8	6.5	3.0	9.8	6.5	4.0	10.8	5.0	2.0	10.0

Arm Lever	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arm and Leg Lever	1.0	0.0	2.0	1.0	0.0	4.0	1.0	0.0	2.8	2.0	0.0	4.0	2.0	1.0	6.0	3.0	0.0	6.5	3.0	1.0	4.0
Minimum Lever	0.0	0.0	0.3	0.0	0.0	2.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Trunk/leg Lever	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0
Medium length	0.5	0.0	2.0	1.0	0.0	2.0	1.0	0.3	2.0	1.0	0.0	2.8	0.5	0.0	1.0	0.5	0.0	2.8	0.0	0.0	1.0
Maximal length	0.5	0.0	2.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0	1.0	0.5	0.0	2.3	0.0	0.0	0.0
Attacks to the Front	0.5	0.0	1.3	1.0	0.0	2.0	1.0	0.0	3.0	1.0	0.0	1.8	1.0	0.0	3.5	1.5	0.0	3.5	1.0	0.0	2.0
Attacks to the Right	0.5	0.0	2.5	1.0	0.0	4.0	1.0	0.0	3.0	1.0	0.0	2.0	1.0	0.0	2.0	0.5	0.0	6.0	1.0	0.0	2.0
Attacks to the Rear	2.0	0.0	3.0	2.0	1.0	4.0	1.0	0.0	2.0	2.0	1.0	2.8	2.0	0.3	3.0	2.0	0.8	4.0	1.0	0.0	5.0
Attacks to the Left	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0	1.0	1.0	0.0	4.0	1.0	0.0	2.0	0.5	0.0	1.5	1.0	0.0	2.0
Defense phase	3.5	1.0	7.5	6.0	3.0	10.0	8.0[e]	3.3	11.5	2.0	1.0	4.8	5.5	1.3	13.0	6.0	2.8	9.3	2.0	1.0	6.0
Use of counter-attack	0.0	0.0	0.3	0.0	0.0	1.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0
Use of tae-sabaki to the right	1.0	0.0	2.8	2.0	0.0	4.0	2.0	0.3	4.8	1.0	0.3	3.8	2.0	0.0	5.0	3.0	1.0	5.8	1.0	0.0	3.0
Use of tae-sabaki to the left	2.0	0.8	3.3	2.0	1.0	5.0	4.5[f]	2.3	6.0	0.5[g]	0.0	1.8	2.0	0.0	5.8	2.0	1.0	3.3	1.0	0.0	2.0
GROUNDWORK PHASE	4.5	2.5	10.0	9.0	6.0	11.0	10.0	5.5	12.8	5.5	2.0	10.8	4.0	1.3	8.0	6.0	4.0	10.0	2.0[h]	1.0	4.0
Osae-waza	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kansetsu-waza	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shime-waza	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAUSE PHASE	7.0	3.0	13.3	13.0	9.0	18.0	14.0	8.0	19.8	9.5	6.0	12.8	7.5	3.3	13.8	10.5	6.0	17.0	6.0	1.0	14.0
Initial penalty received	0.0	0.0	1.0	1.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	1.0
Initial opponent penalty	0.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	1.0	1.0[i]	0.0	1.8	1.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0
Subsequent penalty received (score)	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.5	0.0	1.0	0.0	0.0	1.0
Subsequent opponent penalty (score)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MD – Median, Q1 – 1st Quartile and Q 3 – 3rd Quartile. [a] $p \leqslant .047$ from this weight division vs. extra-lightweight and middleweight, [b] $p = .002$ from this weight division vs. middle-lightweight and lightweight, [c] $p \leqslant .041$ from this weight division vs. Half-middleweight, half-heavyweight and heavyweight, [d] $p = .026$ from this weight division vs. half-heavyweight, [e] $p = .013$ from this weight division vs. half-middleweight, [f] $p \leqslant .04$ from this weight division vs. extra-lightweight, half-middleweight and heavyweight, [g] $p \leqslant .032$ from this weight division vs. half-lightweight and middleweight, [h] $p \leqslant .013$ from this weight division vs. half-lightweight, half-middleweight and half-heavyweight, [i] $p = .003$ from this weight division vs. heavyweight.

The analysis showed a main effect of weight division in approach phase ($\chi^2 = 13.507$, $p = .036$, $\eta^2 = .09$), multiple comparisons did not showed effect between groups ($p > .005$ for all comparisons). Determinant effect of weight divisions was observed in Right foot forward position ($\chi^2 = 15.794$, $p = .015$, $\eta^2 = .14$), where half-middleweight used a higher frequency than extra-lightweight ($p = .01$, 95% CI = 0.67 to 10.13), middleweight ($p = .047$, 95% CI = .03 to 8.74) and heavyweight ($p = .014$, 95% CI = 0.53 to 8.98). A main effect of weight divisions was observed in Frontal foot position frequency ($\chi^2 = 32.313$, $p < 0.001$, $\eta^2 = .17$), where middleweight presented higher values than middle-lightweight ($p = .002$, 95% CI = 1.46 to 11.15) and lightweight ($p = .002$, 95% CI = 1.57 to 11.63). No effect was observed in approach with Left foot forward position ($p = .298$). Determinant effect of weight divisions was observed in approach with attempts to grip ($\chi^2 = 23.224$, $p < 001$, $\eta^2 = .19$), half-lightweight showed higher frequency than half-middleweight ($p = .002$, 95% CI = 1.8 to 13.27), half-heavyweight ($p = .036$, 95% CI = 0.24 to 14.05), and heavyweight ($p = .011$, 95% CI = 0.85 to 12.41) and lightweight division demonstrated higher frequency trying to grip than half-middleweight ($p = .002$, 95% CI = 1.67 to 13.6), half-heavyweight ($p = .041$, 95% CI = 0.14 to 14.34), and heavyweight ($p = .015$, 95% CI = 0.72 to 12.74).

Determinant effect of weight divisions was observed in *gripping phase* ($\chi^2 = 12.784$, $p = .047$, $\eta^2 = .08$), where Extra-Lightweight presented lower values than Half-heavyweight group ($p = .026$, 95% CI = -26.7 to -0.84). Determinant effect of weight divisions was observed in Gripping on the left back/sleeve ($\chi^2 = 12.747$, $p = .047$, $\eta^2 = .10$), no effects were observed in multiple comparisons ($p > .05$ for all comparisons). Determinant effect of weight divisions was observed in Gripping on left/right sleeve ($\chi^2 = 23.680$, $p < .001$, $\eta^2 = .11$), no effects were observed in multiple comparisons ($p > .05$ for all comparisons). No effects were observed in comparisons of gripping on right back ($p = .610$), gripping on right back/sleeve ($p = .536$), gripping on left back ($p = .133$), gripping on right collar ($p = .128$), gripping on right collar/ sleeve ($p = .650$), gripping on left collar ($p = .243$), gripping on left collar/ sleeve ($p = .301$), gripping on left/ right collar ($p = .116$), gripping on right sleeve ($p = .213$) and gripping on left sleeve ($p = .194$).

No effects were observed when compared the frequency of attack phase ($p = .67$) and their orientations, to the front ($p = .59$), to the right ($p = .82$), to the rear ($p = .96$), and to the left direction ($p = .30$). No effects were observed in throwing types according to the specific biomechanical principles utilized of arm lever ($p = .293$), arm and leg lever ($p = .128$), trunk/ leg lever ($p = .123$), minimal length ($p = .117$), medium length ($p = .246$) and variable length or maximal length ($p = .265$).

Determinant effect of weight division was observed in defense phase ($\chi^2 = 18.003$, $p = .006$, $\eta^2 = .12$), Lightweight presented higher values than half-middleweight group ($p = .013$, 95% CI = 0.55 to 9.14). No effect was observed in counter-attack comparisons ($p = .562$) and in *tae-sabaki* to the right side ($p = .38$). Determinant effect of weight divisions was observed in

tae sabaki to the left (χ^2 = 33.312, p < .001, η^2 = .2), Lightweight division demonstrated higher frequency of *tae sabaki* to the left than extra-lightweight (p = .04, 95% CI = 0.05 to 4.62), half-middleweight (p < .001, 95% CI = 0.39 to 5.51), and heavyweight (p < .001, 95% CI = 1.08 to 5.23), and half-middleweight presented lower values than half-lightweight (p < .001, 95% CI = -4.11 to -0.15) and middleweight group (p = .032, 95% CI = -4 to -0.09).

A main effect of weight divisions was observed in groundwork phase (χ^2 = 37.584, p < .001, η^2 = .23), heavyweight presented lower values than lightweight division (p < .001, 95% CI = -11.4 to -3.31), half-lightweight (p < .001, 95% CI = -9.93 to -2.14), half-middleweight (p = .003, 95% CI = -8.36 to -0.96) and half-heavyweight (p = .013, 95% CI = -9.65 to -0.61), and middleweight presented lower values than lightweight group (p = .01, 95% CI = -8.95 to -0.65). No effects were observed in *Osae-waza* (p = 1.00), *Kansetsu-waza* (p = 1.00) and *Shime-waza* (p = 1.00).

The analysis showed a main effect of weight division in pause phase (χ^2=14.552, p = .024, η^2 = 0.1), multiple comparisons did not showed effects between weight divisions (p > .005 for all comparisons). Determinant effect of weight divisions was observed in opponent penalties (χ^2 = 14.783, p = .022, η^2 = .22), half-middleweight presented higher values than heavyweight (p = .003, 95% CI = 0.15 to 1.26). Determinant effect of weight divisions was observed in opponent's score by penalties (χ^2 = 18.372, p = .005, η^2 = .9), no effects were observed in multiple comparisons (p > .05 for all comparisons). No effects were observed when compared the number of penalties received (p = .112) and score by opponent's penalties (p = .228). The

Table 2 presents the CC between weight (W) and height (H) and approach and gripping.

TABLE 2. Correlation (CC) between weight and height and Approach and Gripping T-T indicators.

T-T INDICATORS		WEIGHT(KG)	HEIGHT(CM)
APPROACH PHASE	CC	-0.08	-0.12
	P	0.31	0.19
Right foot forward position	CC	-0.04	-0.08
	P	0.67	0.38
Left foot forward position	CC	-0.12	-0.13
	P	0.16	0.15
Frontal foot position	CC	0.223**	0.191*
	P	0.01	0.03
Attempts to grip	CC	-0.188*	-0.213*
	P	0.02	0.01
GRIPPING PHASE	CC	0.1	0.09
	P	0.24	0.33
Gripping on the right back	CC	-0.02	0.11
	P	0.77	0.2
Gripping on the right back/sleeve	CC	0.03	0.16
	P	0.69	0.07
Gripping on the left back	CC	0.03	0.06
	P	0.74	0.52
Gripping on the left back/sleeve	CC	0.332**	0.29**
	P	0.001	0.001
Gripping on the right collar	CC	0.09	0.07
	P	0.27	0.44
Gripping on the right collar/sleeve	CC	0.02	-0.02
	P	0.81	0.86
Gripping on the left collar	CC	-0.05	-0.08
	P	0.52	0.34
Gripping on the left collar/sleeve	CC	-0.09	-0.13
	P	0.27	0.15
Gripping on right/left collar	CC	0.12	0.07
	P	0.14	0.41
Gripping on right sleeve	CC	0.03	0.01
	P	0.74	0.9
Gripping on left sleeve	CC	0.09	0.03
	P	0.3	0.75
Gripping on left/right sleeve	CC	-0.204*	-0.269**
	P	0.01	0.001

** Coefficient Correlation (CC) statistical (P) significant at the 0.01 level (2-tailed);
* CC significant at the 0.05 level (2-tailed).

W and height H present a significantly and direct correlation with frontal foot position (r = .223; p = .0.01 for W and r = .191; p = .03 for H), gripping on the left back/sleeve (r = .332; p = .001 for W and r = .29; p = .001 for H), and inversely correlation with attempts to grip (r = -.188; p = .02 for W and r = -.213; p = .01 for H), and gripping on left/ right sleeve (r = -.204; p = .01 for W and r = -.269; p = .001 for H). The Table 3 presents the CC between W and H versus attack and defense T-T.

TABLE 3. Correlation (CC) between weight and height versus Attack and Defense T-T indicators.

T-T INDICATORS		WEIGHT(KG)	HEIGHT(CM)
ATTACK PHASE	CC	0.01	-0.03
	P	0.93	0.76
Arm Lever	CC	-0.07	-0.06
	P	0.41	0.51
Arm and Leg Lever	CC	0.173*	0.15
	P	0.04	0.1
Minimum Lever	CC	-0.1	-0.214*
	P	0.21	0.01

Trunk/leg Lever	CC	-0.16	-0.16
	P	0.06	0.07
Medium length	CC	-0.13	-0.176*
	P	0.13	0.05
Maximal length	CC	0.0	0.0
	P	0.97	0.96
Attacks to the Front	CC	0.07	0.05
	P	0.37	0.59
Attacks to the Right	CC	-0.05	-0.05
	P	0.55	0.55
Attacks to the Rear	CC	0.02	0.01
	P	0.81	0.9
Attacks to the Left	CC	-0.05	-0.05
	P	0.54	0.59
DEFENSE PHASE	CC	-0.01	-0.07
	P	0.9	0.42
Use of counter-attack	CC	-0.03	-0.03
	P	0.73	0.74
Use of tae-sabaki to the right	CC	0.03	0.01
	P	0.68	0.94
Use of tae-sabaki to the left	CC	-0.02	-0.11
	P	0.77	0.21
Groundwork Phase	CC	-0.11	-0.13
	P	0.2	0.15

** Coefficient Correlation (CC) statistical (P) significant at the 0.01 level (2-tailed);
* CC significant at the 0.05 level (2-tailed).

The W was directly correlated with arm and leg lever (r = .173; p = .04) and H was inversely correlated with minimum lever (r = -.214; p = .01) and medium length (r = -.176; p < .05). The Table 4 presents the CC between W and H versus technical-tactical indicators on pause phase. There was no significant correlation (p > .05) between the variables.

TABLE 4. Correlation (CC) between weight and height versus Technical-Tactical indicators on Pause phase.

TECHNICAL-TACTICAL INDICATORS		WEIGHT (KG)	HEIGHT (CM)
PAUSE PHASE	CC	-0.06	-0.08
	P	0.47	0.36
Golden score	CC	-0.12	-0.10
	P	0.16	0.25
Initial penalty received	CC	0.03	0.03
	P	0.72	0.71
Initial opponent penalty	CC	0.0	0.0
	P	0.98	10.0
Subsequent penalty received (with score)	CC	0.1	0.14
	P	0.24	0.1
Subsequent opponent penalty (with score)	CC	-0.01	-0.03
	P	0.93	0.72

DISCUSSION

This study aimed to quantify T-T indicators in high level judo matches, specific actions among weight divisions during combat/ pause phases and determine the anthropometric influence in T-T actions between Olympic level judo athletes. The present investigation assumed that weight divisions would significantly affect T-T and biomechanical patterns during individual combat phases. The main results indicated that athletes of half-middleweight division have more combat time with the right foot on forward position and middleweight perform a higher time in frontal foot position. The light categories are those that most change the handgrip, as half-lightweight and lightweight change more handgrip, and extra-lightweight maintaining a lower grip time. The half-middleweight is more defensive and that causes higher number of penalties to the opponent. The heavyweight division dedicated lower time to ground combat. Weight and height significantly correlate with frontal foot position, attempts to grip and gripping position. Weight significantly correlates with arm and leg lever, height significantly correlate with minimum lever and medium length. The knowledge about the T-T actions can assist in guiding the coaches to planning the training (Miarka, Del Vecchio, et al., 2016), improving the accuracy and precision of the athlete in the application of a technique (Drust, 2010) and establish a precise strategies for specific opponent (Miarka, Del Vecchio, et al., 2016).

APPROACH FREQUENCY

We observed differences in T-T actions during the approach phase in some weight division. Intermediary weight divisions (half-middleweight and middleweight) seem to be those that best differentiate as to approach strategies. These strategies are important for the judoka advantage in handgrip (Heinisch, Oswald, & Büsch, 2010), can be result in better combat posture, which can result in a penalty for the opponent (Miarka et al., 2014). In contrast, Miarka, Del Vecchio, et al. (2016) observed that, in Olympic games, the approach strategies do not differentiate between winners and their opponents. The results highlighted here point to a homogeneous behavior among the weight categories, it is noteworthy, however, that particularities should be considered in the intermediary divisions, which an approach strategy can become a competitive advantage. In this sense, it may be advantageous in these categories apply the left handgrip, thus, the opposition (*kenka-yotsu*) seems to be more effective (Courel et al., 2014).

GRIPPING FREQUENCY

There is a range of primary and secondary factors influencing the development of judo expertise, and gripping appears to be one of the essential characteristics that determines proficiency in competition (Sterkowicz et al., 2010). The currently identified differences in specific T-T gripping actions between weight division athletes are of particular importance due to recent findings outlining the relationship between gripping and attacking on competitive success (Heinisch et al., 2010). A factor that possibly determines the higher handgrip change and shorter handgrip time is related to the agility of athletes from lighter divisions (extra-lightweight, half-lightweight and lightweight). In fact, biomechanical and anthropometric characteristics affect the preferred techniques choices made by judokas (Sterkowicz et al., 2013). Then, regarding the T-T strategies by lighter athletes in judo, it is important to domain the handgrip fight in order to be able to perform more sequential attacks which are needed for competing at a high-level in these categories. It must be noted that, judokas of lighter categories have lower handgrip strength in comparison the heavy weight (Gutierrez Sanchez, Soria Dominguez, Perez Turpin, Cortell Tormo, & Suarez Llorca, 2011), so, it seems indispensable to adopt, for example, visual search training methods to improve the visual-motor coordination skills and perform, efficiently, the handgrip before the opponent (Piras, Pierantozzi, & Squatrito, 2014). Extended approach time could be used by athletes to quickly analyze the opponent and execute their desired gripping strategy, which has been established to be a key indicator of technical efficiency (Imamura, Hreljac, Escamilla, & Edwards, 2006). In addition, athletes may utilize this time to engage in evasive actions in order to control space and, ultimately, gain control of their opponent for subsequent attacks (Heinisch et al., 2013).

ATTACK AND DEFENSE FREQUENCIES

We observed slight differences between attack and defense actions in weight divisions, some indicators can be applied to the establishment of specific training strategies. According to Franchini et al. (2008) the variability and attack's orientation is the key aspect that discriminates Olympic level athletes. In this sense, seems to be fundamental training of multiple attack strategies that imposed difficulties to the opponents and achieved competitive advantages (Sterkowicz et al., 2013), especially in the half-lightweight division, which was more defensive and at the same time one where the opponents receive greater amount of penalties. Defensive strategies appear to be fundamental in combat sports; karateka's who have greater competitive success are those who present a better defense (Tabben et al., 2015). This difference indicates the need for a more aggressive strategy, which can be achieved by effectiveness in approach, gripping and dodge (*tae-sabaki)* (especially in half-lightweight and half-middleweight division). The frequency of attacks from the current sample appear to be similar to those described by previous authors in international medalists and non-medalists (Heinisch et al., 2013). Although not observed great differences between weight divisions, the correlations between body weight/ height and combined handgrips sleeve-sleeve and back-sleeve, weight and arm and leg lever and height with minimum lever and medium length should be considered. These results support the view that attacking strategies are an important factor in the technical development of judo athletes. Sterkowicz et al. (2013) observed a predominance of upper extremity actions during the London Olympic Games, but with specific differences in the techniques utilized.

Our results agree with those obtained by Miarka, Del Vecchio, et al. (2016), where judokas winners in the Olympic Games not differ from the opponents, except for the attacks performed to the right side. However, they differ from previous studies that observed difference in weight categories and biomechanical characteristics of the attacks (Imamura et al., 2006; Imamura, Iteya, Hreljac, & Escamilla, 2007; Sacripanti, 2012). Imamura et al. (2006) suggest that the lower extremity techniques (*ashi-waza)* executed to the front or side (left/ right), such as *o-soto-gari* and *de-ashi-haraí*, require high amounts of torque and/ or velocity before contact with the opponent (*uke*), while those executed to the rear orientation that involve rotation, such as *morote-seoi-nage*, and sacrifice techniques (*sutemi-waza*), such as *tomoe-nage,* require more time to be applied. Furthermore, lower extremity techniques are generally more successfully incorporated by wider, stronger and heavier athletes, while sacrifice techniques tend to be used more by smaller and lighter athletes that possess superior agility (Imamura et al., 2006; Imamura et al., 2007; Sacripanti, 2012).

GROUNDWORK FREQUENCY

Overall, there were no differences in the weight divisions and the time of groundwork combat. Groundwork actions are related to attacking actions during standing combat and 20% of all attempts to attack during the 2012 Olympic Games occurred during the transition to/ or into groundwork (Heinisch et al., 2013). Our results indicate that the time on the groundwork is less effective, especially in the heavyweight division, thus it appears to be more effective for this division weight, the use of standing combat strategies. In fact, Miarka, Del Vecchio, et al. (2016) observed that winners in the Olympic Games spend less time in the groundwork combat. Furthermore, fewer *ippons* are scored during international competition compared to Olympic Games, while elite athletes strategically place their opponents in susceptible positions during the transition to groundwork (Heinisch et al., 2013).

PAUSE FREQUENCY

Our results showed no difference between the penalties during pause periods, except for the half-middleweight. According to Miarka, Del Vecchio, et al. (2016), winning in Olympic Games did not differ from their opponents in the pause phase of combat. The number of penalties given at the Olympic Game has been trending upward since before Beijing in

2008 and outweighed the number of full point scores awarded in London 2012 (Heinisch et al., 2010). Despite the rule modifications in 2009, the number of penalties increased in the senior world championships, with 1.58 penalties/min, which was greater than in junior world championships, with 1.46 penalties/min, but less than in the under-23 world championships, with 2.17 penalties/min (Heinisch et al., 2010). Subsequent reports have demonstrated an increase in the number of penalties and fewer partial scores in high level athletes, and fewer full point scores awarded and disqualifications due to penalties in men, when compared to the two previously held European championships (Franchini, Takito, & Calmet, 2013). This contextual information about weight division differences can be used to support technical-tactical skill improvement efforts which are the primary goal of any judo development program for Olympic athletes.

LIMITATIONS AND PERSPECTIVES

A potential limitation of notational analysis methods is the reliability of the data entry procedure, or the researcher's ability to reproduce the observed value when measurement is repeated (Miarka, Del Vecchio, et al., 2016; Miarka, Fukuda, Del Vecchio, & Franchini, 2016; Tabben et al., 2015). Large variations in the total time, frequency and mean duration of combat actions measured during reliability analyses can affect inter-observer consistency (Tabben et al., 2015). The observational-descriptive approach implemented in the current investigation may limit extrapolation of the results. Furthermore, there was a limited detailed data available comparing the match demands between weight divisions. The results of this study are based on analysis of the most recent Olympic Games (up to date), it should be noted, however, that changes occurred in judo rules in 2013 (Franchini et al., 2013), so future studies should focus on analyzing the impact of these changes in the Olympic Games following (Rio, 2016 and Tokyo 2020).

PRACTICAL APPLICATIONS AND THEORETICAL IMPLICATIONS

The present study partially validates the biomechanical analysis of judo techniques described by Sacripanti (2012) with respect to the notational analysis of movement patterns. Thus, coaches and analysts can make extensive use of video analysis and data collection procedures to provide useful feedback about each combat phase (approach, gripping, attack, defense, groundwork and pause moments) while developing systematic methods of technical observation. The present research was primarily concerned with the methodological processes associated with competitive tactics and strategies, including the specific problems associated with technical observations in match analyses, and their connection with the biomechanical aspects of judo. The differences in T-T variables by weight division, as well as those associated with the weight and height profile can be a reference for coaches to identify optimal and sub-optimal performances of Olympic judo athletes and facilitates comparative analyses.

CONCLUSION

Based on these results and applied methodology, we can conclude that weight divisions would significantly affect T-T and biomechanical patterns during individual combat phases. Athletes of half-middleweight division have more combat time with the right foot on forward position and middleweight athletes perform more time in frontal foot position. The lightweight divisions are those that most change the handgrip, as half-lightweight and lightweight change more handgrip and extra-lightweight maintaining a lower grip time. The half-middleweight is more defensive and that causes higher number of penalties to the opponent. The heavyweight division dedicated lower time to ground combat. Weight and height significantly correlate with frontal foot position, attempts to grip and gripping position. Weight significantly correlates with arm and leg lever, height significantly correlate with minimum lever and medium length.

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