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Time Motion Analysis of Cadet Taekwondo Athletes According to Gender and Weight Category

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Abstract
Aim. The aims of this study were to analyze time motion (non-fighting, fighting and stoppage phases) of cadet athletes according to their gender (male or female) and weight category (light, middle and heavy) participating in the 2014 World Cadet Taekwondo Championships.
Methods. The analysis included 4,535 phases by 80 athletes in 47 semi- and finals bouts in the first WTF World Cadet Taekwondo Championship. Kruskal Wallis and Mann-Whitney U tests for pair comparisons were conducted to test the differences between the duration of activity phases (i.e. non-fighting, fighting and stoppage) in relation to weight category and gender.
Results. The results obtained show that females had longer fighting, non-fighting and stoppage phases than males. By weight category, heavyweight athletes engaged in longer non-fighting phases than lightweight fighters and longer stoppage phases than middleweight athletes. Heavyweight females had longer fighting phases than males, middleweight females had longer phases than males and lightweight females had longer phases than males ($p \leq 0.05$).
Conclusions. The activity profile in *taekwondo* cadet competition was influenced by the competitors' gender and weight category. Females had longer phases than males, while heavyweight athletes had longer non-fighting phases than the other weight categories and middleweights had shorter stoppage phases than heavyweights. These findings suggest the need for specific training for both genders in each weight category when planning training for cadet *taekwondo* competitors.

Introduction

Taekwondo is a high-intensity intermittent combat sport that requires complex skill and tactical excellence for success [Bridge *et al.* 2009; Santos *et al.* 2011]. Points can be won by kicking the permitted scoring areas (trunk or head) and punches to the body. Under the current World Taekwondo Federation (WTF) scoring system for all ages, different points can be obtained by kicking the opponent's trunk or head or by punches to the body [WTF, 2018]. WTF events are normally organized at the regional, national and international levels by weight categories, sex and age. In cadet competitions, bouts consist of three one-and-a-half minute rounds, with a one-minute rest period between rounds. From the perspective of physical fitness, the objective of training is to prepare competitors to effectively manage the physical and physiological demands of a bout [Santos *et al.* 2014].

One of the methods used to quantify the physiological demands is to use time-motion analysis (TMA), which provides information directly applicable to the design of physical conditioning and testing programs [Deustch *et al.* 2006; Miarka *et al.* 2012; Ouergui *et al.* 2014]. The bout time structure (effort: pause [E:P] ratio) was used to mirror competition demands and to prescribe the training characteristics related to competition time (effort time) and pauses [Buse, Santana 2008; Glaister 2005]. In taekwondo, the bout time structure is determined by fighting and non-fighting activities [Bridge *et al.* 2011; Campos *et al.* 2012; Heller *et al.* 1998; Matsushigue *et al.* 2009; Tornello *et al.* 2013; Santos *et al.* 2011], which are synonyms with effort and pause, respectively. These ratios correlate with the use of aerobic and anaerobic metabolism during bouts, heart rate values and lactate concentrations [Bridge *et al.* 2013; Campos *et al.* 2012; Chiodo *et al.* 2012; Heller

et al. 1998; Herrera *et al*. 2014; Markovic *et al.* 2008; Matsushigue *et al*. 2009].

Previous studies found that adult taekwondo competitors had fighting periods ranging from one to five seconds followed by longer periods of non-fighting activity, with an E:P ratio ranging from 1:1 to 1:7 [Bridge *et al*. 2011; Campos *et al.* 2012; Heller *et al.* 1998; Matsushigue *et al*. 2009; Santos *et al*. 2011]. Similar results were found in males and females [Santos *et al.* 2011], however differences emerged between the weight categories that affected the different E:P, i.e. heavier competitors had shorter fighting phases and had longer non-fighting phases than lighter categories [Bridge *et al*. 2011; Santos *et al*. 2011]. In an intermittent sport like taekwondo, physiological responses depend on the duration and intensity of the effort and the associated pauses [Santos *et al*. 2011], so that taekwondo training must consider this intermittent nature when trying to mirror the demands of a competition. In the case of cadet taekwondo athletes, the E:P ratio seems to be 1:2 with 2.8±1.0 s fighting and 6.5±1.8 s non-fighting time [Tornello *et al.* 2013], which differs from the adults, who usually have ratios of 1:7 [Santos *et al*. 2011]).

Considering the different physiological and combative behavior of the different age groups [Herrera *et al.* 2014], extrapolating results from adults to cadets seems inappropriate [Tornello *et al.* 2013]. The study by Tornello *et al.* [2013], the only research conducted on cadet taekwondo athletes, established the basis of TMA in taekwondo cadet championships and showed that it was not related to gender or the weight category. This study analyzed the finals and semifinals of a national tournament (the 2010 Italian Taekwondo Championship) [Tornello *et al.* 2013], however, the neither phase of the tournament in which the athletes took part [Menescardi *et al. 2*014] nor international competitors were considered in the study. The aim of the present study was thus to analyze the TMA (non-fighting, fighting and stoppage phases) of cadet athletes participating in a world cadet taekwondo championship according to gender and weight category in order to gain greater knowledge of not only the effect of gender but also of the weight category in taekwondo bouts. It has been hypothesized that males and females [Menescardi *et al.* 2015] and also the light, middle and heavyweight categories [Menescardi *et al.* 2012] have different TMAs.

Methods

Experimental approach to the Problem

To test the hypothesis that TMA varies during bouts, the first World Cadet Taekwondo Championship (2014) was analyzed according to weight category and gender. TMA includes: (a) Non-Fighting, (b) Fighting, and (c) Stoppage or passive phases [Tornello *et al.* 2013]. The non-fighting phase was considered as an active phase that included strategy planning, observation and physical preparation for the attack (e.g. judging safety distances, changing stances and directions, planning feints and steps). The fighting phase was considered as an active phase that includes technical exchanges (e.g., kicking, punching and blocking techniques) between opponents and tactical movements (e.g., feints, changing stances and directions, steps etc.) preceding the attack with the aim of confusing or surprising the opponent, in order to score. This phase began when the second foot left the floor for the first kick or punch and ended when both feet touched the floor again, the punching or blocking limb was retracted or the referee stopped the bout. The stoppage phase refers to a passive temporal phase for: a) solving technical problems, b) giving warnings, c) administering first aid to an injured athlete (1-min) d) replaying videos following an objection to a judgment. The referee marks the start and end of stoppage time by hand signals.

Subjects

Following the practice in previous studies [Ouergui *et al.* 2014; Tornello *et al*. 2013], the 10 official Cadet weight divisions were grouped to represent "light" (lightweight; females: 29, 33 and 37 kg; males: 33, 37 and 41 kg), "middle" (middleweight; adolescent females: 41, 44, 47, and 51 kg; adolescent males: 45,49, 53, and 57 kg) and "heavy" (heavyweight; adolescent females: 55, 59 and >59 kg; adolescent males: 61,65 and >65 kg) athletes.

To avoid any potentially confusing factors related to the athletes' proficiency levels, only semifinal and final matches were considered (adolescent females: $n = 22$; adolescent males: $n = 25$). The athletes involved in the qualifying, semifinal and final matches performed all the bouts in a single day. As the data used were images from the public galleries, informed consent was not needed for the study, according to Belmont's Report [National Institutes of Health 1978].

Procedures

In line with previous studies [Matsushigue *et al.* 2009; Santos *et al.*2011; Tornello *et al*. 2013] and to avoid any disagreement between the observers, a single highly experienced taekwondo observational analyst studied all the videos taken from public TV channels. Intra-reliability was checked by scoring a match twice [Tornello *et al.* 2013]. Observational reliability was established in accordance with the literature [Falco *et al*. 2012; Menescardi *et al.* 2012, 2015]) and HOISAN video analysis software [Hernandez-Mendo *et al.* 2012] was used to analyze the videos.

Statistical Analyses

Before the study, the Kolmogorov test revealed the non-normal distribution of all the considered variables. A Kruskal Wallis followed by the Mann-Whitney U test were conducted on SPSS 23.0 (SPSS Inc., Chicago, IL, USA) to detect differences between the duration of activity phases (i.e., fighting, non-fighting, and stoppage), in relation to weight category (i.e., lightweight, middleweight, and heavyweight) and gender (adolescent males and females) and the interaction effect by calculating the differences between weight categories in each gender [Falco *et al.* 2012] and genders in each weight category [Menescardi *et al.* 2012]. The alpha level was set at 0.05 for all the statistical analyses. As non-parametrical tests are based on median and ranks [Nachar 2008], both these statistics were calculated in addition to mean and standard deviation. Effect size *r* was calculated by the formula: $r = Z/\sqrt{N}$. Values of 0.1, 0.3, and 0.5 were considered to have small, moderate, and large effects, respectively [Fritz *et al.* 2012].

Results

The results showed that TMA was characterized by fighting phases of 2.67 ± 2.01 s (mean and standard deviation), non-fighting of 3.27±2.35 s and stoppage phases of 13.28 ± 30.66 s (Table 1).

Gender

The results by gender showed significant differences in fighting (U = 473033.50; p = 0.02; r = 0.05), non-fighting (U = 373095.50; p< 0.01; r = 0.09) and stoppage (U = 52525.00; p = 0.01; r = 0.09) phases, and indicated that females performed longer fighting (2.70 ± 2.05 s), non-fighting (3.43±2.48 s) and stoppage (15.57±35.20 s) phases than males (2.59 ± 1.97 s; 3.07±2.18 s, and 11.54±26.61 s, respectively).

Weight category

The results by weight category indicated no significant differences in fighting phases ($\chi^2_{(2)}$ = 1.26; p = 0.53). However, there were significant differences in non-fighting ($\chi2_{(2)}$ = 10.45; p< 0.01) and stoppage ($\chi2_{(2)}$ = 7.09; p = 0.03) phases. Heavyweights performed longer non-fighting phases than lightweights (U = 146466.00; p = 0.01; r = 0.08) and middleweights (U = 179570.00; p< 0.01; r = 0.08), while middleweights had shorter stoppage phases than heavyweights (U = 38834.50; p< 0.01; r = 0.08).

Weight category x gender

With regard to fighting phases, significant differences between genders were found in heavyweights (U = 45103.50; p< 0.01; r = 0.12), i.e. females performed longer fighting phases (2.84 ± 2.15 s) than males (2.65 ± 2.03 s). Differences emerged in middleweights as regards non-fighting phases (U = 46299.50; p< 0.01; r = 0.21) in which females had longer phases (3.49 ± 2.14 s) than males (2.66 ± 1.69 s). A significant difference in stoppage time was also found in the lightweight category (U = 731.500; p < 0.01; r = 0.28), with longer stoppage phases for females (15.02 ± 25.96 s) than males (9.34 ± 20.04 s) (Table 1).

Table 1. Descriptive statistics (mean duration, standard deviation, in addition to median and rank) of TMA according to the gender and weight category.

	M ± SD	Male			Female			*Differences in gender*	Total		
		Md	*Rank*	*M ± SD*	*Md*	*Rank*		*M ± SD*	*Md*	*Rank*	
Total	Fighting (s)	2.59±1.97	2.08	16.28	2.70± 2.05	2.20	17.44	*	2.67±2.01	2.12	17.48
	Non-Fighting (s)	3.07±2.18	2.48	16.96	3.43±2.48	2.89	35.28	*	3.27±2.35	2.68	35.36
	Stoppage (s)	11.54±26.61	4.12	212.84	15.57±35.20	4.44	211.12	*	13.28±30.66	4.16	212.84
Light Weight	Fighting (s)	2.66±2.08	2.20	16.28	2.53±1.72	2.10	17.44		2.66±2.08	2.12	17.48
	Non-Fighting (s)	2.97±1.63a	2.52	8.00	3.17±2.62ab	2.68	35.28		3.09±2.28a	2.64	35.28
	Stoppage (s)	9.34±20.04	3.62	102.36	15.02±25.96	4.76	96.76	*	12.21±23.27	4.16	102.40
Middle Weight	Fighting (s)	2.69±1.95	2.12	15.48	2.84±2.15	2.32	16.24		2.69±1.95	2.18	16.24
	Non-Fighting (s)	2.66±1.69b	2.24	10.56	3.49±2.14a	2.92	11.68	*	3.08±1.98b	2.56	11.72
	Stoppage (s)	12.13±27.94c	3.88	163.36	15.47±36.94	3.92	210.96		13.56±32.09c	3.88	211.16
Heavy Weight	Fighting (s)	2.65±2.03	1.88	13.36	2.84±2.15	2.20	15.24	*	2.65±2.03	2.04	15.32
	Non-Fighting (s)	3.69±2.92ab	2.76	16.96	3.64±2.64b	3.02	15.76		3.66±2.77ab	2.88	16.96
	Stoppage (s)	11.47±26.74c	4.36	212.84	15.94±36.57	4.58	205.32		13.30±31.64c	4.52	212.84

Note: * show differences between genders (p > 0.05) while similar letters (a,b,c) show differences between weight categories in each column (p > 0.05). Md = Median.

According to weight category and gender, there were no differences in the fighting phases between weight categories in males or females. In the non-fighting phases, significant differences were found between weight categories in males ($\chi 2_{(2)} = 21.43$; $p < 0.01$), in which light and middleweights had shorter phases than heavyweights ([$U = 33214.50$; $p < 0.01$; $r = 0.07$] and [$U = 35462.00$; $p < 0.01$; $r = 0.18$], respectively). Significant differences were also found in females ($\chi 2_{(2)} = 6.96$; $p < 0.03$) where lightweights had shorter non-fighting phases than middleweights ($U = 53592.50$; $p = 0.01$; $r = 0.09$) and heavyweights ($U = 47553.50$; $p = 0.03$; $r = 0.08$). In the stoppage phases there were significant differences only in males ($\chi 2_{(2)} = 6.62$; $p = 0.04$), with middleweights having shorter stoppage phases than heavyweights ($U = 129797.00$; $p = 0.02$; $r = 0.12$).

Discussion

To the authors' knowledge, this is one of the first studies to analyze TMA by weight category and gender in international cadet taekwondo competitors. The main findings of the present study were the different time motion patterns found by gender (females had longer phases than males) and weight category (heavier athletes spent more time in non-fighting activity than others who opt to fight) which could influence their competition E:P ratio and thus their training.

The results obtained show total non-fighting (3.27 ± 2.35 s), fighting (2.67 ± 2.01 s) and stoppage times (13.28 ± 30.66 s) that show some discrepancies with previous studies. Some authors obtained similar E:P ratio (1:1) and activity phases [Santos *et al.* 2011] to our results, while others found similar ratios but longer phase times [Matsushigue *et al.* 2009] and yet others found different ratios (1:7) in adults [Heller *et al.* 1998; Matsushigue *et al.* 2009; Santos *et al.* 2011] and 1:2 in a younger population [Tornello *et al.* 2013]. These discrepancies could be attributable to cadet athletes spending less time studying the opponent and anticipating new attacks because they are less experienced than adults [Tornello *et al.* 2013]. These results could be applied in training by introducing heart rate (HR) control activities to mirror the characteristics of competition. Previous studies [Heller *et al.* 1998; Markovic *et al.* 2008; Matsushigue *et al.* 2009] highlighted the importance of aerobic and anaerobic metabolism during non-fighting phases of 1 to 5 s between two high-intensity actions (fighting phase), as actually occurs in bouts. Coaches should emphasize high-intensity interval training with this time structure (3 s of high-intensity taekwondo techniques interspersed with 3 s of rest or low-intensity activity) to prepare the athlete for the appropriate metabolic and physiological demands.

The analyses by gender found that females had longer fighting, non-fighting and stoppage phases than males. While these results do not agree with those obtained by Santos *et al.* [2014], who found similar phases in males and females, other studies found a different fighting structure. Santos et al. (2014) obtained structures of 1.5 ± 0.3 s of fighting and 14 s of *balancing time* (BT) (synonymous for the total of non-fighting and stoppage phases) in both genders. In our case, the fighting phases are longer, 2.59 ± 1.97 s (Md = 2.08, Rank =16.28) for males and 2.70 ± 2.05 s (Md = 2.20, Rank =17.44) for females, while the balancing time is similar to that of elite athletes [Santos *et al.* 2014]. Our study suggests that females spend more time evaluating their adversary than males and are also more combative than males, as shown by their longer fighting phases. Future studies will be required not only in the observational but also in the physiological field to determine their fighting pattern.

The analysis of E:P ratio by weight category in elite athletes found that heavyweights had longer non-fighting and shorter fighting phases than those in the lighter categories [Santos *et al.* 2011]. On the other hand, Bridge *et al.* [2011] found that heavyweights had longer fighting phases than lightweights and shorter non-fighting phases than middleweights. Although our results do not support these findings, they do agree with those of Tornello *et al.* [2013], who found no differences in fighting by weights. Longer non-fighting phases are revealed in heavyweights than other categories. This could be explained by the heavyweights' higher body mass requiring more energy in fighting phases than the others and therefore a longer rest time than lighter athletes [Santos *et al.* 2011]. In the stoppage phases, middleweights had shorter phases than heavyweights. These phases are normally determined by the referee and used to solve technical problems, warn a competitor, administer first aid to an injured athlete or request a video-replay after a coach objects to a decision [Tornello *et al.* 2013]. Although this phase might not be modified by athletes or coaches, it could be taken into consideration for modifying the performance in future matches and tactics.

As this is the first study to analyze genders differences amongst the different weight categories in taekwondo athletes, it is difficult to compare its findings with previous studies. Our results showed that each weight category had a particular behavior and then the following differences between the genders emerged: female heavyweights had longer fighting phases than males, female middleweights had longer non-fighting phases than males and lightweight females had longer stoppage phases than males. These results suggest that female heavyweights are more combative than males, female middleweights are more conservative than males and female lightweights are more passive than males. In addition, the differences between the weight categories in each gender showed that both male and female heavyweights had longer non-fighting phases than the others, as described above. This shows that the different genders

and weight categories had very different behavior during the first World Cadet Taekwondo Championship, and further studies will be required to determine the prevalence or absence of these patterns in future tournaments.

One of the limitations of the present study is that as the effectiveness of the different behaviors was not analyzed, it is impossible to decide whether the described conservative or combative behavior could have influenced the score obtained by the competitors, and this aspect should be analyzed in future studies. It is important to note that TMA has been shown to be a highly objective and reliable method. As the size effect found in the analysis carried out was small (0.1) [Coolican, 2009], the results should thus be considered to mirror the demands of a competition and indicate that specific training should be given to each gender in the different weight categories.

Practical applications

The TMA results found in the present study indicate that a structure of 3.27 ± 2.35 s of non-fighting followed by 2.67 ± 2.01s of fighting phases (ratio around 1:1) could be applied in preparation activities during training. Coaches should prepare high-intensity interval training with the same time structure (i.e., 3 ± 2 s of high-intensity taekwondo techniques interspersed with 3 ± 2 s of rest or low-intensity efforts) to prepare athletes for the metabolic (aerobic and anaerobic) and physiological demands (high HR) of a bout.

The results also suggest gender differences, that is, females had longer phases (fighting, non-fighting, and stoppage) than males. A 1:1 training structure is therefore recommended for males and females, with phases of 3.07±2.18 and 2.59±1.97 s for males and 3.43±2.48 and 2.70± 2.05 for females. However, males and females do not usually train together but are normally divided into genders and weight categories. In considering both variables, no differences were found in the fighting: non-fighting structure in lightweight, but large differences emerged in the middleweight category, in which males had shorter non-fighting phases than females and heavyweights. Thus, middleweight males are characterized by two and a half s of fighting and non-fighting (fighting: 2.69±1.95; non-fighting: 2.66±1.69) and females have longer phases (fighting: 2.84±2.15; non-fighting: 3.49±2.14). There were also gender differences in heavyweights indicating a three and three and a half s structure of fighting and non-fighting, respectively, in heavyweight females, who had longer phases (fighting: 2.84±2.15; non-fighting: 3.64±2.64) than males (fighting: 2.65±2.03; non-fighting: 3.69±2.92). These results can be applied in taekwondo training, dividing athletes by gender and weight in the cadet category.

If we look at the relation between the fighting and non-fighting phases, an E:P ratio of around 1:1 can be considered as the time spent by cadets in preparing the tactics to be used. It is recommended that athletes should not take the initiative in the match (i.e. should be a counter-attacker), pay attention to the type of attack used by his/her opponent [Falco *et al.* 2014; Menescardi *et al*. 2019] and prepare a pre-determined tactical action, because with this ratio (1:1) the actions are more pre-mechanized than a tactically structured action. It is also recommended that coaches prepare combinations for one of the athletes or interactions between both athletes (attacks and counterattacks) of between 2 and 5 seconds (considering the mean and standard deviation of the fighting phases) in which they could perform around 2-5 actions in a sequence, since taekwondo kicks are extremely fast (taking from 0.74±0.09 to 1.19±0.12 s, depending on the technique used) [Falco *et al.* 2009; Falco *et al.* 2011].

Conclusions

The activity profile in taekwondo cadet competitions was influenced by the competitors' gender and weight category. Four conclusions can be drawn from the present study:

— The duration of the fighting phase is similar in all weight categories.
— The duration of the non-fighting phase is longer in heavyweights than the light and middleweight categories, especially in males. In females, this phase is longer in middle and heavyweights than lightweights.
— The duration of the stoppage phase is longer in the heavyweight category than middleweight, especially in males.
— In general, females have longer fighting phases (especially relevant in the heavyweight category), longer non-fighting phases (especially in the middleweight category), and longer stoppage phases (especially in the lightweight category) than their male counterparts.

It is therefore suggested that training sessions should be tailored to mirror the specific characteristics and requirements of each gender and weight category when planning the intensity and amount of training.

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Analiza czasu ruchu kadetów taekwondo w zależności od płci i kategorii wagowej

Słowa kluczowe: analiza wydajności, mężczyzna, kobieta, klasa wagowa, sporty walki, młody sportowiec

Abstrakt

Cel. Celem pracy była analiza czasu ruchu (faza bez walki, walki i postoju) kadetów w zależności od ich płci (mężczyzna lub kobieta) i kategorii wagowej (lekkiej, średniej i ciężkiej) biorących udział w Mistrzostwach Świata Kadetów Taekwondo 2014.
Metody. Analiza obejmowała 4,535 faz 80 zawodników w 47 półfinałowych i finałowych walkach w pierwszych Mistrzostwach Świata Kadetów WTF w Taekwondo. Przeprowadzono test Kruskala Wallisa i test U Manna-Whitney'a dla porównania par, aby sprawdzić różnice pomiędzy czasem trwania faz aktywności (tj. w czasie bez walki, walki i postoju) w odniesieniu do kategorii wagowej i płci.
Wyniki. Uzyskane wyniki pokazują, że zawodniczki odbywały dłuższe fazy walki, bez walki i postoju niż zawodnicy. W zależności od kategorii wagowej, zawodnicy wagi ciężkiej brali udział w dłuższych fazach bez walki niż zawodnicy wagi lekkiej i dłuższych fazach postoju niż zawodnicy wagi średniej. Zawodniczki w ciężkiej kategorii wagowej odbywały dłuższe fazy walki niż mężczyźni, zawodniczki wagi średniej miały dłuższe fazy walki niż mężczyźni, a zawodniczki wagi lekkiej odbywały dłuższe fazy walki niż zawodnicy ($p \leq 0,05$).
Wnioski. Na profil aktywności w zawodach kadetów taekwondo wpływ miała płeć i kategoria wagowa zawodników. Zawodniczki odbywały dłuższe fazy walki niż mężczyźni, natomiast zawodnicy wagi ciężkiej mieli dłuższe fazy bez walki niż pozostałe kategorie wagowe. Zawodnicy wagi średniej mieli krótsze fazy postoju niż zawodnicy wagi ciężkiej. Wyniki te sugerują potrzebę specjalnego treningu dla obu płci w każdej kategorii wagowej przy planowaniu treningów dla zawodników taekwondo w kategorii kadetów.