Can simulation tasks reproduce the taekwondo match physiological responses?

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Abstract

Background and Study Aim: Using specific training methods is an important aspect in the preparation of taekwondo athletes. The purpose of the present study was the knowledge about physiological responses, during three different training protocols and official taekwondo matches.

Material and Methods: Eleven black-belt taekwondo athletes: age 24 ±5 years; body mass 76.8 ±15.3 kg; height 178 ±0.1 cm and MBI 24.1 ±3.7 kg/m^2) completed a official taekwondo competition and three experimental conditions of training (2 , 4 and 6 *kicks bandal tchagui*, each 10 seconds, respectively) with the same total duration (3 rounds of 2 min with 1 min rest between each round), the physiological variables were measured, blood lactate concentration, heart rate (HR) and rating of perceived exertion (RPE).

Results: For the HR_{peak} a round effect was identified ($F_{1.294;\ 12.936}$ = 59.940; p<0.001, η^2 = 0.857 [large]), with round 2 was superior to round 1 (p = 0.001), round 3 was superior to round 1 (p<0.001) and round 2 (p<0.001). For the blood lactate concentration a round effect was identified ($F_{3;\ 30}$ = 133.441; p<0.001, η^2 = 0.930 [large]), with lower values being observed at pre compared to all post-rounds measurements (p<0.001 for all comparisons).

Conclusions: The taekwondo exercise reached the same heart rate peak and blood lactate concentration that the rates presented during the taekwondo match, therefore, can replicate the physiological response of the official competition. However, it will be necessary to verify the effects of more prolonged periods of these exercises to know if the stress generated is adequate to improve the physical performance.

Keywords: athletic performance • blood lactate concentration • HR zones • rating of perceived exertion

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Bandal tchagui – the main kick applied to score is a semicircle kick.

Taekwondo – *noun* a Korean martial art that resembles karate but also employs a wide range of acrobatic kicking moves [26].

Combat sport – *noun* a sport in which one person fights another, e.g. wrestling, boxing and the martial arts [26].

Martial arts – *plural noun* any of various systems of combat and self-defence, e.g. judo or karate, developed especially in Japan and Korea and now usually practised as a sport [26].

INTRODUCTION

Taekwondo is a modern Olympic combat sport, practised in the five continents around the world [1]. The purpose of the athletes is to obtain a knockout or make a larger number of points, without allowing for opponent's counterattack. During a taekwondo match complex blows, originated mainly of kicks, are executed. The main kick applied to score is a semicircle kick denominated *bandal tchagui* [2]. Recently, different studies have been conducted to increase the knowledge about taekwondo characteristics to improve athletes performance, and most of these investigations have focused on physiological responses [3-7], time-motion [2, 8-10], and training methods [3, 11-16].

Time-motion taekwondo studies provide information about the relationship between high-intensity activities, low-intensity activities, and pauses in high-level competitions [2, 8, 14]. Additionally, the physiological demand during the taekwondo match can be simulated using the time-motion studies as an indicator. Actually, two studies have investigated taekwondo exercise protocols to try to recreate physiological responses of a taekwondo match [3, 17]. Previous studies assessed heart rate and venous blood to describe and compare lactate, glycerol, adrenaline, and noradrenaline during matches and taekwondo exercises [3, 17]. The experimental protocol exercise was composed of action sequences, performed during the taekwondo matches and training in response to audio signals. It was described lower stress rates during the taekwondo exercise, compared with the lactate in the taekwondo match (match: 12.2 ±4.6 mmol.L^{-1} and exercise: 3.6 ±2.7 mmol.L^{-1}), glucose (match: 10.3 ±1.1 mmol.L^{-1} and exercise: 5.9 ±0.8 mmol.L^{-1}), glycerol (match: 143.4 ±49.4 µmol.L^{-1} and exercise: 77.7 ±21.3 µmol.L^{-1}), adrenaline (match: 2.7 ±1.7 nmol.L^{-1} and exercise: 0.6 ±0.2 nmol.L^{-1}), and noradrenaline (match: 14.3 ±9.4 nmol.L^{-1} and exercise: 3.0 ±1.1 nmol.L^{-1}).

Additionally, it has been suggested that coaches, strength and conditioning professionals need to structure taekwondo training sessions considering cardiovascular stress [18, 19]. The taekwondo training elicited maximal heart rate percentage ($HR_{\%max}$) between 65-81%, while intensities between 65-69% of $HR_{\%max}$, were observed during elastic technical combination and step sparring exercise, and classified as moderate. During the activities as pad work, forms, basic techniques, sparring drills, and free sparring reached between 75-81% of $HR_{\%max}$ and were classified as hard [18]. Other studies described $HR_{\%max}$ during taekwondo practice between 80-92% [20, 21]. However, until the present moment, the physiological responses generated during taekwondo exercise protocols do not correspond to the taekwondo match [17].

The purpose of the present study was the knowledge about physiological responses, during three different training protocols and official taekwondo matches. It was hypothesised that taekwondo training protocols can simulate physiological responses presented during the match.

MATERIAL AND METHODS

Participants

Eleven black-belt taekwondo athletes (age 24 ±5 years; body mass: 76.8 ±15.3 kg; height: 178 ±0.1 cm and BMI 24.1 ±3.7 kg/m^2) volunteered to participate in this study and provided written consent after being informed about the procedures and risks associated. No athlete was younger than 18 years old. The athletes were competing in the elite category and practice taekwondo during 12 hours per week. They are free from any lower injury and neuromuscular disorder.

This research was approved by the Institutional Ethics Committee. All the evaluations were realised during the competitive period.

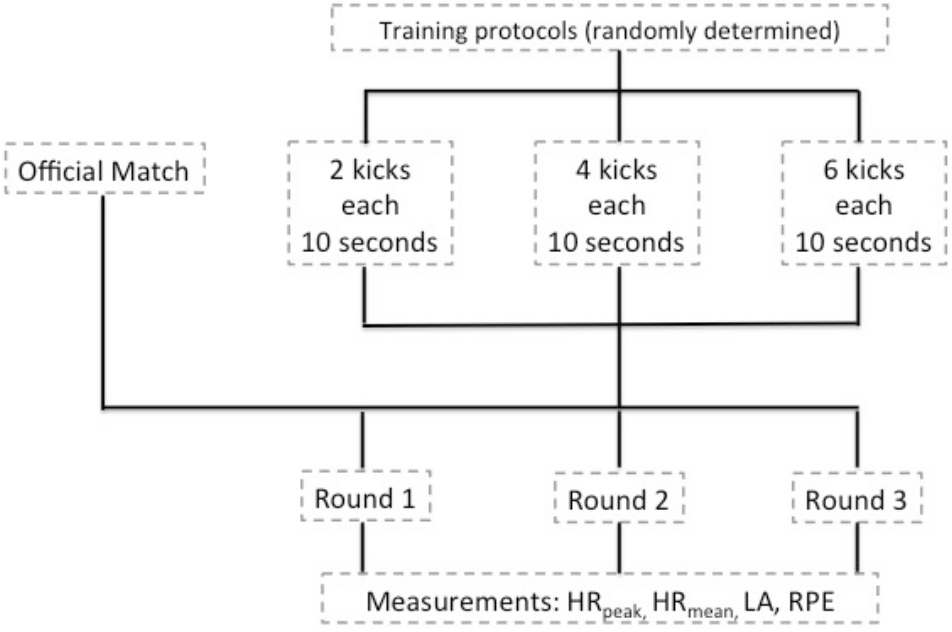

Figure 1. Experimental design.

Experimental Approach

Taking into account the dynamic of this sport and its regulation, three experimental conditions of training were considered in order to seek some similarity in the physiological response presented during the official competition. To organise the three training protocols which are detailed below, it began by defining the duration of the work, in accordance with the provisions of the official taekwondo combat regulation [22]. Straightaway the material to use was determined, a punch bag (Mooto, Korea) fixed with counterbalancing base installing an electronic trunk protector TK-Strike (Daedo, Spain), while an evaluator is holding the punch bag to prevent the loss of stability of the implement.

Official taekwondo competition. The selected competition to evaluate the athletes of this study corresponded to University Naval Tournament of Taekwondo, developed in the region of Valparaiso, Chile. Such competition was realised according to the official combat taekwondo established rules [22], therefore: 3 rounds of 2 min per 1 min rest between each round were fought, obtaining athletes information during the first combat performed. The taekwondo matches were realised in a 'Dojan', occupying an enclosed area with Eva foam floor of 23mm, the average temperature of 18°C and relative humidity of 50%.

Experimental conditions. Three experimental conditions were used during this research to investigate the physiological response. All experimental conditions were composed by the same temporal match structure (each kicks 10 seconds). The taekwondo athlete performed 2 kicks during first; 4 kicks during seconds; 6 kicks during third experimental condition. The experimental conditions were randomly determined and had a time of 48 hours between protocol (Figure 1).

Procedures

Heart Rate (HR). Firstly a heart rate monitor (Polar Team System, Polar, Finland) was put in each subject 10 min before to start the competition. This way we could obtain the HR_{mean}, the HR_{peak} and the $\%HR_{zone}$ with the aim of quantify the training charge and the official competition.

The HR_{peak} was considered as the highest HR achieved during the competition. To determinate the HR zones (HR_{zone}) the classification established by Edwards [23] was used: zone 1 (50-60% of the $HR_{peak)}$; zone 2 (60-70% of the $HR_{peak)}$; zone 3 70-80% of the HR_{peak}; zone 4 (80-90% of the $HR_{peak)}$; and zone 5 (90-100% of the $HR_{peak)}$.

The data were registered in a laptop (Apple MacBook Pro, USA) through the Polar Team

Table 1. Heart rate (bpm) of taekwondo athletes (n = 11) during different experimental conditions (data are presented as a mean and standard deviation).

Official match		Kick number during training protocols [each10 seconds]		
		2	4	6
Round		**HR_{peak} (bpm)**		
1	186 ±13	179 ±11	179 ±10	182 ±9
2^	189 ±11	184 ±10	185 ±10	186 ±9
3^″	191 ±10	188 ±8	187 ±12	188 ±9
Round		**HR_{mean} (bpm)**		
1	170 ±11	156 ±13	157 ±11[a]	161 ±10
2^	179 ±12	171 ±12	170 ±12[a]	175 ±9
3″	180 ±11	174 ±9	174 ±13[a]	174 ±11

HR_{peak}: ^different from round 1 (p = 0.001); ″different from round 2 (p<0.001); HR_{mean}: ^different from round 1 (p<0.001); ″different from round 2 (p<0.001), [a]different from oficial match (p = 0.042).

System Software (Polar, Finland) by trained evaluators who monitored the 3 experimental training conditions and the participation in the official competition.

Blood lactate concentration (LA). In relation with LA in the athletes' blood, these were submitted to 4 blood drawn for each experimental condition, and the competition: the first sample was taken immediately before to start each experimental condition and competition. The following samples were taken immediately after finishing the first, second and third rounds. A portable analyser was used (Lactate pro 2, ArKay, Japan).

Rating of perceived exertion (RPE). The 0-10 RPE Borg scale was used (accepted units) [24]. Each athlete asked concerning his general perceived effort in all experimental conditions, and in the official competition.

Statistical analysis

The data were presented as a mean and standard deviation. The Shapiro-Wilk test was used to verify the normality and Mauchly's test was used to investigate the sphericity. The Greenhouse-Geisser test will be used when necessary. A two-way (round and experimental condition) ANOVA with repeated measurements was used to establish the differences among experimental conditions. The Bonferroni test was used as post hoc ANOVA when a significant difference was identified. The effect size was calculated using eta squared (η^2), and classified using the following scale: small <0.5; moderate 0.5 to 0.8; large >0.8. All analyses were conducted using the alpha = 0.05.

RESULTS

For the HR_{peak} a round effect was identified ($F_{1.294; 12.936}$ = 59.940; p<0.001, η^2 = 0.857 [large]), with round 2 was superior to round 1 (p = 0.001), round 3 was superior to round 1 (p<0.001) and round 2 (p <0.001). No interaction effect was presented to HR_{mean} ($F_{3.191; 31.910}$ = 1.494; p = 0.234, η^2 = 0.130 [small]) but a round ($F_{2; 20}$ = 109.191; p < 0.001, η^2 = 0.916 [large]) and condition ($F_{2.011; 20.112}$ = 6.509; p = 0.007, η^2 = 0.394 [small]) effects were found. Values on round 1 were lower than on round 2 and 3 (p<0.001), and round 2 lower than on round 3 (p<0.001). The taekwondo match was different to the four kicks experimental protocol (p = 0.042) (Table 1, see also Figure 2).

For the blood lactate concentration a round effect was identified ($F_{3; 30}$ = 133.441; p<0.001, η^2 = 0.930 [large]), with lower values being observed at pre compared to all post-rounds measurements (p<0.001 for all comparisons). Additionally, round 1 resulted in lower values compared to rounds 2 and 3 (p<0.001 for both comparisons) (Table 2).

Finally, for RPE round ($F_{1.082; 10.820}$ = 39.053; p<0.001, η^2 = 0.796 [moderate]) and condition effects ($F_{3; 30}$ = 42.874; p<0.001, η^2 = 0.811 [large]) were found. RPE was lower in round 1 compared to rounds 2 and 3 (p<0.001), and round 2 RPE was lower than on round 3 (p<0.001). Moreover, the match condition was lower/higher than the four kicks (p = 0.001) and six kicks conditions (p<0.001). The two kicks condition was lower/higher than the four kicks (p = 0.020) and six kicks (p<0.001) conditions, and the four kicks condition was lower/higher than the six kicks experimental protocol (p = 0.002).

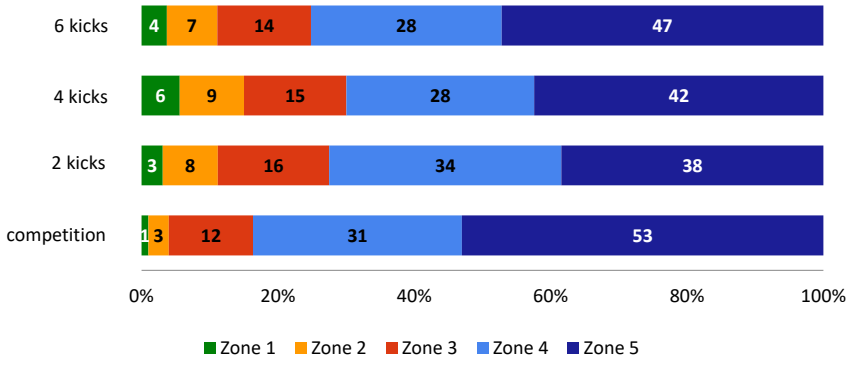

Figure 2. Total time percentage in each HR_{zone} in taekwondo athletes during different experimental conditions (competition means official match).

DISCUSSION

The main results were that the taekwondo exercise reached the same heart rate peak and blood lactate concentration that the rates presented during the taekwondo match. The heart rate peak was observed during the taekwondo match and had the same values as during the 2, 4 and 6 kicks and 10s rest protocol. The RPE was the same between the taekwondo match and the 2 kicks and 10s rest protocol. The protocols suggested can help strength and conditioning coaches to prescribe activities closely and calculate time spent in each HR_{zone} intensity.

The different protocols generate the same cardiovascular stress presented during the taekwondo match. The same HR_{peak} was achieved in all taekwondo exercises and the taekwondo match. Additionally, HR_{mean} was the same between taekwondo match and the exercise conducted using 6 kicks and 10s rest, while the two other protocols (2 and 4 kicks with 10s rest intervals) generated lower cardiovascular stress in the first block compared with the first round during the taekwondo match. Previous studies described that taekwondo practice stresses the cardiorespiratory system between 65-92% HR_{max} [18, 20, 21]. This is an important characteristic to generate cardiorespiratory adaptations and maybe improve taekwondo performances during competitions. However, previous studies report reduced cardiorespiratory stress during the taekwondo training in comparison to the taekwondo match [17]. The protocols applied in the present study can be used to reproduce the cardiorespiratory stress observed during the match and improve the physical fitness of the taekwondo athletes.

Another characteristic that requires attention concerning the cardiovascular system is the time an intensity ($HR\%_{max}$) that causes adaptations can be maintained [25]. Previous studies described the duration over each session in minutes per session of exercises classified as hard (pad work: 20-36 min; forms: 20 min; basic techniques and forms: 26 min; sparring drills: 30 min; free sparring: 6-15 min) [18]. Taekwondo exercises are classified as hard, as for example free sparring, represent only 3.7% of weekly training duration. This is the reason why can be justified the moderate VO_{2max} normally measured in taekwondo athletes [1]. The protocol that generated a larger time in zone four and five was the 6 kicks and 10s of rest. However, to improve the aerobic fitness, it would be necessary to apply many blocks with this duration during the taekwondo practice because the protocol investigated has 6 minutes of duration, and this is a short time to cause adaptations in the cardiovascular system.

The blood lactate concentration generated during the taekwondo exercise did not present differences when compared with the taekwondo match. During different protocols conducted in the present study, an increase was observed in blood lactate concentration when it was compared with round 1. The same characteristic was observed during the match, i.e., rounds 2 and 3 presented a higher blood lactate concentration in comparison with round 1. This kinetic is necessary for exercises with intermittent characteristic, which tries to

Table 2. Blood lactate concentration (mmol.L^{-1}) of taekwondo athletes (n = 11) during different experimental conditions (data are presented as a mean and standard deviation).

Official match		Kick number during training protocols [each10 seconds]		
		2	4	6
Round		mmol.L^{-1}		
1[b]	8.0 ±32	7.5 ±3.3	9.7 ±4.4	9.2 ±2.7
2^ [b]	12.9 ±3.6	11.7 ±4.0	12.3 ±3.0	12.7 ±0.8
3^ [b]	14.0 ±4.2	12.4 ±3.6	14.5 ±3.6	14.1 ±3.3
Pre	4.3 ±1.9	3.8 ±1.7	4.0 ±2.5	3.7 ±2.2

^different from round 1 (p<0.001); **Pre** pre compared; [b]different from **Pre** (p<0.001).

Table 3. Rating of perceived exertion (accepted units) of taekwondo athletes (n = 11) during different experimental conditions (data are presented as a mean and standard deviation).

Official match		Kick number during training protocols [each10 seconds]		
		2	4	6
Round		accepted units		
1	3 ±2	5 ±2	6 ±1[a,c]	8 ±1[a,c]
2^	5 ±2	6 ±2	7 ±1[a,c]	9 ±1[a,c]
3^″	6 ±2	7 ±2	8 ±2[a,c]	10 ±1[a,c]

^different from round 1 (p<0.001),″different from round 2 (p<0.001), [a]different from oficial match (p = 0.001), [c]different from two kicks (p = 0.001).

reproduce the taekwondo match because it is possible to generate the same physiological stress and increase ecological validity of the exercise. A limitation of the present study was not to diversify the high-intensity kicks, but the main purpose of the present study was to generate the same physiological stress without reproducing all technical and tactical variations during the match. Previous studies did not report about reproducing in physiological variables with the use of taekwondo exercises diversity [17].

CONCLUSIONS

The taekwondo exercise reached the same heart rate peak and blood lactate concentration that the rates presented during the taekwondo match, therefore, can replicate the physiological response of the official competition. However, it will be necessary to verify the effects of more prolonged periods of these exercises to know if the stress generated is adequate to improve the physical performance.

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