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HEART RATE AND LACTATE RESPONSES TO TAEKWONDO FIGHT IN ELITE WOMEN PERFORMERS

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Abstract. The purpose of this study was to examine heart rate (HR) and blood lactate (LA) concentration before, during and after a competitive Tae kwon do (TKD) fight performed by elite women performers. Specifically, we were interested to see weather HR and LA responses to competitive fight were greater than to TKD or karate exercises published in scientific literature. Seven international-standard women TKD fighters participated in the study. HR was recorded continuously throughout the fight using Polar Vantage telemetric HR monitors. LA samples were taken before and 3 min after the fight and analysed using an Accusport portable lactate analyzer. At the beginning of the fight, HR significantly increased ($p<0.01$) from pre-fight values of 91.6±9.9 beats min^{-1} to 144.1±13.6 beats min^{-1}. During the whole fight the HR_{mean} was 186.6±2.5 beats min^{-1} and remained significantly elevated ($p<0.01$) at 3 min into recovery. HR values expressed as a percentage of HR_{max} averaged during the whole fight at 91.7±2.6%, respectively. LA concentration significantly increased ($p<0.01$) 3 min after the fight and averaged 82% of LA_{peak} values measured after the VO_2max test. Results of the present study indicate that physiological demands of competitive TKD fight in women, measured by HR and LA responses, are considerably higher than the physiological demands of TKD or karate training exercises. The observed HR and LA responses suggest to us that conditioning for TKD should generally emphasise high-intensity anaerobic exercise.

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Key words: Exercise – Martial arts - Physiology – Anaerobic glycolisis – High-intensity

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Introduction

Tae Kwon do (TKD) is an Olympic sport that requires complex motor skills, tactical excellence and high levels of fitness to excel [11,16,18,26]. In particular, it has been suggested that during TKD competitions, athletes perform 3-5 s bouts of high-intensity exercise alternated with low-intensity periods during which heart rate (HR) can reach levels as high as 100% of maximum HR (HR_{max}) and lactate responses of 11.4 mmol l^{-1} [11]. Metabolic responses to TKD exercise have been scarcely studied, in fact, most of the studies presented in scientific literature dealt with injury patterns in TKD [15,17,26].

Considering the growing interest versus this martial art, it is important to define the metabolic demands of competitive activities in order to provide precise and effective guidelines for physical training of TKD athletes. Nevertheless, in sports characterised by intermittent activities, physiological demands imposed on the athletes during competition cannot be simulated in controlled laboratory settings and hence have to be determined during actual competitions.

Due to the contact nature of TKD, the possibility of studying metabolic responses during competitions are very limited, being restricted HR and limited blood sampling procedures. In particular, HR and blood lactate (LA) measurements represent a simple and cost/effective procedure to study competitive demands since they cause limited disturbance to the athlete. Moreover, although HR and LA measurements are problematic when associated with the intensity of physical stress, in particular in combat sports, they provide valuable information about the physiological demands of a given physical activity. To our knowledge, only few studies examined HR [11] and LA responses to TKD fight [11,14]. Some studies examined HR and oxygen uptake during various forms of Taekwondo [16,24] and karate exercises [12,13,22,23]. In particular, the information on female competitions seems to be limited. The purpose of this study was to measure HR and LA responses during official competitions in female TKD elite athletes. We hypothesized that the HR and LA responses to the actual fight were higher than the ones observed during training in previous studies [13,16,24].

Materials and Methods

Participants: With the Local Ethics Committee approval, 7 international-standard female TKD fighters provided written informed consent and participated in this study. All participants were members of Croatian National Tae kwon do Team and 4 of them have already won medals at European and/or World

Championships in the past 3 years. All of them have trained TKD for at least 8 years. Four different women weight categories (up to 51, up to 55, up to 59 and over 72 kg) were included in the study. Physical characteristics of subjects are presented in Table 1.

Table 1
Physical characteristics of subjects

	Mean ± SD
Age (years)	22.9±3.5
Body mass (kg)	59.8±10.5
Body height (cm)	169.1±6.6
Body fat percentage (%)	14.8±1.7
VO_{2max} (ml kg^{-1} min^{-1})	49.8±2.8
HR_{max} (beats min^{-1})	195.3±4.4
VAT (ml kg^{-1} ·min^{-1})	40.7±3.3
HR_{VAT} (beats min^{-1})	169.9±6.8
LA_{peak} (mmol l^{-1})	14.1±1.1

Laboratory testing procedures: Laboratory assessments were performed 10 days before the National Championship and started with anthropometric measurements. Body mass was assessed to the nearest 0.1 kg using balance beam scale with the athletes wearing minimal clothing. Body height was assessed to the nearest 0.1 cm using fixed stadiometer. Four skinfolds (subscapular, suprailiac, triceps and biceps) were measured using the Harpenden caliper. The percentage of body fat was estimated using the techniques proposed by Durnin and Rahaman [8].

Maximal oxygen uptake (VO_2max) was determined during the continuous incremental test to volitional exhaustion on motorized treadmill (Techno-Gym, Runrace 9600). After a 10 min warm-up and stretching procedure, the work protocol begun with three minutes of walking at 3 $km \cdot h^{-1}$, and then speed was being increased by 1 $km \cdot h^{-1}$ every minute until voluntary exhaustion. Inclination was constant at 1.5º.

Expired air was collected and analyzed by breath-by-breath system (COSMED, Quark b^2, Italy). The system was calibrated immediately before the testing using gases of known concentration. End-of-test criteria included two of the following: 1) volitional exhaustion, 2) achieving a plateau in VO_2 (highest values were

calculated as arithmetic means of the two consecutive highest 30s values), and 3) HR ≥ 90% of age-predicted maximum. Heart rate (HR) was monitored with a Polar Vantage XL (Finland) telemetric heart rate monitor. Individual maximal heart rates (HR_{max}) were taken as the highest HR recorded during the treadmill test. This value was used for the expression of percentage of HR_{max} for the recorded HR values during the fight (see further text).

Ventilatory anaerobic threshold (VAT) was determined non-invasively from the gas exchange parameters. A systematic increase in ventilatory equivalent for O_2 (VE/VEO_2) without an increase in the ventilatory equivalent for CO_2 ($VE/VECO_2$) was used as a marker of VAT [7,19]. HR at ventilatory anaerobic threshold (HR_{VAT}) was also determined.

5 microliters of blood were drawn from the fingertip 3 minutes after the interruption of the VO2max test for determination of maximum blood lactate concentration (LA_{peak}). All samples were taken while the athletes were standing and were analysed with a portable semi-automated lactate analyzer (Accusport®, Bohringer and Mannheim, Germany).

Testing procedures before, during, and after taekwondo fight: A day before the start of the National Taekwondo Championship, all participants, coaches and official judges were informed about the testing procedures, and both coaches and judges gave their approval of the experiment. Each volunteer was asked to wear a chest-belt HR monitor (Polar Vantage XL, Finland) and a wrist receiver for collecting HR data. For safety reasons, a wrist strap was used to cover and protect the HR receiver. HR was sampled in 5sec intervals. The collected HR data were then downloaded to a computer and analysed. Pre and post- competition blood LA values were also determined from a 5 μL sample obtained from the fingertip and analysed for LA concentration by a portable semi-automated lactate analyzer (Accusport®, Bohringer and Mannheim, Germany). After their usual 20-min pre-match warm-up and stretching, each subject sat in a chair for 5 min and initial HR and blood LA were recorded. Two to three minutes later the fight begun. Each subject manually started the recording of the HR at the start of the first round and stopped it immediately after the end of the fight. Final HR and LA were determined 3 minutes after the end of the fight. For reasons of practicality, LA concentrations were not corrected for blood plasma volume changes that may have occurred during the fight [6].

The duration of TKD fight in women was 3x2 min, with 1 min pause between the rounds. However, since judges during the fight usually stop the official timer if there are some longer breaks (eg. injuries, equipment setting), the actual duration

of the rounds is ordinarily longer than 2 min. Therefore, the duration of each round in each fight was monitored using the digital timer. Based on the actual duration of each round and recorded HR values, HR at the start of the fight and mean HR values (HR_{mean}) for each round and for pauses were determined. These HR_{mean} values were also expressed as percentages of HR_{max} recorded during the treadmill test to provide a measure of relative intensity. Rating of perceived exertion (RPE) using 9-point Borg's scale [4] was obtained immediately after each round. Video recordings of each subject were made during the National championship.

Time-motion analysis procedures: The competitions in which the volunteers were involved were video taped and allowed the carry out of a simple time-motion analysis. In particular, two time-motion characteristics which might influence the functional and energy demands of TKD performance were identified: 1) number of kicks that the participant performed in each round, and 2) net fight time (time in which subjects were in contact fight).

Statistical analysis: Descriptive statistics included means and SD. Differences between initial and subsequent HR values of participants were tested using an ANOVA with repeated measures and Scheffè post hoc test when appropriate. Differences between pre- and post-competition LA values were tested using a depended samples *t*-test. Alpha was set at $p<0.05$ level.

Results

The HR and RPE responses to a fight, as well as time-motion characteristics of the fight, are presented in Table 2 and Fig. 1. As expected, at the beginning of the fight, HR significantly increased ($p<0.01$) from pre-fight values of 91.6±9.9 beats min^{-1} to 144.1±13.6 beats min^{-1}. During the whole fight the HR_{mean} was 186.6±2.5 beats min^{-1} and remained significantly elevated ($p<0.01$) at 3 min into recovery. HR values expressed as a percentage of HR_{max} averaged during the whole fight at 91.7±2.6%, respectively.

During the fight, RPE increased over time, with the highest mean values recorded at the end of the third round (Table 2). Similar trend was obtained for the time-motion characteristics, i.e. number of kicks and net fighting time (Table 2).

Table 2
Heart rate (HR), ratings of perceived exertion RPE and blood lactate (LA) responses to a Taekwondo fight, and time-motion characteristics of the fight (Mean ± SD)

	Rest	1st round	2nd round	3rd round	3 min rest
HR_{mean} (beats min^{-1})	91.6±9.9	181.7±5.4	190.4±3.1	192.8±3.0	115.7±5.3
RPE	-	11.2±0.4	12.4±0.6	13.6±1.1	-
LA (mmol lL^{-1})	0.9±0.2	-	-	-	11.7±1.8
Number of kicks (n)	-	7.9±3.2	9.9±1.8	14.3±4.0	-
Net fights (s)	-	16.7±6.2	18.1±4.3	23.5±3.8	-

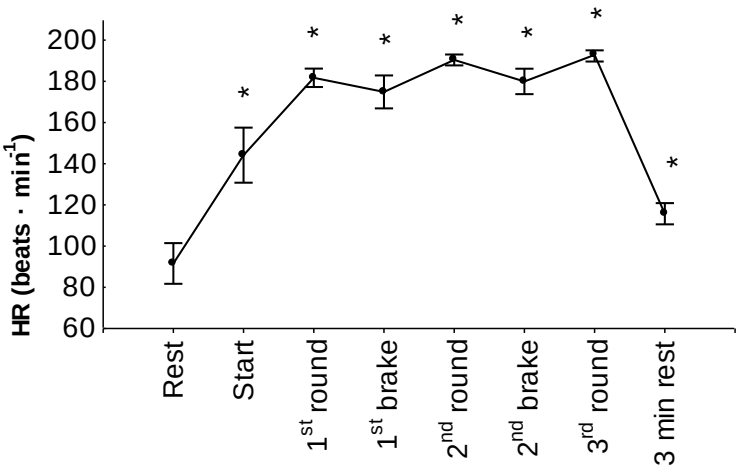

Fig. 1A

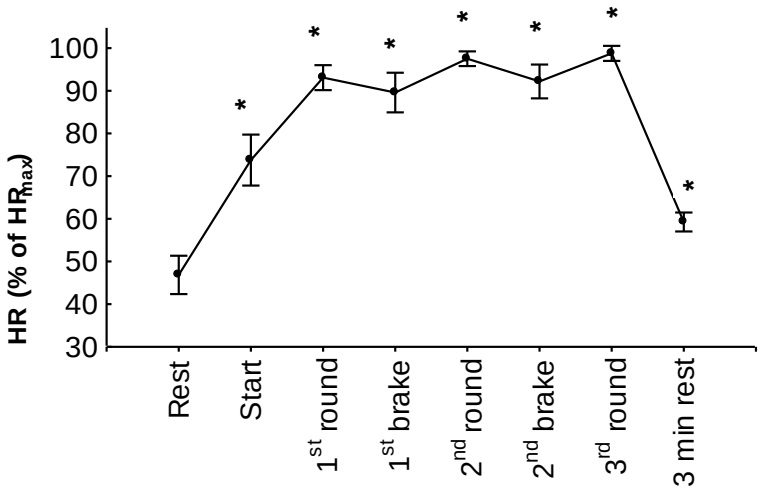

Fig. 1B
Fig. 1
A time plot of HR_{mean} (A) and percent of HR_{max} (B) before, during and after Taekwondo fight in women (*$p<0.05$ when compared to rest)

Compared to the corresponding pre-fight values, LA concentration significantly increased ($p<0.01$) 3 min after the fight (Fig. 2), and averaged 82% of LA_{peak} values measured after the VO_2max test.

Typical example of HR and LA response patterns to a TKD fight is illustrated in Fig. 3.

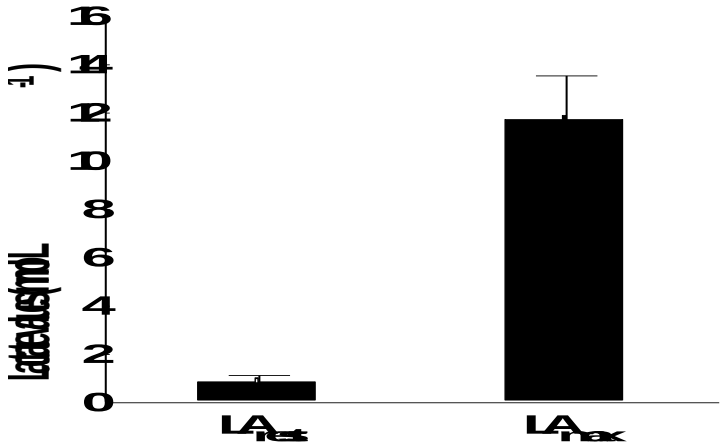

Fig 2
Blood lactate (LA) responses to the taekwondo fight in women (*p<0.05 compared to the LA_{rest})

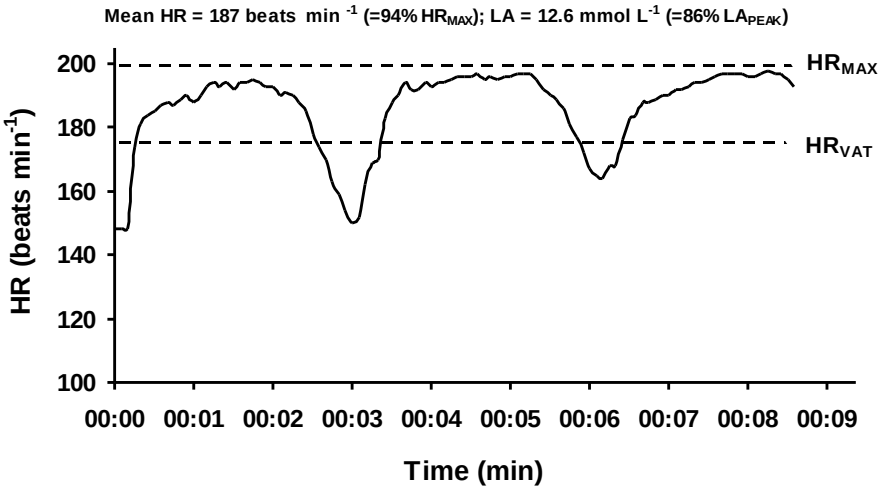

Fig. 3
Heart rate (HR) and blood lactate (LA) responses of the winner of the 59 kg women category in national competition in relation to the laboratory maximum (HR_{max} and LA_{peak}) and ventilatory threshold levels (VAT)

Discussion

It is important to note that the subjects participating in our study showed lower body fat percentages and higher cardiovascular fitness as compared to the athletes studied in similar studies [11,13,20] suggesting that our sample was a true expression of elite performers in TKD.

The increase in HR values from the start of the fight suggest that TKD performance, even if characterized by intermittent patterns of activity, has high physiological demands. It must also be pointed out that, regardless of the intermittent character of the exercise load, HR during TKD fighting oscillated close to maximum values without substantial decrease. In particular, the results suggest that women TKD fight relies mainly on anaerobic metabolism, with athletes spending most of the fighting time close to the maximal relative exercise intensity. However, it should be also considered that due to the particular competitive situation a TKD athlete experiences high levels of arousal, which can be manifested in changes in many physiological variables, including HR [10]. Although the psychological stress of a fighting should not be neglected and could affect HR data interpretation, it should be noticed that our results are similar to the ones previously reported by Heller et al. [11]. Other authors that studied HR responses to TKD or karate exercises [16,23,24,25] reported HR values during the exercises between 80 and 100% of HR_{max}. The present results and previous findings on physiological responses to TKD fight [11,14] provide coaches and athletes with valuable information on intensity of TKD fight that may be used for the preparation of general and specific training programmes.

As we can see from Table 2 and Fig. 1, HR_{mean} gradually increased over time, achieving peak values in third round. Since both time-motion characteristics had similar trend over time, these characteristics might be used as one of the indicators of intensity of the fight. However, further studies with more participants are needed to support this hypothesis. Although RPE responses also increased over time (Table 2), actual RPE values ranged form 11.2 (fairly light) after first round to 13.6 (somehow hard) after third round. These results indicate that subjects underestimated actual intensity of the load determined by HR and LA responses to the fight. A recent study on validity of RPE as indicators of the actual physiological load showed that 15-point scale tends to be more valid than the 9-point scale used in this study [5]. In addition, lowest validity coefficients were reported for studies examining random intermittent activities, like TKD fight [5]. Therefore, the use of 9-point RPE scale as an indicator of intensity of the load in competitive TKD might be questionable.

LA concentration is often used as an indicator of energy production from anaerobic glycolysis [3,21]. As shown in Fig. 2, LA response to TKD fight was very high. The observed LA concentrations after women's TKD fight (11.7±1.8 $mmol \cdot l^{-1}$) were higher than the one reported by Lehman (9.0±1.8 $mmol \cdot l^{-1}$) [14], and similar to the ones reported by Heller at al. for male TKD competitors (11.4±3.2 $mmol \cdot l^{-1}$) [11]. In contrast, LA responses to TKD and karate training exercises were rather low to moderate (1 to 3 $mmol \cdot l^{-1}$) in both, man and women [12,13,24,25]. When expressed as percentages of the maximum attained following VO_2max treadmill test, it was 82% of LA_{peak} values. Similar percentage of LA_{peak} (81%) was also reported by Heller et al. [11]. However, it should be noted that blood LA concentration tends to underestimate muscle LA concentration [2]. Consequently, actual muscle LA response to TKD fight may be even higher. But then, many other factors, including fitness level, psychological stress and environmental conditions may affect LA concentrations. Therefore, caution must be taken when interpreting LA responses to an actual competitive fight [6]. Nevertheless, the observed LA responses suggest to us that conditioning for TKD should generally emphasise high-intensity exercises above anaerobic threshold.

The results of this study clearly indicate that most of the fighting time athletes perform close to the maximum intensity, as estimated by the observed HR values. Furthermore, LA responses suggest that large part of energy needed for performance during woman TKD fight is synthesized by anaerobic glycolysis. Therefore, we suggest that the emphasis in conditioning for TKD should be on performance of high-intensity intermittent exercises. We are not suggesting that aerobic metabolism is not an important factor in TKD. It probably is, and some studies examining the role of aerobic metabolism during high-intensity, short duration intermittent exercises have confirmed it [1,9]. Consequently, intermittent exercise programs alternating high and low-intensity aerobic training should be included in conditioning for TKD.

Conclusions

In summary, results of the present study indicate that physiological demands of competitive TKD fight in women, measured by HR and LA responses, are considerably higher than the physiological demands of TKD or karate training exercises. LA values determined after the fight suggest that the anaerobic metabolism plays a major role in this particular sport. Based on our results and the results of previous research we believe that the emphasis in conditioning for TKD should be placed on high-intensity anaerobic exercises and intermittent activities.

In particular, simulations of competitive actions should be optimized to match the physiological demands of actual competitions. However, since accurate conclusions cannot be made about the precise contribution of anaerobic metabolism to TKD performance, further studies are needed to analyse the acute responses of other physiological indicators (hormonal responses, muscle glycogen depletion, etc.) to TKD fight in both men and women. Finally, further studies should be developed in analyzing different training modalities for maximizing TKD performance, in order to develop precise guidelines for coaches.

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