Taekwondo: Physiological Responses and Match Analysis

Karin A. Matsushigue,[1] Kátia Hartmann,[1] and Emerson Franchini[2]

[1]Department of Physical Education, Pontifical Catholic University of Paraná, Curitiba, Brazil; and [2]Martial Arts and Combat Sports Research Group, School of Physical Education and Sport, University of São Paulo, São Paulo, Brazil

Abstract

Matsushigue, KA, Hartmann, K, and Franchini, E. Taekwondo: Physiological responses and match analysis. *J Strength Cond Res* 23(4): 1112–1117, 2009—The aim of the present study was to determine the time structure and physiological responses during Songahm Taekwondo (TKD) competition and to compare these variables between winner and non-winner athletes. Fourteen men subjects were analyzed. Blood lactate concentration (LA) and heart rate (HR) were determined before and after the match. The match was filmed for the determination of the number of techniques used, the duration of effort and rest periods (RPs), and the interval between high-intensity movements (HM). Post-match LA was 7.5 ± 3.8 mmol·L^{-1}, HR was 183 ± 9 b·min^{-1}, and HM was 31 ± 16 seconds. The mean effort time (8 ± 2 seconds) did not differ from mean interval time (8 ± 3 seconds). Winners used a smaller total number of techniques, but post-match LA or HR did not differ from that of non-winners. In conclusion, the glycolytic metabolism was not the predominant energy source and the physiological responses did not differ between winners and non-winners. Coaches and sports scientists should prepare a technical or physical training session considering the low glycolytic contribution in this sport, hence the training protocol should involve high-intensity movements interspersed with longer RPs to provide the creatine phosphate recovery, with special attention given to the technical quality of TKD skills and not to higher technique volume during a simulation of matches.

Key Words lactate, heart rate, performance, martial arts

Introduction

The definition of the metabolic profile of any sports activity is essential for the determination of the functional conditions necessary for good performance because the quality of the development of technical skills throughout a competition depends on the specific functional and physical preparation for the requirements of the task (27).

During continuous activities, metabolic cost is associated with the intensity and duration of exercise. During activities consisting of alternating exercise and rest periods (RPs), other factors such as the ratio between the duration of exercise and rest, as well as the recovery characteristics also become important, a fact that renders the definition of metabolic cost much more complex in these activities (11). Thus, the measurement of blood lactate concentration and the analysis of the pattern of alternating high- and low-intensity movements during the activity have been adopted as methods for the evaluation of metabolic cost in intermittent sports (24). However, most studies on taekwondo (TKD) have focused on the physical fitness characteristics of athletes or practitioners (13,19,20,30) or on the physiological responses to forms (poomses) and technique execution (4,14,22,29). The few studies available on competitive taekwondo only investigated physiological responses (3,5) or the technical profile during matches (16).

Intermittent activities such as combat sports involve high-intensity movements alternating with low-intensity periods or even periods of inactivity, and are generally considered to be predominantly glycolytic activities. Studies aimed at identifying the metabolic cost in these modalities have analyzed simulated matches of karate (2), judo (6), or TKD (3,5). In the case of TKD, a sequence of 3 simulated matches of 3 minutes each, with a 1-minute RP, was found to result in a constant increase of heart rate (HR) and blood lactate concentration during the sequence, demonstrating the high intensity of the exercise (3). The authors suggested that anaerobic metabolism is important during the attacks, whereas aerobic metabolism predominates during the intervals between attacks. However, the characteristic of alternating periods of exercise and rest and the frequency of high-intensity movements and the total duration of the activity are determinant factors for a better understanding of the meaning of blood lactate and HR.

The project was approved by the Ethics Committee of the Pontifical Catholic University of Paraná (process 444).

Address correspondence to Emerson Franchini, emersonfranchini@hotmail.com.

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The TKD competition of the Songahm Taekwondo Federation (STF) is divided into 3 rounds: weapons, poomse, and sparring, with different intervals between rounds for each competitor. During a championship, which is performed on a single day, the winner athlete executes various sequential matches, with variable time intervals between one match and the other, a fact that in practice results in different match entry conditions between athletes. In addition, it is important to note that studies on TKD have analyzed different styles (3,5,16).

In view of the above considerations, the objective of the present study was to analyze the metabolic profile of athletes during a non-simulated TKD-STF competition by determining HR, blood lactate, and the pattern of technique execution. In addition, the variables obtained were compared between winners and non-winners.

Methods

Experimental Approach to the Problem

The subjects were evaluated during a Brazilian national TKD competition. The categories were, as usual, determined by belt rank and age of the athletes. The competition started with the poomse round, followed by the weapons and sparring rounds and lasted about 2 hours and 20 minutes. Although participation in the 3 rounds of the competition is optional, participation in all 3 was considered to be an inclusion criterion for the study. Thus, all subjects participated in the 3 rounds and were analyzed during the last round, which took place at variable intervals (10–20 minutes) after the previous task, following the sequence determined for the competition. Before the competition, permission for the research procedures during the event was obtained with the National Federation of STF.

Subjects

Fourteen men subjects with the age range from 17 to 27 years were studied after a round of matches in a Brazilian national TKD competition. This competition was their main competition in that year. All subjects were in the black belt rank of the STF style, had more than 2 years of experience with the participation in national and international competitions, and signed a written informed consent form, agreeing with the procedures and publication of the data. The investigation was conducted according to the Helsinki guidelines on human research and the protocol was approved by the local ethics committee.

Procedures

Before the match, a blood sample was obtained from the earlobe for the determination of blood lactate concentration (LA_{pre}) and an HR monitor (model S610; Polar Electro Oy, Kempele, Finland) was positioned for pre-match HR measurement (HR_{pre}), with the subject in the standing position. The whole match was filmed with a digital camera for subsequent analysis and determination of the types of techniques used and the duration of exercise and RPs. According to STF rules, a match lasts a maximum period of 2 minutes or is finished according to the points scored by one of the athletes. In the case under study, all the matches were finished by the criterion of maximal duration and, therefore, all matches completed the duration of 2 minutes. Immediately after the end of the match, HR (HR_{post}) was recorded and another blood sample was obtained from the earlobe (LA_{post}). The blood samples were immediately placed on strips for analysis in a validated portable lactate analyzer (Accutrend; Roche, Mannheim, Germany) (8). Delta lactate (ΔLA) was calculated by subtracting LA_{post} from LA_{pre}.

The images of each match were analyzed for the determination of effort period (EP), RP, ratio between the duration of effort and rest (E:R), time interval between high-intensity movements (HM), and the number of different types of techniques (offensive techniques) performed by each athlete. The EP corresponded to the time interval between the start (or restart) command and subsequent interruption defined by the referee throughout the match. The RP was defined as the time interval between the beginning of each interruption and restarting the match. Thus, each 2-minute match consisted of various effort and RPs for each athlete. For the determination of HM attacks, movements were subjectively classified into categories of high or non–high intensity. High-intensity movements corresponded to techniques that included kicking and jumping: jump round side kick, butterfly kick, jump reverse side kick. On the basis of movements classified as high intensity, the time interval between the end and beginning of the next high-intensity movement was analyzed for each athlete throughout the match and the mean HM was considered to be representative for each athlete. Thus, during

Table 1. Physiological variables before and after the match.*

	HR_{pre} ($b \cdot min^{-1}$)	HR_{post} ($b \cdot min^{-1}$)	LA_{pre} ($mmol \cdot L^{-1}$)	LA_{post} ($mmol \cdot L^{-1}$)	ΔLA ($mmol \cdot L^{-1}$)
Mean ± *SD*	113 ± 25	183 ± 9†	3.1 ± 2.7	7.5 ± 3.8†	4.4 ± 3.5
Range	43–157	166–193	0.8–11.8	2.0–12.7	0.2–9.2

*HR_{pre} and HR_{post} = heart rate before and after the match; LA_{pre} and LA_{post} = blood lactate concentration before and after the match; ΔLA = difference between blood lactate before and after the match.

†Significantly different compared with value before match ($p < 0.01$).

Table 2. Mean number of techniques per athlete and match during a Taekwondo competition.*

Technique	Non-winners	Winners	Total
Punch	4 ± 3	3 ± 1	4 ± 2†
Kicks			
Round side	19 ± 7	11 ± 6‡	15 ± 8
Side	4 ± 2	4 ± 5	4 ± 4†
Jump round side	2 ± 1	0 ± 1	1 ± 1†
Butterfly	1 ± 1	0 ± 0	0 ± 1†§
Reverse side	3 ± 2	1 ± 1	2 ± 2†
Axe	0 ± 1	0 ± 1	0 ± 1†§
Jump reverse side	2 ± 2	1 ± 1	1 ± 2†

*Significantly different from round side kick.
†Significantly different from non-winners.
‡Significantly different from side kick.
§To techniques factor, $p < 0.01$; to winners vs. non-winners factor, $p < 0.05$; and to interaction factor, $p < 0.05$.

this interval, the subjects were resting or were performing moderate- or low-intensity movements. The whole analysis of every match was completed by the same researcher, who was an experienced coach.

Blood samples were analyzed only once as Pinnington and Dawson (23) demonstrated a high reliability (intraclass correlation coefficient [ICC] = 0.995, $p < 0.05$) for duplicate measurements using the same equipment. The ICC of the lactate values was determined in a previous study with judo athletes (9) performing 2 matches (ICC = 0.92, $p < 0.05$). The video analysis followed the STF rules for techniques determination, which is considered to be both objective and reliable as it is used to determine the score. This kind of analysis was used in a previous study with TKD athletes (16) and has been used in other combat sports as judo with an ICC superior to 0.93 for all variables (26).

Statistical Analyses

The association between variables was determined using Pearson correlation analysis. Data were compared between winners and non-winners and between sampling times by the *t*-test for paired samples, considering the interdependence of action between athletes. Comparison between the number of techniques and outcome of the match was done by repeated-measures analysis of variance, assuming sphericity (32). The level of significance was set at 5%. Data are reported as mean and *SD*.

Results

Mean HR and blood lactate concentration before and after the match are shown in Table 1, with a wide variation in these 2 variables being observed before the match. Fighting promoted a significant increase in HR and blood lactate concentration (Table 1). However, a high value of the *SD* and of the range was observed for LA_{post} and ΔLA.

The round side kick was the most frequently applied technique ($p < 0.01$, Table 2), whereas the butterfly spinning kick was only used by 2 athletes. The mean number of techniques per athlete was 27 ± 13 in each match. The mean number of techniques was 19 ± 10 for athletes who won the match and 35 ± 10 for athletes who lost, with this difference being significant ($p < 0.05$). In addition, winners also used significantly fewer high-intensity techniques per match (1 ± 2) than non-winners (4 ± 2) ($p < 0.01$).

In general, a high-intensity technique was performed every 31 ± 16 seconds, with HM tending to be higher among winners than among non-winners ($p = 0.07$) (Table 3), indicating a trend of athletes who won the match to perform fewer intense movements than non-winners. No difference in the physiological variables was observed between winners and non-winners (Table 3).

There was no difference in the duration of the exercise (7.5 ± 1.8 seconds) or rest (7.5 ± 2.6 seconds) periods, with an E:R ratio of 1:1.

Table 3. Physiological responses and high-intensity movements interval in winners and non-winners.*

	HM (s)	HR_{pre} ($b \cdot min^{-1}$)	HR_{post} ($b \cdot min^{-1}$)	LA_{pre} ($mmol \cdot L^{-1}$)	LA_{post} ($mmol \cdot L^{-1}$)	ΔLA ($mmol \cdot L^{-1}$)
Winners	41 ± 17	119 ± 20	181 ± 11	3.4 ± 3.8	7.8 ± 4.4	4.4 ± 3.8
Non-winners	22 ± 9	106 ± 30	185 ± 7	2.8 ± 1.3	7.2 ± 3.4	4.8 ± 3.3

*HM = time interval between high-intensity movements; HR_{pre} and HR_{post} = heart rate before and after the match; LA_{pre} and LA_{post} = blood lactate concentration before and after the match; ΔLA= difference between blood lactate before and after the match.

No significant correlation ($p > 0.05$) was observed between HM and LA_{post}, ΔLA, or HR. There was also no significant correlation ($p > 0.05$) between LA_{post} and the number of high-intensity techniques, LA_{post} and the total number of techniques, ΔLA and the number of high-intensity techniques, ΔLA and the total number of techniques, HR_{post} and the number of high-intensity techniques, or HR_{post} and the total number of techniques. The pre-match variables (HR_{pre} and LA_{pre}) also showed no significant correlation ($p > 0.05$) with the total number of techniques performed or with the number of high-intensity techniques.

Discussion

The main objective of the present study was to obtain measurements of physiological variables and data characterizing the pattern of technique execution in a match during real competition. To our knowledge, this is the first study evaluating athletes during a non-simulated TKD-STF competition.

Pieter and Pieter (21) observed high speeds in TKD techniques applied by athletes of the North American Team, especially during round kick (speed ranging from 6 to 16 $m \cdot s^{-1}$ for different types of kicks). Thus, considering that the technique is applied at a distance of less than 2 m, the time of execution is approximately 0.12–0.31 seconds. In the case of this powerful action, a marked contribution of phosphagens to the energy supply is expected for technique execution. However, metabolic cost resulting from the execution of the techniques depends on the frequency of these techniques throughout the match. In the present study, a low frequency of techniques was observed, which tended to be even lower for subjects who won the match. Athletes who lost the match performed about 3 high-intensity techniques per minute of match, whereas winners performed 1.5 techniques per minute. These values are lower than those observed during simulated karate fighting (3.4 high-intensity actions per minute) (2).

Considering that the duration of an attack starting from its preparation ranges from 1 to 5 seconds (3) and the mean HM observed in the present study was ≅31 seconds, the ratio between the duration of high-intensity movements and the duration of low-intensity movements or inactivity is higher than 1:6. A slightly different value (1:3 to 1:4) has been observed by Heller et al. (13) during match simulations of TDK-International Taekwondo Federation (ITF) in athletes from the Czech National Team. Thus, the 6 times longer RP compared with the intense EP might be sufficient for important recovery of phosphocreatine (PCr) degraded during explosive movement. This hypothesis is supported by the study of Gaitanos et al. (10), in which an RP 5 times higher than the 6-second exercise bout resulted in adequate recovery of PCr, allowing the predominant contribution of phosphagens until the end of 10 repetitions of maximum power cycle ergometer exercise. The predominance of the alactic metabolism during fighting agrees with the small increase in blood lactate concentration observed in the present study. According to Glaister et al. (12), who evaluated exercise protocols with different recovery periods (5:30 vs. 5:10 seconds), the lower lactate concentration observed with the 30-s recovery period is related to the availability of PCr. On the other hand, during the interval between high-intensity movements, the athlete remains in low-intensity activity and the effect of low-intensity exercise on PCr resynthesis is still uncertain, but evidence indicates that active recovery impairs PCr resynthesis (28). In the present study, the E:R ratio between the period of activity and passive rest was only 1:1, with each period lasting about 8 seconds, a time not sufficient for important PCr resynthesis considering the biexponential characteristics of PCr resynthesis (18) and a rate constant of more than 20 seconds (31). However, it should be emphasized that the E:R ratio cited above involves all activities performed, and this ratio increases to 1:6 when high-intensity actions are considered.

Measurement of blood lactate concentrations has been adopted as a simple method for determination of the role of the glycolytic metabolism in energy production during exercise (7). Although lower during intermittent exercise than during continuous exercise at the same intensity, blood lactate concentration has been shown to be sensitive to exercise duration and E:R ratio (1) and is also consistent at the same E:R ratio involving different exercise and rest durations (6:9, 12:18, and 24:36 seconds) (25). The absolute lactate concentration observed at the end of the match might indicate a moderate contribution of the glycolytic metabolism during fighting.

The mean blood lactate concentration observed at the end of the match is higher than both the value measured by Butios and Tasika (5) after 3 rounds of 3 minutes of TKD competition simulation (3.35 $mmol \cdot L^{-1}$) and the value reported by Bouhlel et al. (3) after 3 minutes of TKD match (4.5 $mmol \cdot L^{-1}$), but similar to that observed after the second round of 3 minutes (6 $mmol \cdot L^{-1}$) of competition simulation. However, the blood lactate concentration found for athletes of the present study is lower than those measured by Bouhlel et al. (3) after the third round of 3 minutes (10.2 ± 1.2 $mmol \cdot L^{-1}$), those reported for athletes performing a simulated match according to the ITF norms after 2 rounds of 2 minutes each (11.4 ± 3.2 $mmol \cdot L^{-1}$) (13), and those observed at the end of matches during an Austrian TKD Championship (10.87 ± 1.92 $mmol \cdot L^{-1}$) (17). This difference might be attributed to the different types of competition. Competitions according to the World Taekwondo Federation consist of 3 rounds of 3 minutes each, with a 1-minute recovery period, whereas in the STF style the matches last only 2 minutes. In the study of Bouhlel et al. (3), ΔLA was apparently higher in the third round than in the first and second rounds, indicating higher exercise intensity as determined by the pattern and frequency of movements in the third round. In the present study, all subjects participated in the match after 2 previous rounds of competition, a fact

explaining the higher HR and blood lactate concentration before the match and also the high standard variation of the variables, as well as the higher post-match lactate concentration compared with the first 3 minutes of match in the study of Bouhlel et al. (3) and compared with the three 3-minute rounds reported by Butios and Tasika (5).

Beneke et al. (2) observed a 5.9 $mmol \cdot L^{-1}$ increase in blood lactate after the first karate match of more than 3 minutes, followed by a decrease over the 3 subsequent matches, with a consequent significant reduction in the absolute contribution of the glycolytic metabolism. However, even in the first match, the main energy source was the oxidative system (78%), with the contribution of the glycolytic system being low (6%). Despite an E:R ratio of 2:1, with the exercise period lasting about 18 seconds intercalated with 9 seconds of interruption of the match determined by the referee, the authors observed a predominance of the oxidative system, followed by the phosphagen system (16%). Thus, the small increase of lactate concentration observed in the present study, together with the wide interval between high-intensity movements, suggests that the contribution of the glycolytic system to the total energy required for activity is low in TKD. In addition, the lack of a significant correlation between post-match blood lactate concentration or ΔLA and the number of high-intensity techniques or the total number of techniques used is probably related to the greater importance of the alactic or aerobic metabolism in TKD.

The HR values observed in the present study are higher than those reported in response to different TKD training activities, including sparring drills and free sparring (4), but similar to those reported by Heller et al. (13) who found an HR of 184 ± 6 $b \cdot min^{-1}$ after the first round and of 186 ± 7 $b \cdot min^{-1}$ after the second round (each lasting 2 minutes), and close to those (approximately 10 $b \cdot min^{-1}$) observed during the first 2 minutes of fighting in the study of Bouhlel et al. (3). In addition, the lack of a difference in HR between winners and non-winners agrees with Toskovic et al. (29), who observed no difference in absolute or maximal percent HR when comparing experienced and novice men and women TKD athletes submitted to a typical training session. The same was observed for absolute and relative to maximum oxygen uptake during the session. However, more experienced athletes presented a lower subjective perception of effort.

Interestingly, winners generally performed a smaller number of techniques per match than non-winners, although the matches were won based on the number of points scored, a fact probably reflecting a lower technical quality or a larger number of penalty points received by non-winners. Similar findings have been reported by Kazemi et al. (16). No significant difference between winners and non-winners was observed for the other variables analyzed.

An important result of the present study is that winners used a smaller number of high-intensity techniques and presented the same type of physiological response (lactate concentration and HR) than non-winners, who performed a larger number of this type of techniques. This finding suggests that winners performed these techniques at a higher intensity because other study investigating kung fu have indicated that athletes with a better technical level presented a less pronounced physiological response (15).

Although the exact determination of metabolic contribution throughout a TKD match requires the analysis of the temporal response of metabolic variables throughout the match, the present study indicates that the glycolytic metabolism was not the predominant energy source and that the frequency of techniques applied was low, in addition to showing that winners tend to be more efficient (smaller number of techniques and higher points scored). Despite this higher scoring efficiency, the intensity of the actions of winners was probably higher than that of non-winners, considering that the physiological response of winners was similar to that of non-winners, although they had used a smaller number of techniques.

Practical Applications

The findings of this study suggest that most successful TKD athletes used a lower number of techniques during the match, although they were able to obtain higher points, indicating that a higher technique volume may be not the best strategy to win the match. As their physiological response was similar to that presented by non-winners, it should be hypothesized that each technique was performed at a higher intensity. Another important finding was the 1:1 action to rest ratio, with approximately 8 seconds for each period, and a 1:6 high-intensity movement to rest ratio, suggesting that the PCr stores may be the main source during these actions phases (1–5 seconds), whereas the aerobic metabolism may be responsible for energy supply during the interval between 2 high-intensity actions. Thus, coaches should emphasize high-intensity interval training with this time structure (i.e., high-intensity specific TKD techniques interspersed with 6 seconds of low- to moderate-intensity movements; and interval training with 8 seconds of high-intensity efforts and 8 seconds of rest or low-intensity efforts) to prepare the athlete to be able to handle the metabolic and physiologic demands of the match.

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