Time-Motion Analysis of Elite Male Kickboxing Competition

Ibrahim Ouergui,[1] Nizar Hssin,[1] Monoem Haddad,[2] Emerson Franchini,[3,4] David G. Behm,[5] Del P. Wong,[6] Nabil Gmada,[1] and Ezzedine Bouhlel[7,8]

[1]*Athletic Performance and Physical Rehabilitation Research Unit, High Institute of Sport and Physical Education, Kef, University of Jendouba, Jendouba, Tunisia;* [2]*Sport Science Program, College of Arts and Sciences, Qatar University, Doha, Qatar;* [3]*Martial Arts and Combat Sports Research Group, School of Physical Education and Sport, University of Sao Paulo, Sao Paulo, Brazil;* [4]*Faculty of Sports Sciences, University of Montpellier, Montpellier, France;* [5]*School of Human Kinetics and Recreation, Memorial University of Newfoundland, Newfoundland, Canada;* [6]*Human Performance Laboratory, The Technological and Higher Education Institute of Hong Kong, Hong Kong;* [7]*Laboratory of Physiology, Faculty of Medicine of Sousse, University of Sousse, Sousse, Tunisia; and* [8]*High Institute of Sports and Physical Education (ISSEP) of Ksar Said, University of Manouba, Manouba, Tunisia*

Abstract

Ouergui, I, Hssin, N, Haddad, M, Franchini, E, Behm, DG, Wong, DP, Gmada, N, and Bouhlel, E. Time-motion analysis of elite male kickboxing competition. *J Strength Cond Res* 28(12): 3537–3543, 2014—The objective of the study was to analyze the time structure of high-level kickboxing matches. A total of 45 combats from 2 male World Championships were monitored using a time-motion analysis system. The combat time structure (i.e., high-intensity activity [HIA], low-intensity activity [LIA], and referee breaks or pauses) during competition and weight divisions was determined and compared. Results indicated that the time structures were HIA: 2.2 ± 1.2 seconds; LIA: 2.3 ± 0.8 seconds; pauses: 5.4 ± 4.3 seconds; and 3.4 ± 1.2 seconds between 2 subsequent HIA. The fighting to nonfighting ratio was found to be 1:1. Moreover, the number of HIA and LIA and the time of LIA decreased in latter rounds (e.g., the average number of HIA was 27.1 ± 7.1, 25.1 ± 6.6, and 24.9 ± 6.1, respectively, for rounds 1, 2, and 3), meanwhile the time and number of pauses increased (e.g., the average pause times were 12.8 ± 11.4, 22.3 ± 22.6, and 24.6 ± 23.3 seconds, respectively, for rounds 1, 2, and 3). The activity times did not differ among weight categories. The present results confirm the intermittent nature of kickboxing competition and provide coaches with more information on how to structure training sessions to mimic the physical demands in competition.

Key Words notational analysis, time structure, combat sports, weight categories, combat period

Address correspondence to Dr. Monoem Haddad, monnomtkd@hotmail.com.

28(12)/3537–3543

Journal of Strength and Conditioning Research

Introduction

Full-contact kickboxing is a combat sport requiring complex skills and tactical excellence for success. Combat success and overcoming an opponent requires either obtaining a greater number of points by kicking and punching or by achieving a technical knockout during a typical competition that consists of 3 rounds of 2 minutes with 1-minute recovery between rounds (22,24). Success in kickboxing is associated with physiological (19,24,28), biomechanical (14), and psychological (9) aspects.

Although various methodological approaches (e.g., measuring physiological parameters in simulated combats) have been adopted in a limited number of investigations to examine the physiological responses during kickboxing competitions (19,28), other techniques that could be used to conduct physiological measurements during competition in combat sports are restricted by the rules and regulations of the event (4,27). Therefore, time-motion analysis, a noninvasive performance analysis technique, may provide broader insights into the physical demands of combat sport competitions (e.g., taekwondo) (11). This approach has been recently used in many combat sports to quantify the different activity phases such as in judo (15,18), wrestling (21), taekwondo (4,6,16,23,26), karate (12,13), boxing (8), Muay Thai (5,24), kickboxing (24), Brazilian jiu-jitsu (1), and mixed martial arts (27). These analyses enable the coaches to plan their specific training based on the discipline demands (10). The attractions of this method are its relatively low cost, accessibility, and portability in comparison to other methods (11).

Only 1 previous study (24) has analyzed the time structure of amateur kickboxing matches. The study showed an effort/pause ratio of 1:2 with an average of 6 seconds of effort duration and 12 seconds for pauses (i.e., observation and preparation phases). However, the results of this investigation cannot be generalized to kickboxing matches of the World Association of Kickboxing Organizations (WAKO),

because the previous study used only amateur level kickboxers with a limited number of analyzed combat (only 7 kickboxing competitions).

Therefore, the objective of this study was to measure the time-motion structure of international kickboxing competitions in different weight divisions (light, middle, and heavy categories) and combat periods (i.e., first, second, and third rounds).

Methods

Experimental Approach to the Problem

To evaluate the time structure during high-level kickboxing competitions, videos of matches in the male category of the 2 World Championship competitions (2009 and 2011 World Championship disputed in Lignano, Italy and Dublin, Ireland, respectively) were downloaded from the official Web site of WAKO. The time-motion analyses for the kickboxing World Championship were chosen in an attempt to obtain realistic values for different variables during high-level kickboxing competitions. All competitors were tracked round by round during each combat. Each competition consisted of 3 rounds of 2 minutes with 1 minute of passive rest in between the rounds.

To analyze the activity profile related to the competitor's weight divisions, 12 official senior male weight divisions (i.e., ranging from <51 to >91 kg) were grouped to represent "light" (<51, <54, <57, and <60 kg), "middle" (<63.5, <67, <71, and <75 kg), and "heavy" (<81, <86, <91, and >91 kg) athletes (22), considering the typical distribution of combats during kickboxing competitions. The time structure (the duration and number of sequences of each time variables) was determined and classified into 3 phases: (a) high-intensity activity (HIA): offensive/defensive actions; (b) low-intensity activity (LIA): preparation and observation; and (c) referee pause. This classification was used in previous studies in striking combat sports (4,26). Moreover, the time between consecutive HIAs was identified. In addition, the ratio between the time duration of HIA and the sum of LIA and referee pause's time (i.e., HIA/[LIA + pause]) was calculated.

Subjects

Eighty-four senior male kickboxers participated in 45 combats in the 2 WAKO full-contact World Championships in Lignano ($n = 44$), Italy (2009) and in Dublin ($n = 40$), Ireland (2011). Six athletes took part in 2 matches. The age category of senior athletes participating in full-contact combats was above 18 years. Forty-five combats and a total of 135 rounds provided by all grouped weight divisions (light: 39, middle: 48, and heavy: 48 rounds) were analyzed. As Morley and Thomas (20) affirmed that there are no ethical issues in analyzing or interpreting data obtained in secondary form and which are not generated by experimentation, we ensured anonymity and confidentiality by replacing the athletes' personal identification by a code. The local university ethics committee approved the study.

Procedures

A single investigator, who was highly experienced in and familiar with kickboxing competitions, analyzed all videos to determine the time spent and the duration of each variable (i.e., HIA, LIA, and referee's pause). To avoid interobserver variability, a single observer scored all the combats. The single observer responsible for the analysis in our study followed strictly the recommendations reported in previous studies about time-motion or technical-tactical analyses in kickboxing (22,24) and other striking combat sports such as taekwondo (23) and boxing (8). To verify the reliability, a total of 69 rounds were randomly chosen and reanalyzed using the Nero ShowTime program (version 2; Toshiba Samsung Storage Technology Corporation, Tokyo, Japan) with 7 days (27) of separation after the first observation. Reliability was verified using intraclass correlation coefficients (ICCs). The ICC for all variables was 0.99, 0.99, and 1 for HIA, LIA, and referee breaks/pauses, respectively, which represents a high reliability profile for the evaluator conducting the combat analysis. Thus, considering the high intra-observer reliability found for our analyst, the results found can be considered reliable.

To elaborate the time-motion system, several kickboxing combats from the World Championship event were initially examined to identify the typical activities and activity phases as used in other studies (4,6). A time-motion system was subsequently developed considering these initial observations (Table 1). To allow a comprehensive appraisal of the activity profiles, individual activities were recorded and classified.

The following criteria were adopted to quantify the occurrence and duration of HIA, LIA, and referee pause variables with precision:

a. The HIA was described as the phase when fast movements were performed to gain a specific position, to defend a favorable position by the opponent, or in an attempt to strike the opponent with power. The HIA was considered when 1 foot or hand moved to initiate the attack. In turn, HIA phase time was considered finished when (i) the foot/hand that delivered the last kick/punch of the action returned to the floor/guard, (ii) the punching or blocking limb was retracted, (iii) a "knockdown" followed the technique, or (iv) the referee used the stop hand signal.
b. The LIA was considered when stable positions or movements (e.g., foot work: step, slide, bounce; deceptive movements: foot, head/body, or hand feint) requiring little effort to maintain low-speed displacements or movements without opposition.
c. Referee pause was considered when stoppage time was initiated by the referee's "break" hand signal or if a competitor was knocked to the ground. Stoppage time ceased on the referees hand signal to "begin."

Statistical Analyses

All statistical tests were processed using SPSS software (version 15.0; SPSS, Inc., Chicago, IL, USA). Mean and *SD*

Table 1. Classification of kickboxing activities.

High-intensity activity	Low-intensity activity	Pause referee
Punch	Foot work	Referees general break
		knocked down
Jab-cross (straight punch)	Stand	
Hook	Bounce	Injury
Uppercut	Slide	Penalty
Kick	Step	
Roundhouse kick	Turn	
Front kick	Active movements	
Axe kick	No interaction	
Side kick	Feint	
Jumping and spinning kicks	Deceptive movements (Foot, head/body, or hand feint [lead or rear])	
Sweeping		
Defense		
Block/parry		
Slip left/right		
Role clockwise/ anticlockwise		
Foot defense		

were calculated for the selected variables. A 2-way (3 weight categories: light, middle, and heavy × 3 rounds: first, second, and third) mixed model analysis of variances with repeated measures in the second factor (i.e., round number) was used to compare time and number of HIA, LIA, pause periods, ratio between high-intensity actions and the sum of LIA and referee pause's time, and the time interval between consecutive HIA. For all measured variables, the sphericity estimated was verified according to the Mauchly's W test, and the Greenhouse-Geisser correction was used when necessary. When a difference was found, a Bonferroni post hoc test was applied. Effect sizes were calculated for each output and the following scale was used for the interpretation of the effect size: trivial <0.2;

Table 2. Time duration of each high-intensity action, low-intensity action, stoppage combat phase in kickboxing matches ($n = 135$ rounds).*

	HIA (s)	LIA (s)	P (s)	HIA/(LIA + P) ratio	HIA-HIA (s)
Light-weight category					
Round 1	1.7 ± 0.4	2.3 ± 0.6†	6.0 ± 4.7	0.6 ± 0.1	3.1 ± 0.8
Round 2	1.9 ± 0.6	2.0 ± 0.6	4.9 ± 3.2	0.7 ± 0.2	3.0 ± 0.8
Round 3	2.0 ± 0.7	2.1 ± 0.4	4.9 ± 3.1	0.6 ± 0.2	3.3 ± 1.5
Middle-weight category					
Round 1	2.3 ± 1.7	2.5 ± 0.7†	4.4 ± 4.9‡	0.8 ± 0.6	3.3 ± 1.3
Round 2	2.6 ± 2.1	2.4 ± 1.0	5.6 ± 6.2	0.8 ± 0.6	3.8 ± 1.3
Round 3	2.3 ± 1.1	2.3 ± 0.6	5.1 ± 3.3	0.7 ± 0.4	3.4 ± 0.9
Heavy-weight category					
Round 1	2.1 ± 0.8	2.5 ± 1.0†	5.0 ± 3.1‡	0.7 ± 0.4	3.3 ± 1.5
Round 2	2.3 ± 1.0	2.2 ± 0.7	7.0 ± 6.3	0.7 ± 0.3	3.6 ± 1.3
Round 3	2.5 ± 0.9	2.0 ± 0.9§	5.8 ± 4.1	0.8 ± 0.3	3.7 ± 1.5
Average of all round 1	2.1 ± 1.2	2.4 ± 0.8†	5.1 ± 4.3‡	0.7 ± 0.4	3.2 ± 1.2
Average of all round 2	2.3 ± 1.5	2.2 ± 0.6	5.9 ± 5.5	0.7 ± 0.4	3.5 ± 1.2
Average of all round 3	2.3 ± 0.9	2.1 ± 0.7	5.2 ± 3.5	0.7 ± 0.3	3.5 ± 1.3
Average of 3 rounds	2.2 ± 1.2	2.2 ± 0.7	5.4 ± 4.5	0.7 ± 0.4	3.4 ± 1.2

*HIA = high-intensity actions; LIA = low-intensity actions; P = pause; HIA-HIA = interval time between 2 consecutive high-intensity actions.
†Significantly different from rounds 2 and 3 ($p < 0.001$).
‡Significantly different from rounds 1 ($p = 0.036$) and round 3 ($p = 0.005$).
§Significantly different from round 1 from other categories and own category ($p \leq 0.05$).

Table 3. Total time duration of high- and low-intensity actions and pause times during each round in kickboxing matches ($n = 135$ rounds).

	High-intensity actions (s)	Low-intensity actions (s)	Pause (s)
Light-weight category			
Round 1	48.9 ± 6.5	65.7 ± 6.8*	15.8 ± 11.8
Round 2	51.3 ± 8.9	58.0 ± 13.1	20.4 ± 12.0
Round 3	52.1 ± 10.8	60.8 ± 9.2	27.9 ± 28.6
Middle-weight category			
Round 1	54.5 ± 25.1	66.1 ± 11.6*	10.2 ± 10.6†
Round 2	51.1 ± 14.3	59.3 ± 13.5	23.1 ± 32.3
Round 3	51.3 ± 14.1	60.6 ± 14.2	16.2 ± 11.9
Heavy-weight category			
Round 1	50.6 ± 11.4	63.5 ± 11.3*	13.1 ± 12.1†
Round 2	51.8 ± 11.3	56.6 ± 13.7	23.1 ± 16.8
Round 3	54.9 ± 11.5	48 ± 17.1‡	31.1 ± 26.4
Average of all round 1	51.6 ± 17.0	65.1 ± 10.2*	12.8 ± 11.4
Average of all round 2	51.4 ± 11.7	58.0 ± 13.2	22.3 ± 22.6
Average of all round 3	52.7 ± 12.2	56.5 ± 15.0	24.6 ± 23.3

*Significantly different from round 2 and 3 ($p < 0.001$).
†Significantly different from round 1 ($p = 0.036$) and round 3 ($p = 0.005$).
‡Significantly different from round 1 from other categories and own category ($p \leq 0.05$).

small 0.2–0.6; moderate 0.6–1.2; large 1.2–2.0; and very large >2.0 (7). Statistical significance was set at $p \leq 0.05$.

Results

Tables 2 and 3 illustrate the mean and total time athletes from different weight categories spent performing HIA, LIA, and pause periods during the matches, whereas Table 4 presents the number of these activities.

There was no main effect of weight categories ($F_{2,42} = 0.09$; $p = 0.915$; $\eta^2 = 0.004$) and rounds ($F_{2,84} = 0.30$; $p = 0.740$; $\eta^2 = 0.007$) on time duration of each activity (Table 2). Likewise, no interaction effect was observed ($F_{2,84} = 0.80$; $p = 0.527$; $\eta^2 = 0.04$). However, there was a main effect of round on the number of high-intensity actions ($F_{2,84} = 5.63$; $p = 0.005$; $\eta^2 = 0.12$) with higher values in the first compared with the second ($p = 0.026$; Table 3) and third rounds ($p = 0.036$). No main effect of weight category ($F_{2,42} = 1.74$; $p = 0.319$; $\eta^2 = 0.05$) or interaction ($F_{2,84} = 0.45$; $p = 0.772$; $\eta^2 = 0.02$) was found on the number of each activity.

There was a main effect of round ($F_{2,84} = 13.05$; $p < 0.001$; $\eta^2 = 0.24$) and an interaction effect between round and weight category ($F_{4,84} = 2.50$; $p = 0.048$; $\eta^2 = 0.11$), but no effect of weight category ($F_{2,42} = 1.45$; $p = 0.247$; $\eta^2 = 0.06$) on time of low-intensity actions (Tables 2 and 3). A longer time of low-intensity actions were performed in the first as compared with the other 2 rounds ($p < 0.001$ for both comparisons).

Table 4. Number of high- and low-intensity actions and pause in kickboxing matches ($n = 135$ rounds).*

	Number of HIA	Number of LIA	Number of pause
Light-weight category			
Round 1	28.8 ± 6.5†	30.6 ± 6.9‡	2.8 ± 2.4§
Round 2	27.8 ± 5.5	30.5 ± 6.3	4.4 ± 2.3
Round 3	27.0 ± 5.2	29.8 ± 6.1	5.5 ± 3.1
Middle-weight category			
Round 1	26.5 ± 7.8†	28.2 ± 7.8‡	1.8 ± 1.4§
Round 2	23.7 ± 7.6	26.2 ± 8.0	3.2 ± 2.6
Round 3	24.5 ± 6.2	26.8 ± 6.6	3.1 ± 2.4
Heavy-weight category			
Round 1	26.2 ± 6.8†	28.4 ± 7.8‡	2.3 ± 1.4§
Round 2	24.5 ± 6.0	27.1 ± 6.7	4.1 ± 2.1
Round 3	23.5 ± 6.7	25.1 ± 7.3	4.6 ± 3.0
Average of all round 1	27.1 ± 7.1†	29.0 ± 7.4‡	2.2 ± 1.8§
Average of all round 2	25.1 ± 6.6	27.8 ± 7.2	3.9 ± 2.3
Average of all round 3	24.9 ± 6.1	27.1 ± 6.8	4.3 ± 2.9

*HIA = high-intensity actions; LIA = low-intensity actions.
†Significantly different from round 2 ($p = 0.026$) and round 3 ($p = 0.036$).
‡Significantly different from round 2 and round 3 ($p = 0.032$).
§Significantly different from round 2 and round 3 ($p < 0.001$).

The number of low-intensity actions also differed across rounds ($F_{2,84} = 3.59$; $p = 0.032$; $\eta^2 = 0.08$), with lower values in the third as compared with the first round ($p = 0.025$; Table 4). No main effect of weight category ($F_{2,42} = 1.19$; $p = 0.316$; $\eta^2 = 0.05$) or interaction ($F_{2,84} = 1.07$; $p = 0.379$; $\eta^2 = 0.05$) was found for this variable.

The time of the pauses also differed across rounds ($F_{2,84} = 5.42$; $p = 0.006$; $\eta^2 = 0.11$), being lower in the first as compared with the second ($p = 0.036$) and third rounds ($p = 0.005$) (Table 2). No effects of weight category ($F_{2,42} = 0.90$; $p = 0.416$;

$\eta^2 = 0.04$) or interaction ($F_{2,84} = 1.01$; $p = 0.407$; $\eta^2 = 0.05$) were found for this variable.

The number of pauses also differed among rounds ($F_{2,84} = 17.83$; $p < 0.001$; $\eta^2 = 0.30$), with lower values in the first as compared with the other 2 rounds ($p < 0.001$ for both comparisons). No effects of weight category ($F_{2,42} = 2.44$; $p = 0.099$; $\eta^2 = 0.10$) or interaction ($F_{2,\ 84} = 0.78$; $p = 0.541$; $\eta^2 = 0.04$) were found for this variable.

There was no effect of weight category ($F_{2,42} = 0.06$; $p = 0.946$; $\eta^2 = 0.003$), round ($F_{2,84} = 0.76$; $p = 0.473$; $\eta^2 = 0.02$), or interaction effect ($F_{2,84} = 1.08$; $p = 0.371$; $\eta^2 = 0.05$) on the ratio (HIA/[LIA + pause]), which was 1:1 for all weight categories and combat rounds (Table 2).

In the same manner, the mean interval time between consecutive HIA did not differ among weight categories ($F_{2,42} = 0.39$; $p = 0.682$; $\eta^2 = 0.02$; Table 2) or rounds ($F_{2,84} = 0.47$; $p = 0.629$; $\eta^2 = 0.01$), and no interaction effect was found ($F_{2,84} = 0.85$; $p = 0.496$; $\eta^2 = 0.04$).

Discussion

This study is the first to analyze the activity profile of WAKO international kickboxing competitions across weight categories and combat rounds. Results from this study indicated that the activity profile was modulated by the combat period (rounds). In fact, the highest time of low-activity actions and the highest number of sequences of high- and low-intensity actions were obtained in the first round as compared with other rounds. Also during the first round, the lowest values for pause durations and sequences number were recorded. Weight categories did not affect the time of different activities. For ratios and time interval between 2 consecutive high-intensity activities, values did not differ among weight categories and rounds.

The overall combat data presented in this study highlighted the intermittent activity pattern of international level kickboxing competition. An average of 2.2 ± 1.2 seconds of fighting activities (i.e., HIA) was typically interjected with 2.2 ± 0.7 seconds of nonfighting activities (i.e., LIA). Furthermore, 5.4 ± 4.5 seconds of referee pause and a mean time of 3.4 ± 1.2 seconds were obtained as the interval time between 2 subsequent high-intensity activities in all the combat matches (Table 2).

Bridge et al. (4) reported different mean time results for different activity phases (e.g., fighting time was 1.7 ± 0.3 seconds, preparatory time 6.4 ± 2.1 seconds, nonpreparatory time 3.0 ± 0.6 seconds, referee stoppage time 2.8 ± 0.9 seconds) in international taekwondo competition. These results highlight the differences between combat sports in terms of activity phases despite their technical similarities (i.e., offensives kick techniques).

In this study, these periods resulted in a fighting to nonfighting ratio of 1:1. Despite the findings of Matsushigue et al. (16) who reported a similar effort-pause ratio during taekwondo competition, results of this study are not in-line with other studies in kickboxing, Muay Thai (24), karate kumite (3), and taekwondo (4,26), which found ratios ranging from 1:2 to 1:6. Likewise, Davis et al. (8) reported an activity-to-break ratio of 9:1 (not including breaks between rounds) in boxing combats.

These differences can be attributed to the specificity of the sport. The technical and tactical aspects and rules of kickboxing are different from the rules of other combat sports that can influence the combat's rhythm (e.g., knock-out system vs. control system, duration of match).

In the same context, the length of LIA relative to the intense effort actions (i.e., high-intensity actions) may be insufficient for the full recovery of phosphocreatine (PCr) degraded during explosive movements (17). This result can be explained by the short period of recovery between successive high-intensity actions, which is not long enough to provide adequate oxygen consumption to allow for a high quantity of PCr resynthesis degraded during exercise (17). Additionally, during the interval between high-intensity movements (~3.4 seconds), the athlete remains in LIA (i.e., active displacements, bounce, slide) instead of passive recovery, which could impair PCr resynthesis (25).

The percentage of fighting (i.e., offensive and defensive actions) and nonfighting activities (i.e., low-intensity actions with pause time) in kickboxing were ≈40 and 60%, respectively, during all rounds of combats regardless to weight categories. The findings of this study are not similar to those of Cappai et al. (5), who demonstrated that Muay Thai combat matches had an average of about 60% of the time of a round spent in fighting (i.e., clinches or attacks at distance), whereas about 40% was spent in preparation phases. These findings show the difference that may exist between combat sports in terms of activity phases despite their high technical similarities (8).

The assessment of the data across rounds illustrated that the activity profile was modulated by the combat period with a decrease in time of low-intensity actions, sequences and number of high-intensity actions and LIA. However, an increase in the sequences number and time of referee pauses across combat was observed. Similar results were found in a previous study (4) analyzing taekwondo combats with significant reductions in the preparatory time across rounds. Contrary to the results of this study, Santos et al. (23) found that the ratio between attack time and skipping time in high-level taekwondo matches was higher in round 3 than in round 1 or 2, which shows an increase in the combat rhythm due to the attempts made by athletes being defeated to try to increase the rate of their attacks to win the match.

Besides, the decrease in time of low-intensity actions, sequences and number of high- and low-intensity actions noticed in this study suggests that this decrease may be due to fatigue, as explained by Ashker (2) in boxing contests. However, an increase in referee intervention was observed from rounds 1 to 3. This fact can be explained by the increase in the number of clinches applied, especially by those winning the match, who try to block the offensive

actions of their opponents. Likewise, the athletes being defeated try to attack more to win the match. Although the time of high-intensity activities remaining unchanged across rounds, the decrease in sequence number of high-intensity actions showed that the length of each high-intensity sequence increased across rounds 2 and 3. This increase in duration of high-intensity sequences may be explained by the fact that kickboxers tend to use combined actions (i.e., 2 or more punches/kicks or punch and kicks combinations) rather than using single techniques (i.e., 1 punch or isolated kick) to create uncertainty for the opponent by achieving different legal targets. However, the decline of low-intensity actions during the rounds 2 and 3 shows that kickboxers in round 1 probably used a strategy based on the observation of opponent's movements before initiating attacks.

In this study, the activity changes identified across rounds highlighted the importance of specific kickboxing training sessions using specific movements (e.g., offensives techniques and combinations) and the fighting/nonfighting ratio that better mirrors the activity structure of WAKO international kickboxing combats.

The activity profile of combat was not modulated by the competitors' weight category. Disparate results were found by Bridge et al. (4) who demonstrated the modulation of the activity profile during international taekwondo competitions by weight categories. The authors (4) highlighted the predominance of fighting activity for heavyweights and preparatory activity and the least frequent exchanges for feather weights. Likewise, during the 2007 taekwondo World Championship, Santos et al. (23) found that the heaviest weight divisions (>78 kg) exhibited a lower average attack time, lower summed attack time, lower attack numbers, and higher average skipping time than lighter weight divisions (<58 kg). However, no significant differences across weight divisions were found during the 2008 Taekwondo Beijing Olympic Games (23).

Practical Applications

The present findings provide additional support to help coaches to plan conditioning sessions for kickboxers based on combat demands. Coaches and fitness coaches should therefore structure their training plan including a work to rest ratio of 1:1, which better corresponds to the specific activity structure of high-level kickboxing combats. Moreover, interval training should include specific kickboxing drills using specific techniques, either single or combined, for 2–4 seconds interspersed with 3–5 seconds of low- or moderate-intensity movements (e.g., foot work such as bounce, slide, step, and turn) to enhance physical abilities of kickboxers and then increase the frequency of their attacks and thus maintaining a high level of activity rate across rounds. Finally, results of this study may present relevant constructs for the validity of a kickboxing specific test for the assessment of kickboxers' physical condition.

References

1. Andreato, LV, Franchini, E, de Moraes, SMF, Pastório, JJ, Silva, DF, Esteves, JVDC, Branco, BHM, Romero, PV, and Machado, FA. Physiological and technical-tactical analysis in Brazilian jiu-jitsu competition. *Asian J Sports Med* 4: 137–143, 2013.
2. Ashker, SE. Technical and tactical aspects that differentiate winning and losing performances in boxing. *Int J Perform Anal Sport* 11: 356–364, 2011.
3. Beneke, R, Beyer, T, Jachner, C, Erasmus, J, and Hütler, M. Energetics of karate kumite. *Eur J Appl Physiol* 92: 518–523, 2004.
4. Bridge, CA, Jones, MA, and Drust, B. The activity profile in international taekwondo competition is modulated by weight category. *Int J Sports Physiol Perform* 6: 344–357, 2011.
5. Cappai, I, Pierantozzi, E, Tam, E, Tocco, F, Angius, L, Milia, R, Squatrito, S, Concu, A, and Crisafulli, A. Physiological responses and match analysis of Muay Thai fighting. *Int J Perform Anal Sport* 12: 507–516, 2012.
6. Casolino, E, Lupo, C, Cortis, C, Chiodo, S, Minganti, C, Capranica, L, and Tessitore, A. Technical and tactical analysis of youth taekwondo performance. *J Strength Cond Res* 26: 1489–1495, 2012.
7. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates, 1988.
8. Davis, P, Wittekind, A, and Beneke, R. Amateur boxing: Activity profile of winners and losers. *Int J Sports Physiol Perform* 8: 84–91, 2013.
9. Devonport, TJ. Perceptions of the contribution of psychology to success in elite kickboxing. *J Sports Sci Med* 5: 99–107, 2006.
10. Haddad, M, Chaouachi, A, Wong, DP, Castagna, C, and Chamari, K. Heart rate responses and training load during nonspecific and specific aerobic training in adolescent taekwondo athletes. *J Hum Kinet* 29: 59–66, 2011.
11. Hughes, M and Franks, I. *The Essentials of Performance Analysis: An Introduction*. New York, NY: Routledge, 2007.
12. Laird, P and McLeod, K. Notational analysis of scoring techniques in competitive men's karate. *Int J Perform Anal Sport* 9: 171–187, 2009.
13. Lapresa, D, Ibáñez, R, Arana, J, Garzón, B, and Amatria, M. Spatial and temporal analysis of karate kumite moves: Comparative study of the senior and 12-13 year old groups. *Int J Perform Anal Sport* 11: 57–70, 2011.
14. Machado, SM, Osório, RAL, Silva, NS, and Magini, M. Biomechanical analysis of the muscular power of martial arts athletes. *Med Biol Eng Comput* 48: 573–577, 2010.
15. Marcon, G, Franchini, E, Jardim, JR, and Barros, NTL. Structural analysis of action and time in sports: Judo. *J Quant Anal Sports* 6: 1–10, 2010.
16. Matsushigue, KA, Hartmann, K, and Franchini, E. Taekwondo: Physiological responses and match analysis. *J Strength Cond Res* 23: 1112–1117, 2009.
17. McMahon, S and Jenkins, D. Factors affecting the rate of phosphocreatine resynthesis following intense exercise. *Sports Med* 32: 761–784, 2002.
18. Miarka, B, Panissa, VLG, Julio, UF, del Vecchio, FB, Calmet, M, and Franchini, E. A comparison of time-motion performance between age groups in judo matches. *J Sports Sci* 30: 899–905, 2012.
19. Moreira, A, Arsati, F, Lima-Arsati, YB, Franchini, E, and de Araújo, VC. Effect of a kickboxing match on salivary cortisol and immunoglobulin A. *Percept Mot Skills* 111: 158–166, 2010.
20. Morley, B and Thomas, D. An investigation of home advantage and other factors affecting outcomes in English one-day cricket matches. *J Sports Sci* 23: 261–268, 2005.

21. Nilsson, J, Csergö, S, Gullstrand, L, Tveit, P, and Refsnes, PE. Work-time profile, blood lactate concentration and rating of perceived exertion in the 1998 Greco-Roman Wrestling World Championship. *J Sports Sci* 20: 939–945, 2002.

22. Ouergui, I, Hssin, N, Franchini, E, Gmada, N, and Bouhlel, E. Technical and tactical analysis of high level kickboxing matches. *Int J Perform Anal Sport* 13: 294–309, 2013.

23. Santos, VGF, Franchini, E, and Lima-Silva, AE. Relationship between attack and skipping in Taekwondo contests. *J Strength Cond Res* 25: 1743–1751, 2011.

24. Silva, JJR, Del Vecchio, FB, Picanço, LM, Takito, MY, and Franchini, E. Time-motion analysis in Muay-Thai and kick-boxing amateur matches. *J Hum Sport Exerc* 6: 490–496, 2011.

25. Spencer, M, Bishop, D, Dawson, B, Goodman, C, and Duffield, R. Metabolism and performance in repeated cycle sprints: Active versus passive recovery. *Med Sci Sports Exerc* 38: 1492–1499, 2006.

26. Tornello, F, Capranica, L, Chiodo, S, Minganti, C, and Tessitore, A. Time-motion analysis of youth olympic taekwondo combats. *J Strength Cond Res* 27: 223–228, 2013.

27. del Vecchio, FB, Hirata, SM, and Franchini, E. A review of time-motion analysis and combat development in mixed martial arts matches at regional level tournaments. *Percept Mot Skills* 112: 639–648, 2011.

28. Zabukovec, R and Tiidus, PM. Physiological and anthropometric profile of elite kickboxers. *J Strength Cond Res* 9: 240–242, 1995.