Time–Motion Analysis and Physiological Responses to Karate Official Combat Sessions: Is There a Difference Between Winners and Defeated Karatekas?

Helmi Chaabène, Emerson Franchini, Bianca Miarka, Mohamed Amin Selmi, Bessem Mkaouer, and Karim Chamari

**Purpose:** The aim of this study was to measure and compare physiological and time–motion variables during karate fighting and to assess eventual differences between winners and defeated elite karatekas in an ecologically valid environment.

**Methods:** Fourteen elite male karatekas who regularly participated in national and international events took part in a national-level competition.

**Results:** There were no significant differences between winners and defeated karatekas regarding all the studied variables. Karatekas used more upper-limb (76.19%) than lower-limb techniques (23.80%). The *kisami-zuki* represented the most frequent technique, with 29.1% of all used techniques. The duration of each fighting activity ranged from <1 s to 5 s, with 83.8% ± 12.0% of the actions lasting less than 2 s. Karatekas executed 17 ± 7 high-intensity actions per fight, which corresponded to ~6 high-intensity actions per min. Action-to-rest ratio was about 1:1.5, and high-intensity-action-to-rest ratio was ~1:10. The mean blood lactate response at 3 min postcombat (*La*post) elicited during karate fighting was 11.18 ± 2.21 mmol/L (difference between *La*pre and *La*post = 10.01 ± 1.81 mmol/L). Mean heart rate (HR) was 177 ± 14 beats/min (91% ± 5% of HRpeak). Karatekas spent 65% of the time exercising at HR >90% of the individual HRpeak. **Conclusion:** Karatekas predominantly use upper-limb karate techniques. Karate’s nature is intermittent, with fighting activities representing ~6% of total combat’s duration and ~84% of actions lasting less than 2 s, with ~21-s mean time interval in between. Kumite combat sessions induced high *La* and near-maximal cardiovascular strain. Other key success factors should be investigated to properly discriminate winners and defeated athletes.

**Keywords:** karate kumite, physiological parameters, activity profile

Officially, karate athletes have 3 minutes of combat to perform different technical and tactical actions. During this time, various arrangements are performed intermittently with variations of intensity and constant interruptions being the main characteristic of this combat sport. There is relatively little scientific evidence dealing with the physiological requirement of competition. In this context, there are only 2 studies dealing with both physiological responses and karate combat analysis, but they were conducted using simulated fighting conditions. Beneke et al. reported that simulated karate competition has 18 ± 6 efforts per 9 ± 6 seconds of recovery pattern (ie, effort:pause ratio of 2:1). Activity phases contained 16.3 ± 5.1 high-intensity actions per fight lasting 1 to 3 seconds each, which resulted in 3.4 ± 2.0 high-intensity actions per minute. Furthermore, they reported a post-combat blood lactate concentration ([*La*]) of 7.7 ± 1.9 mmol/L. Iide et al. demonstrated that the duration of the shortest offensive and/or defensive techniques was 0.3 ± 0.1 second for both 2- and 3-minute bouts of combat (ie, fighting match), while the longest offensive and defensive combination techniques were 2.1 ± 1.0 and 1.8 ± 0.4 seconds, respectively. The total times of offensive and defensive techniques during 2- and 3-minute bouts of combat were 13.3 ± 3.3 and 19.4 ± 5.5 seconds, respectively. In the same study, peak heart-rate responses, ([*La*]), and rating of perceived exertion for both the 2-minute and the 3-minute bouts of fighting were 160 ± 12.8 and 169.9 ± 9.1 beats/min, 3.1 ± 1 and 3.4 ± 1 mmol/L, and 13.5 ± 1.8 and 15.3 ± 1.7, respectively. Rating of perceived exertion has been recently established by Milanez et al. to be a valid tool in quantifying karate training sessions involving basic techniques (*kihon*) and combat.
Thus, since greater understanding of both time–motion analysis and physiological parameters of an official karate combat will assist coaches, scientific experts, and even athletes in the best way to optimize sport-specific training programs and consequently enhance karate’s high-level performance, a study conducted in this combat environment seemed to be needed. Particularly, time–motion analysis is important to applied sport scientists and strength and conditioning coaches to assist in the development of game-specific conditioning programs. In addition, research into the physical demands, movement patterns, and combat performance analysis of martial arts athletes and more specifically karate is still very limited.

Matsushigue et al7 revealed that winners used fewer tae kwon do techniques during an official tae kwon do competition, while physiological responses (ie, [La] and heart rate [HR]) did not differ from those of defeated athletes. Similarly, Roschel et al8 reported no significant difference in [La] between winners and defeated karate athletes. However, to our knowledge, detailed analysis of combat’s physiological responses and performance aspects has not been previously reported during official competition in high-level karatekas. Thus, the aims of the current study were to verify the relationship between performance analysis with physiological responses during official karate combat and to compare winners and defeated athletes in relation to performance analysis, as well as combat physiological responses in a sample of high-level karatekas.

**Methods**

**Subjects**

Fourteen male high-level karate athletes (weight categories: >84 kg, n = 3; <84 kg, n = 2; <75 kg, n = 3; <67 kg, n = 3; <60 kg, n = 3) who regularly participated in national and international events under different weight categories took part in this study (age 21.5 ± 3.1 y, body mass 72.8 ± 10.2 kg, height 180.9 ± 7.8 cm, and karate experience 14.1 ± 2.7 y). All subjects were first-, second-, or third-dan black-belt holders. A total of 14 karate combat sessions were analyzed. All athletes provided written informed consent in accordance with the Declaration of Helsinki. The university ethics committee approved the study protocol.

**Procedures**

**Performance-Analysis Measurements.** All combat sessions were taped by using 2 Sony cameras (model DCR PC 108, CCD 1000,000 pixels, SSC 1/4000 per s, Tokyo, Japan). The cameras (positioned 5 m aside from the competition area) were equipped with a fish-eye lens, allowing coverage of all the combat areas. A video-analysis software program (Dartfish Edition MPT34M Pro 5.5, Lausanne, Switzerland) was used to analyze the footage frame by frame (interval 0.016 s). Similar procedures were used in a previous investigation with a high reliability and objectivity.9

Preparatory-activity time began either after the referee’s hand signal or on termination of the fighting phase, whereas it ended either on the referee’s hand signal or when the successive fighting time started. Fighting-activity time (FT) was considered an exchange between the 2 contestants and began when athletes moved out from the fighting stance toward an exchange and ceased once the final execution was ended. More precisely, an execution finished once the punching limb was retracted, kicking foot was returned to the floor, and when contact between contestants ended. Stoppage activity time was started or stopped when the referee called hajime, which means to begin, or yame, which means to stop.1 Stoppage period included various events: general—the time required for the referee to separate contestants after an exchange, injury—period of time spent when athletes were injured, and penalty/score—the time required when the referees awarded a penalty or score to a competitor.

All matches were analyzed twice with a 1-week interval between by the same researcher (black-belt and expert coach) and by a second observer to determine the objectivity of the procedure. The level of agreement between the 2 observations was determined via Cohen kappa statistic as suggested by Landis and Koch.10 Kappa values were as following: poor, 0 to <.20; fair, .20 to <.40; moderate, .40 to <.60; substantial, .60 to <.80; and almost perfect, .80–1.00. Cohen kappa between the 2 observations applied to the frequencies of technique used was >.80 (range .85–1), almost perfect. The Student t test showed no significant difference in preparatory (t = 1.75, P = .12), fighting (t = –1.05, P = .33), and stoppage (t = –.14, P = .33) activity during the 2 analyses of both observers. The intraclass correlation coefficient (ICC) was higher than .90 for all phases (preparatory activities, .90; FT, .90; stoppage activities, .94), showing the high reliability of this system.

**Physiological Measurements.** Competitors’ HR was recorded at 5-second intervals using the Polar Team System (Team System, Polar, Kempele, Finland). The mean HR (HRmean) was calculated as the average of the HR during the entire karate combat, while peak HR (HRpeak) was defined as the highest match value. HRmean was expressed as percentage of the karateka’s HRpeak attained during the combat.11 Intensity effort was classified according to 5 categories: (1) >95% HRpeak, (2) >90–95% HRpeak, (3) >85–90% HRpeak, (4) >80–85% HRpeak, and (5) ≤80% HRpeak.12 The time spent, expressed as percentage of the total combat time, in each category was calculated.

[La] was measured at rest and at 3 minutes post-combat from the fingertip using the Lactate Pro Analyzer (Arkray, Tokyo, Japan) and used as an indicator of the energy contribution from the anaerobic glycolysis system during combat sessions.2

The rating of perceived exertion (RPE6–20) was assessed on a 6-to-20 scale.13 Recently, RPE (Borg 6–20...
and CR-10 scales, which were correlated, \( r = .78 \) has been presented as a valid tool to assess global exercise intensity during karate.6 The subjects were habituated to the use of the RPE scale and monitoring training load before the commencement of the study.

Statistical Analysis

The statistical analyses were carried out using SPSS 19.0 program for Windows (SPSS, Inc, Chicago, IL, USA). A Kolmogorov-Smirnov test assessed the normality assumption. Variables’ relationships were assessed through Pearson correlation analysis. Reliability of time–motion analysis was checked via ICC. Cohen kappa was calculated to determine the level of agreement between the 2 observations for the time–motion analysis, that is, the frequencies of techniques performed. Comparison between winners and defeated athletes was assessed through independent \( t \) test. Data are presented as mean \( \pm \) SD. Effect sizes (\( d \)) were calculated using GPOWER software (Bonn FRG, Bonn University, Department of Psychology). The following scale was used for the interpretation of \( d \): <0.2, trivial; 0.2 to <0.6, small; 0.6 to <1.2, moderate; 1.2 to <2.0, large; and \( \geq 2.0 \), very large.14 Statistical significance was set at \( P \leq 0.05 \).

Results

Of all techniques used, upper-limb techniques represent 76.19% and lower-limb ones 23.80%. When considering attack techniques, upper-limb techniques represent 64.34% and lower-limb techniques 35.65%. For counterattack technique, upper-limb techniques represent 90.47% and lower-limb one 9.52%. Finally, for combination of attack, upper-limb techniques represent 100%.

Kisami-zuki represented 74.32% of upper-limb attack techniques, 47.82% of all attack techniques, and 29.1% of all techniques used. Concerning lower-limb attack techniques, Mawashi-geri Chudan represented 43.90% of the total. Of all counterattack techniques and upper-limb counterattack techniques, kyaku-zuki jodan represented 54.76% and 60.52%, respectively. From combination of attacks, kisami kyaku-zuki jodan represented 53.12%.

Overall time for fighting, preparatory, and stoppage activity, as well as values recorded according to match outcome, is presented in Table 1.

Athletes used 13 \( \pm \) 4 techniques during each combat, with no significant difference between winners (14 \( \pm \) 5) and defeated (12 \( \pm \) 4). Karatekas performed 17 \( \pm \) 7 high-intensity actions per combat, lasting from <1 second to 5 seconds each, which corresponded to approximately 6 high-intensity actions per minute. There was no significant difference (\( P > .05 \)) in all types of actions used between winners and defeated karatekas. Upper- and lower-limb attack techniques for winners were 2 \( \pm \) 1 and 2 \( \pm \) 1, respectively. For defeated, upper- and lower-limb attack techniques were 2 \( \pm \) 1 and 1 \( \pm \) 0, respectively. Upper- and lower-limb counterattack techniques for winners were 2 \( \pm \) 0 and 1 \( \pm \) 0, respectively, and for defeated values were 2 \( \pm \) 1 and 2 \( \pm \) 0, respectively. Combination of attack techniques was 2 \( \pm \) 1 for winners and 1 \( \pm \) 1 for defeated karatekas.

Total fighting time was 22.8 \( \pm \) 8.4 seconds, with no difference (\( P > .05 \)) between winners (24.1 \( \pm \) 6.0 s) and defeated (22.6 \( \pm \) 13.9 s).

A significant difference (\( t = –2.54, df = 26, P = .01, dz = 0.61 \) [moderate]) was found between the duration of exercise (10.3 \( \pm \) 5.0 s) and pauses (15.4 \( \pm \) 5.6 s; effort:rest ratio of 1:1.5). High-intensity actions (1.5 \( \pm \) 0.7 s) and rest periods (15.4 \( \pm \) 5.6 s) also differed (\( t = –9.29, df = 26, P < .001, dz = 3.51 \) [very large]; effort:rest ratio >1:10).

Preparatory-activity time, FT, and stoppage activity time represented 33.12%, 5.81%, and 59.86% of combat’s total duration, respectively.

The majority (83.8% \( \pm \) 12.0%) of the FT lasted less than 2 seconds. Time interval between high-intensity actions was 21.9 \( \pm \) 10.1 seconds, with no significant difference (\( P > .05 \)) between winners (24.1 \( \pm \) 10.5 s) and defeated athletes (19.05 \( \pm \) 10.7 s).

Physiological and perceptive responses are shown in Table 1.

Karate combat generated a significant increase in \([\text{La}] (t = 17, df = 10, P < .001, dz = 5.06 \) [very large]) and HR (\( t = –12.99, df = 12; P < .0001, dz = 5.31 \) [very large]). There was no significant difference (\( P > .05 \)) in the RPE, \( \text{La}_{\text{rest}}, \text{La}_{\text{post}}, \text{HR}_{\text{peak}}, \text{HR}_{\text{mean}}, \) and \%HRpeak between winners and defeated athletes. There was no significant correlation between \( \text{La}_{\text{post}} \) and the mean total combat time or the number of techniques applied per combat session (\( P > .05 \)). Moreover, there was no significant correlation between high-intensity actions and FT or \( \text{La}_{\text{post}}, \) between \( \text{La}_{\text{post}} \) and both the number of high-intensity actions and RPE (\( P > .05 \)).

Discussion

The aim of this study was to measure and to compare time–motion variables and physiological responses during karate combat sessions and to assess eventual differences between winners and defeated. Results revealed that (1) karate combat showed an overall action:rest ratio of \( \sim 1:1.5 \), which increased to \( \sim 1:10 \) when high-intensity action:rest ratio was considered; (2) FT represented \~6% of total combat duration and \~84% of them lasted less than 2 seconds, with \~21 seconds of high-intensity actions between 2 consecutive high-intensity actions; (3) official karate combat generated high \([\text{La}] \) and high HR; and (4) there was no significant difference between winners and defeated regarding time–motion analysis and physiological responses.

The current study findings suggest that karate athletes use more upper-limb techniques than lower-limb ones. According to Mudric,15 the low frequency of kick techniques can be explained by the longer trajectory, as well as the time that is required for their execution compared with punches. These findings agree with those of
<table>
<thead>
<tr>
<th></th>
<th>FT (s) ± SD</th>
<th>PT (s) ± SD</th>
<th>ST (s) ± SD</th>
<th>H_{peak\ combat} (beats/min)</th>
<th>H_{mean} (beats/min)</th>
<th>%H_{peak\ combat}</th>
<th>L_{rest} (mmol/L)</th>
<th>L_{post} (mmol/L)</th>
<th>ΔLa (mmol/L)</th>
<th>RPE (6–20 scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winners</td>
<td>1.8 ± 0.8</td>
<td>10.2 ± 5.6</td>
<td>16.3 ± 6.4</td>
<td>193 ± 8</td>
<td>180 ± 13</td>
<td>93 ± 3</td>
<td>1.94 ± 0.46</td>
<td>11.29 ± 1.56^*</td>
<td>9.37 ± 1.81</td>
<td>14 ± 2</td>
</tr>
<tr>
<td>Defeated</td>
<td>1.2 ± 0.3</td>
<td>7.3 ± 2.8</td>
<td>13.0 ± 3.1</td>
<td>193 ± 1</td>
<td>171 ± 12</td>
<td>88 ± 7</td>
<td>1.33 ± 0.32</td>
<td>11.07 ± 2.96^*</td>
<td>10.9 ± 1.77</td>
<td>13 ± 2</td>
</tr>
<tr>
<td>Overall</td>
<td>1.5 ± 0.7</td>
<td>8.9 ± 4.5</td>
<td>15.4 ± 5.6</td>
<td>193 ± 8</td>
<td>177 ± 13</td>
<td>91 ± 5</td>
<td>1.73 ± 0.54</td>
<td>11.18 ± 2.21^*</td>
<td>10.01 ± 1.88</td>
<td>14 ± 2</td>
</tr>
</tbody>
</table>

Abbreviations: FT, fighting activity time; PT, preparatory activity time; ST, stoppage activity time; HR, heart rate; La, blood lactate concentration; ΔLa, difference between La before and after the combat; RPE, rating of perceived exertion.

^*Significant difference from before match (P < .01).
Koropanovski et al,16 who established that upper-limb techniques are predominant (89.1%) compared with lower-limb ones (8.4%). In this study, the Kisami-zuki represented 74.3% of upper-limb attack techniques, 47.8% of all attack techniques, and 29.1% of overall used techniques. These data agree with those of Jovanovic and Milosevic,17 who suggested a predominance of this upper-limb technique due to its simplicity. Concerning lower-limb techniques, data showed that Mawashi geri chudan was the most-used technique, with 43.9% of lower-limb attack techniques. This lower-limb attack requires a short time to be performed compared with other lower-limb attacks, preventing opponent defensive actions. Concerning counterattacks, Gyaku-zuki jodan represented 54.8% of total. These findings corroborate other authors’ results, which revealed that 64.9% of Gyaku-zuki were applied during combat, in which 34.9% applications were on the trunk (chudan) and 32.0% were on the head (jodan).18 Laird and McLeod19 reported that Gyaku-zuki to the body (chudan) represented the most frequent technique, with 43.3% of all scores recorded being through the execution of this technique. Hence, punch techniques appear to be more efficient and have greater chance to reach the target compared with kick techniques. This would explain the greater use of upper-limb techniques during karate combat.

Total FT did not differ between winners and defeated athletes and was similar to the values reported by Iide et al.3 The duration of each FT ranged from less than 1 second to 5 seconds, which is similar to those established by Beneke et al. In addition, these findings agree with other studies with tae kwon do athletes that demonstrated that the duration of an attack ranged from 1 to 5 seconds.9,20 Results showed that high-level karate athletes executed 17 ± 7 high-intensity actions per fight (~6 high-intensity actions per minute). These data are similar to those reported by Beneke et al9 and Iide et al.3 The majority (83.8% ± 12.0%) of the current study FT lasted less than 2 seconds. Bridge et al21 showed similar results (ie, 72% ± 16% of FT lasted less than 2 s) during tae kwon do combat. Beneke et al2 identified an activity-to-break ratio of approximately 2:1. Action-to-rest ratio in the current study was about 1:1.5, but when considering high-intensity-action-to-rest ratio it increased to ~1:10. However, the performance analysis of karate combat in the study of Beneke et al20 was not clear. The authors reported only that each fight was recorded on videotape with no additional information. In addition, the simulated character and the difference in karate fighting level between the current study and that of Beneke et al2 may explain the difference between results. Action-to-rest ratio in the current study characterizes the intermittent nature of official karate combat. High-intensity actions (ie, attack and/or defense) are essentially a function of muscle explosive power.5 Thus, in top-level karate performance, the development of the athletes’ anaerobic alactic system is important to perform attacking/defending techniques with extremely high-speed movement.

When other striking combat sports were analyzed, results similar to those of the current findings were reported. Matsushigue et al21 established that the ratio of high-intensity movements to low-intensity ones or inactivity was approximately 1:6 for Songham tae kwon do matches. Bridge et al21 found that the fighting-to-nonfighting ratio was 1:6 during the 2005 Men’s World Taekwondo Championship. Santos et al22 reported similar results (1:7) regarding the effort:pause ratio when reporting time–motion analysis from the 2007 World Taekwondo Championship and 2008 Olympic Games. Unfortunately, to more deeply discuss the current study results, there are no additional available studies dealing with performance analysis of karate fighting activity. Thus, karate combat is characterized by a very short period of high-intensity actions interposed by less intense periods and/or pause with respect to what was shown by the current study for official combat sessions.

Data on energy demand of combat sports, and particularly karate, are scarce in the literature. [La] responses to karate fight in our study were relatively high compared with those reported by Beneke et al9 and Iide et al9 during karate combat simulation. There was no significant difference between winners and defeated regarding postcombat [La] in the current study, confirming the findings from Roschel et al,8 who reported [La] increases from 2.3 ± 0.4 mmol/L to 5.1 ± 1.2 mmol/L in winners and from 1.8 ± 0.6 mmol/L to 5.2 ± 2.2 mmol/L in defeated karate athletes during simulated combat with no significant difference between them. The difference between the current study results and the established one regarding [La] suggests that the type of combat (simulation vs official) and the level of competition and athletes may affect glycolytic system participation. These results agree with those of Lehmann and Jedliczka,23 who found that the number of attacking and defending actions during combat simulation was lower by 30% to 50% than that observed during authentic competition. This may explain why, under official combat conditions, [La] was, most of the time, higher by 10% to 40% compared with that recorded after combat simulation.23 The [La] recorded after karate fight during the current study was slightly higher than that reported by Lehmann24 (9.0 ± 1.8 mmol/L) and Heller et al25 for male tae kwon do competitors (11.4 ± 3.2 mmol/L) and Bouhlel et al20 (10.2 ± 1.2 mmol/L) for male national-level tae kwon do athletes during simulated combat sessions. In addition, Beneke et al2 reported a positive relationship (r = .49) between glycolytic energy contribution and number of attacks per minute during a karate combat simulation, suggesting that more disputed matches should present higher glycolytic participation. Thus, for athletes presenting a more offensive profile, sequences of high-intensity actions should be added to their training program.

The HR values measured during competitive combat sessions indicate the high cardiovascular demands of karate. Nevertheless, there was no difference in cardiovascular strain between winners and defeated athletes. Karate athletes during the current study spent 65% of the
time exercising at HR >90% of their individual HRS_{peak}, indicating that karate combat elicits a high level of cardiovascular strain in elite athletes.

The RPE has been well established as a valid tool for monitoring, prescribing, and regulating exercise intensity and assessing training load,26 being presented as a valid tool to assess global exercise intensity during karate.9 There was no significant difference in perception of effort between winners and defeated athletes, with RPE values (14 ± 2 [somewhat hard]) similar to those reported by tae kwon do athletes during competitive matches.27,28 However, there was a clear dissociation between RPE and physiological load determined via HR and [La] to karate combat. These results may indicate that karatekas underestimate karate’s actual physiological intensity. This can be due to the fact that RPE can be influenced by various physiological (eg, HR, ventilation, VO2, [La]) and psychological (eg, cognition, memory, previous experience, understanding of the task) mediators.29 Similar dissociation between physiological responses and RPE has been established with elite female tae kwon do athletes27 and high-level male tae kwon do practitioners during an international competition28 and in novice and experienced men and women participating to tae kwon do training.30 Although the reasons for such responses are not clear, Bridge et al28 suggested that the attention directed by the athletes to their opponents during the match would interfere with their perception of effort.

Conclusion and Practical Applications

In summary, karate athletes have the tendency to use upper-limb karate techniques much more than lower-limb ones. The intermittent nature of karate combat elicited an action-to-rest ratio of 1:1.5, which increased to 1:10 when high-intensity-action-to-rest ratio was considered. FT lasted from less than 1 second to 5 seconds and ~84% lasted less than 2 seconds. Thus, some karate training sessions should adopt this time frame as a reference, and karate athletes should be submitted mostly to short high-intensity actions interspersed with nearly 10 times low-intensity activities repeated for the total match duration. Karate combat induced moderate to high [La] and near-maximal cardiovascular strain in top-level male karatekas, indicating that karate athletes should be prepared to deal with these physiological responses without losing their attentional focus or quality of technique. RPE must be used by coaches with caution since it has previously been established that there was a clear dissociation between this training-load tool and physiological parameters (ie, [La] and HR).

There was no significant difference between winners and defeated in all parameters of performance analysis, as well as in physiological responses to and perceived exertion of karate combat. The fact that the current study did not show any difference for the measured variables—physiological and perceptual data—and time–motion analysis certainly indicates that the factors determining karate success are to be found elsewhere. It is possible that the timing of technique used could be determinant, and, thus, future studies should aim at detecting the tactical and mental abilities that allow winners to reach victory while their time–motion patterns, physiological responses, and perception of effort are similar to those of their defeated counterparts.

Acknowledgments

The authors would like to thank the Tunisian Karate Federation for granting access to the competitors during the competition and all athletes for their enthusiasm in the completion of this study. We would like to thank Dr Younès Hachana for the relevant comments about this manuscript. The current study was supported by the Ministère de l’Enseignement Supérieur et de la recherche Scientifique, Tunisia

References


