Physiological Responses and Perceived Exertion During International Taekwondo Competition

Craig A. Bridge, Michelle A. Jones, and Barry Drust

Purpose: To investigate the physiological responses and perceived exertion during international Taekwondo competition. Methods: Eight male Taekwondo black belts (mean ± SD, age 22 ± 4 y, body mass 69.4 ± 13.4 kg, height 1.82 ± 0.10 m, competition experience 9 ± 5 y) took part in an international-level Taekwondo competition. Each combat included three 2-min rounds with 30 s of recovery between each round. Heart rate (HR) was recorded at 5-s intervals during each combat. Capillary blood lactate samples were taken from the fingertip 1 min before competition, directly after each round and 1 min after competition. Competitors’ rating of perceived exertion (RPE) was recorded for each round using Borg’s 6-to-20 scale. Results: HR (round 1: 175 ± 15 to round 3: 187 ± 8 beats.min⁻¹; P < .05), percentage of HR maximum (round 1: 89 ± 8 to round 3: 96 ± 5% HRmax; P < .05), blood lactate (round 1: 7.5 ± 1.6 to round 3: 11.9 ± 2.1 mmol.L⁻¹; P < .05) and RPE (round 1: 11 ± 2 to round 3: 14 ± 2; P < .05; mean ± SD) increased significantly across rounds. Conclusions: International-level Taekwondo competition elicited near-maximal cardiovascular responses, high blood lactate concentrations, and increases in competitors’ RPE across combat. Training should therefore include exercise bouts that sufficiently stimulate both aerobic and anaerobic metabolism.

Keywords: martial arts, heart rate, blood lactate, intermittent exercise, physiology

Taekwondo has evolved from a traditional martial art into a modern-day global sport. The sport element of Taekwondo practiced under the administration of the World Taekwondo Federation (WTF) consists of weight-governed, full-contact combat between two opponents. The objective of competition is to knockout an opponent or score a greater number of points via the execution of kicking and punching techniques to legitimate targets. Combats generally comprise three rounds of 2 min, with 1 min of recovery between each round, although this can vary with approval from the federation. World Taekwondo Federation competitions include numerous national, regional, and international events, as well as featuring in the current Olympic Games program.

Bridge and Jones are with the Sport and Exercise Research Group, Edge Hill University, Ormskirk, U.K. Drust is with the Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, U.K.
Despite Taekwondo’s emergence as a modern Olympic sport, relatively little is known about the physiological demands of competition. Such information can be collected by making relevant observations during competition, by obtaining physiological measures during authentic and simulated competition, and by determining the physical capacity of elite competitors.2 Several studies have evaluated the physical capacities of recreational and competitive Taekwondo practitioners.3–8 Research suggests that national- and international-level male competitors generally demonstrate high anaerobic performance abilities (eg, 11.8 to 14.7 W·kg⁻¹ [30-s Wingate peak power]),4,8 with less exceptional aerobic performance abilities (eg, 44.0 to 55.8 mL·kg⁻¹·min⁻¹ [VO₂max]).4,6,8 This data may be associated with the demands of competition, or may simply reflect the influence of genetics and the demands of current training practices as opposed to the adaptation to the regular physiological stress of competition.5,9 As such, these approaches may not accurately represent the demands of the sport.

Direct evaluations of the physiological responses of simulated and authentic competition may, therefore, provide a more effective method of determining the acute physiological demands of competition. Heller et al4 briefly evaluated the physiological responses and time-motion analysis of national-level Taekwondo competition. Time-motion analysis revealed that Taekwondo competition was an intermittent activity, comprising 3- to 5-s maximal intensity efforts interspersed with low-intensity recovery periods at ratios between 1:3 and 1:4. This exercise pattern elicited maximal HR responses (approx. 100% HRmax) and high postcompetition blood lactate concentrations (11.4 mmol·L⁻¹). Similar physiological responses have been reported during simulated Taekwondo competition (approx. 99% HRmax; 10.2 mmol·L⁻¹) using international-level competitors.7 These findings collectively suggest that high demands are placed upon both aerobic and anaerobic metabolism during competitive bouts.

Although previous research provides an insight into the physiological demands of authentic Taekwondo competition,4 it was conducted during a national-level event. The physiological responses of international competition have never been investigated. Significant variation in Taekwondo practitioners’ physical capacities have been observed between levels of experience and competitive success.3,5 Competition level and training status also influence work rate during numerous competition environments.10–13 This would suggest that the available data on the physiological demands of Taekwondo may not be generalizable to other populations of practitioners. Evaluation of the physiological responses of international Taekwondo competition is, therefore, required to enable coaches and practitioners to optimally inform the structure of conditioning sessions at this level. The aim of this study was to investigate the physiological responses and perceived exertion during WTF international-level Taekwondo competition.

Methods

Participants

Eight male Taekwondo black belts (mean ± SD, age 22 ± 4 y, body mass 69.4 ± 13.4 kg, height 1.82 ± 0.10 m, competition experience 9 ± 5 y) from the British national team took part in this study. The sample included three 3rd Dan grades, three 2nd
Dan grades, and two 1st Dan grades. All participants were regularly competing in WTF international events (e.g., European Championship and World Championship events) under different weight categories. More specifically, the current sample comprised one participant from each of the eight standard WTF weight divisions. Taekwondo was the only active form of training for these participants, with the inclusion of some general cardiovascular work and resistance training incorporated within these sessions. All participants were actively involved in the same training program in preparation for the competition event. Participants were informed of the test procedures and potential risks, and informed consent was attained. The project was granted ethical approval in accordance with University Ethics Code of Conduct.

**Competition Procedures**

All participants competed in a WTF-sanctioned senior-level international competition (Swedish Open; Trelleborg, Sweden, 2006). The competition was held in a gymnasium on standard mats, and all qualifying, semifinal, and final phases of the event occurred between the hours of 9:00 and 19:00 during the same day. Combats included three rounds of 2 min with 30 s of recovery between each round. The data inclusion criteria were the successful attainment of HR, blood lactate, and RPE across three rounds of combat. In total, data from 12 combats were successfully recorded, in accordance with the inclusion criteria. Thus, the mean data included here represent eight competitors during a total of 12 combats. These data were obtained from combats contested during qualifying, semifinal, and final phases of the competition event. Competitors who were examined on repeated occasions may, therefore, have been exposed to a higher degree of difficulty as combats progressed during these phases. The structure and start time of combats that were recorded throughout the competitive day are presented in Figure 1. Temperature and humidity was recorded next to the competition area at 9:00, 13:00, and 18:00 using a whirling psychrometer (G.H. Zeal Ltd, London, U.K.). Mean ± SD temperature and relative humidity was 23 ± 1°C, and 38 ± 6%, respectively.

Each competitors’ HR was used to assess the relative cardiovascular strain associated with competition. This methodology was implemented because it is noninvasive and has been used previously as a reliable index of exercise intensity.

![Figure 1 — Structure and start time of competitors’ combats throughout the competitive day. The time line is presented in 24-h format; values represent hours:minutes.](image-url)
during a variety of intermittent exercise situations. Competitors were familiarized with the HR monitors during a number of Taekwondo training activities (eg, contact sparring) and sessions before their use during competition. Competitors indicated that these HR monitors did not impede their movements or behavior in any manner during the Taekwondo activities. During the event, competitors’ HR was recorded at 5-s intervals throughout each combat and recovery using the Polar Team System (Polar Electro Ltd, Warwickshire, U.K.). Each HR transmitter was attached across the participants’ chest under the body armor before each individual combat. Data were subsequently downloaded using Polar Precision Software (Version 4.0, Polar Electro Ltd.). Mean ± SD HR was calculated for each round, the 30-s recovery period between each round, and for a 2-min period before combat to provide an indication of the cardiovascular strain elicited during these specific periods. The SD of individuals’ HR was calculated for each round to examine the degree of variation in the cardiovascular demands during rounds. The HR was expressed as a percentage of competitors’ HRmax and classified into intensity zones identified by the American College of Sports Medicine (ACSM). The average percentage of time spent in specific HR intensity zones was also calculated for each round. Competitors were unavailable for maximal laboratory testing at the time of data collection; thus, HRmax was calculated from the standard equation, 220 - age. It appears pertinent to note that during subsequent evaluations we have identified that the mean ± SD HRmax (n = 8) determined from laboratory-based treadmill tests (191 ± 5 beats·min⁻¹) was lower (P ≤ .01) than that obtained during both Taekwondo competition (199 ± 4 beats·min⁻¹) and estimated from 220 – age (199 ± 4 beats·min⁻¹). Thus, the equation HRmax = 220 – age appears to provide a reasonable estimation of the HRmax in this sample of competitors, as opposed to laboratory-based determinations.

Whole blood lactate concentrations were measured and used as an indicator of the energy production from anaerobic glycolysis during combats. In this environment, the blood lactate concentration represents the balance between production, release, and removal, and hence should be interpreted cautiously. Blood lactate concentrations may reflect, but underestimate, the lactate production in the minutes before sampling during combat. Blood lactate was measured approximately 1 min before combat, directly after each round, and 1 min after combat (Lactate Pro Meter, Akray, KDK). Calibration of the device was completed in accordance with the manufacturers’ instructions before sampling at each combat. Following the insertion of each test strip an approximately 5-μL blood sample was taken from the fingertip. Competitors were familiarized with these sampling procedures during regular training sessions before their use during competition. This method was implemented because of its ease of use in the field and its established reliability in the assessment of whole blood lactate. This device has also been validated against well-established blood assay instruments, such as the ABL 700 Acid-Base Analyzer, YSI 2300 Stat Analyzer, and Accusport Lactate Meter.

The RPE was used as an additional methodology to describe and monitor exercise intensity. Borg’s 6-to-20 scale was implemented to determine competitors’ RPE for each round. Competitors were familiarized with the 6-to-20 scale before competition analysis. This required the competitors to rate their “perceived exertion” in juxtaposition to measures of HR and blood lactate during a range of Taekwondo training activities and physiological loads. During the event, competitors
were instructed to rate their perception of effort for each whole round independently. These perceptions were recorded immediately at the end of combat to prevent interference during competition. Mean ± SD RPE was calculated for each round, and values were classified in accordance with ACSM’s qualitative descriptors.15

Statistical Analysis

All data were assessed for normality using the Shapiro-Wilks test before analysis. Repeated-measures ANOVA was conducted on all dependent variables to identify differences in intensity across rounds and recovery between rounds. Post hoc analysis included pairwise comparisons using Tukey’s HSD test. Friedman’s repeated-measures rank test was used to identify differences in the time spent in specific HR intensity zones. Post hoc analysis included Wilcoxon’s matched-pairs signed-ranks tests, with Bonferroni adjustment for multiple comparisons. All statistical procedures were performed using SPSS for Windows (Version 14.0, SPSS Ltd, Surrey, U.K.). Descriptive data are expressed as means ± SD unless stated otherwise.

Results

The HR, blood lactate, and RPE responses of competition are presented in Table 1. Significant differences in HR ($F_{1,12}=199$, $P=.00$), % HR$_{\text{max}}$ ($F_{1,12}=195$, $P=.00$), blood lactate ($F_{3,33}=104$, $P=.00$), and RPE ($F_{1,13}=19$, $P=.00$) were identified across rounds. Heart rate ($P=.00$), % HR$_{\text{max}}$ ($P=.00$), and blood lactate ($P=.00$) increased significantly from precombat to round 1 and remained significantly higher than precombat throughout rounds 2 and 3 (Table 1). No differences in HR ($P=.27$), % HR$_{\text{max}}$ ($P=.31$), and RPE ($P=.18$) were observed between rounds 1 and 2. Blood lactate continued to increase significantly between rounds 1 and 2 ($P=.00$). No differences in HR ($P=.75$), % HR$_{\text{max}}$ ($P=.76$), RPE ($P=.10$), and blood lactate ($P=0.18$) were identified between rounds 2 and 3. However, significant increases in HR ($P=.03$), % HR$_{\text{max}}$ ($P=.04$), blood lactate ($P=.00$), and RPE ($P=.00$) were evident between rounds 1 and 3. No differences in recovery HR were identified between rounds ($F_{2,22}=3$, $P=.07$).

Table 1  Mean ± SD physiological responses and perceived exertion of eight competitors during a total of 12 international combats

<table>
<thead>
<tr>
<th></th>
<th>HR</th>
<th>Recovery HR</th>
<th>% HR$_{\text{max}}$</th>
<th>Recovery HR$_{\text{max}}$</th>
<th>Blood Lactate</th>
<th>RPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(beats·min$^{-1}$)</td>
<td>(beats·min$^{-1}$)</td>
<td>(beats·min$^{-1}$)</td>
<td>(HR$_{\text{max}}$)</td>
<td>(mmol·L$^{-1}$)</td>
<td>(6–20 scale)</td>
</tr>
<tr>
<td>Precombat</td>
<td>123 ± 6*</td>
<td>62 ± 3*</td>
<td>—</td>
<td>—</td>
<td>2.7 ± 0.6*</td>
<td>—</td>
</tr>
<tr>
<td>Round 1</td>
<td>175 ± 15</td>
<td>89 ± 8</td>
<td>173 ± 15</td>
<td>87 ± 10</td>
<td>7.5 ± 1.6</td>
<td>11 ± 2</td>
</tr>
<tr>
<td>Round 2</td>
<td>183 ± 12</td>
<td>93 ± 6</td>
<td>177 ± 13</td>
<td>90 ± 7</td>
<td>10.4 ± 2.4^</td>
<td>13 ± 2</td>
</tr>
<tr>
<td>Round 3</td>
<td>187 ± 8^</td>
<td>96 ± 5^</td>
<td>178 ± 12</td>
<td>91 ± 7</td>
<td>11.9 ± 2.1^</td>
<td>14 ± 2^</td>
</tr>
<tr>
<td>Mean</td>
<td>182 ± 6</td>
<td>93 ± 3</td>
<td>175 ± 4</td>
<td>89 ± 2</td>
<td>9.9 ± 2.3</td>
<td>13 ± 2</td>
</tr>
</tbody>
</table>

*Denotes precombat values are significantly different from those reported in rounds 1, 2, and 3 ($P<.01$). ^Denotes corresponding values are significantly different from those of round 1 ($P<.05$).
The percentage of time spent in specific HR intensity zones altered significantly between rounds (Figure 2). A significantly greater proportion of time was spent in “hard” HR intensities in round 1 in comparison with rounds 2 and 3, whereas the time spent in “very hard” HR intensities during round 1 was significantly less than during both rounds 2 and 3. Little variation was evident in individuals’ HR during each round. The degree of variation for individuals represented by the SD of each round ranged between 4 and 11 beats∙min⁻¹, 4 and 7 beats∙min⁻¹, and 2 and 7 beats∙min⁻¹ for rounds 1, 2, and 3 respectively.

**Discussion**

To the authors’ knowledge, this is the first study to detail the physiological responses and perceived exertion during authentic international-level Taekwondo competition. The main findings of this study suggest that international Taekwondo competition is a high-intensity activity that elicits near-maximal cardiovascular responses and high blood lactate concentrations, and increases in competitors RPE across combat.

Mean HR elicited during international Taekwondo competition was 182 beats∙min⁻¹. This corresponded to approximately 93% of competitors’ HRₘₐₓ. These HR responses suggest that high demands are placed upon aerobic metabolism during competition. Comparable cardiovascular strain has been reported during national-level Taekwondo competition (approx. 100% HRₘₐₓ), simulated Taekwondo competition (99% HRₘₐₓ), and during analogously structured martial arts competitions such as Pencak Silat (89% to 97% HRₘₐₓ) and Karate (97% HRₘₐₓ).⁴,⁷,¹⁹,²⁰ This would suggest that the physiological demands are similar irrespective of style of combat or level of competition.

![Figure 2](image-url) — Percentage of time spent in HR intensity zones across each round. Data represent mean ± SD. *Denotes significantly different from moderate intensity in round 1, P < .05. **Denotes significantly different from maximum intensity in round 2, P < .05. ***Denotes significantly different from hard intensity in round 3, P < .05. ^Denotes significantly different from corresponding intensity elicited in round 1, P < .05.
Competitors’ HR and % HR$_{\text{max}}$ increased significantly from round 1 to round 3. In addition, the percentage of time spent in “very hard” HR intensities during rounds 2 and 3 was significantly greater than round 1. These findings collectively suggest that the cardiovascular demands increased across rounds. These increased demands could be the result of an increased work rate in response to a greater requirement to obtain points toward the latter stages of combat. The typical duration of combat would suggest that the increased cardiovascular strain is unlikely to be the consequence of physiological mechanisms, such as cardiovascular drift. Competitors’ HR demonstrated little variation during each round, irrespective of Taekwondo competitions’ intermittent activity pattern. Similar responses have been observed during Taekwondo and Pencak Silat competitions using visual inspections of individual competitors’ HR. The small variation in HR during rounds may be attributed to the short work:recovery intervals that are experienced during combats. This would suggest that the physiological demands are sustained throughout the combat, providing the competitors with little time for recovery.

The mean blood lactate concentration elicited during competition was 9.9 mmol·L$^{-1}$. Blood lactate increased significantly from precombat to round 1 and between rounds 1 and 2, although not between rounds 2 and 3. High blood lactate concentrations elicited during each round suggest that high demands are also placed upon anaerobic metabolism during combat, particularly anaerobic glycolysis. The significant increase in blood lactate from precombat to post-round 1 would suggest that anaerobic glycolysis was activated during the early stages of combat. Comparable anaerobic demands have also been reported during national-level Taekwondo competition (11.4 mmol·L$^{-1}$), simulated Taekwondo competition (10.2 mmol·L$^{-1}$), and during analogously structured martial arts competitive environments, such as Pencak Silat (8.8 to 12.5 mmol·L$^{-1}$). This again would suggest that the type of combat and level of competition do not influence anaerobic energy provision.

The mean RPE elicited during competition was 13, corresponding to “somewhat hard” perceptions of effort. The RPE increased significantly from “light” in round 1 to “hard” perceptions of effort in round 3. Although RPE increased significantly across rounds, a clear dissociation between competitors’ physiological strain and perception of effort was observed during competition. For instance, mean competition data suggests that high blood lactate concentrations (9.9 mmol·L$^{-1}$) and “very hard” (93% HR$_{\text{max}}$) HR intensities elicited an RPE of 13, which is typical of “moderate” (eg, 55% to 69% HR$_{\text{max}}$) physiological loads. A similar dissociation between practitioners’ cardiovascular strain and perception of effort has also been observed during Taekwondo training. Ratings of perceived exertion can be affected by numerous physiological and psychological mediators. This makes it difficult to fully elucidate the cause of the low RPE responses in the current data. Despite this, competitors’ direction of attentional focus may have influenced effort sense in this environment. For instance, increased levels of external attentional focus, such as the addition of memory tasks, mental arithmetic, and audio stimuli during exercise bouts, divert attention away from internal attentional focus (eg, cardiorespiratory strain), thus reducing effort sense. It is possible that external sensory cues commonly associated with Taekwondo competition, such as tactical decision making in response to an opponent’s actions and emotional strain (eg, anxiety) could divert attention away from internal sensory cues, thus reducing effort sense in this environment. It is pertinent to note that competitors were evaluated during
a high-level international competition where the consequence of the match outcome was great and hence the emotional strain and such effects are anticipated to be high. Further research is required to substantiate this hypothesis. Irrespective of the potential mechanisms involved, the findings of this study suggest that the independent use of RPE to determine exercise intensity may underestimate the degree of physiological strain in sports such as Taekwondo.

Conclusions and Practical Applications

International-level Taekwondo competition elicited near-maximal cardiovascular responses, high blood lactate concentrations, and increases in competitors’ RPE across combat. Practically, this suggests that Taekwondo conditioning sessions should include exercise bouts, which sufficiently stimulate both aerobic and anaerobic metabolism. Taekwondo practices incorporating comparable activities and work:recovery intervals as those observed during competition should provide a suitable stimulus for such conditioning purposes. Coaches and practitioners should, however, be cautious of using RPE to monitor physiological load in Taekwondo. The present data not only provides the basis of information required to inform the structure of conditioning sessions for international-level competitors, but also appears to be generalizable to other populations of Taekwondo practitioners.

Acknowledgments

The authors would like to thank (1) Gary Hall (performance director for Sport Taekwondo UK Ltd) for the organization of data collection, (2) all the competitors who participated in the study, and (3) the Swedish Taekwondo Federation for granting access to the competitors during the competition. The authors declare that we have no conflict of interest.

References


