The Construct Validity of Session RPE During an Intensive Camp in Young Male Taekwondo Athletes

Monoem Haddad, Anis Chaouachi, Carlo Castagna, Del P. Wong, David G. Behm, and Karim Chamari

Purpose: The session rating of perceived exertion (RPE) is a practical and non-invasive method that allows a quantification of the internal training load (TL) in individual and team sports, but no study has investigated its construct validity in martial arts. Therefore, the purpose of this study was to examine the convergent validity between the session-RPE method and two objective HR-based methods for quantifying the similar TL during a high-TL camp in young Taekwondo (TKD) athletes. Methods: Ten young TKD athletes (mean ± SD: age, 13.1 ± 2.4 y; body mass, 46.1 ± 12.7 kg; height, 1.53 ± 0.15 m; maximum heart rate (HRmax), 201.0 ± 8.2 bpm) participated in this study. During the training period, subjects performed 35 TKD training sessions, including two formal competitions during which RPE and HR were recorded and analyzed (308 individual training sessions). Correlation analysis was used to evaluate the convergent validity between session-RPE method and the two commonly used HR-based methods for assessing TL in a variety of training modes. Results: Significant relationships were found between individual session-RPE and all the HR-based TLs (r values from 0.55 to 0.90; P < .001). Significant correlations were observed in all mode of exercises practiced in TKD. Conclusions: This study shows that session-RPE can be considered as a valid method to assess TL in TKD.

Keywords: youth, martial arts, perceived exertion, combat sports, heart rate.

Taekwondo made its first appearance as a demonstration sport at the 1988 Summer Olympics in Seoul, South Korea. Taekwondo became an official Olympic sport in the 2000 Summer Olympics, in Sydney, Australia. This Korean martial
Monitoring Taekwondo Sessions

art is an intermittent activity that requires fast, high, and spinning kicks. To adapt training for optimal performance in this sport, various studies have used heart rate (HR) to determine the exercise intensity of Taekwondo. To our knowledge, there are no studies using HR to monitor the overall internal load (ie, physiological stress) of Taekwondo sessions. However, training load (TL) is important as it represents the stimulus for obtaining physiological adaptations. The assessment of internal training load requires quantification of the intensity of the physiological stress imposed on the athlete and its duration. Although the duration of a training session is easily measurable in minutes, intensity can be determined with different methods, such as HR. The use of HR to measure exercise intensity is based on the well-known linear relationship between HR and oxygen consumption over a wide range of steady-state submaximal workloads. However, the application of HR as a measure of exercise intensity in Taekwondo has several limitations. For example, the HR response can be a poor method for evaluating intensity during high-intensity exercise such as weight, interval, intermittent, and plyometric training. Many of these training methods are regularly implemented in Taekwondo programs. An additional problem with using HR methods for quantification of internal TL in martial arts such as Taekwondo is that HR transmitter belts are not permitted during official competitions for safety reasons.

A simple perceived exertion–based method for quantifying TLs has been developed. With this method (session-RPE), a single number representing the magnitude of TL for each session is calculated by multiplying the rating of perceived exertion (RPE) with the training session duration (in minutes). The session-RPE has been shown to be a valid method for quantifying the intensity of the whole training for both steady-state and intermittent exercises. The RPE has been reported to be correlated with many physiological measures of exercise intensity such as oxygen consumption (VO₂), ventilation, respiratory rate, blood lactate concentration ([BLa⁻]), heart rate (HR), and electromyography activity during a variety of exercise protocols.

The use of RPE to assess the subjective level of exertion during exercise has also been applied using children as subjects. In general, children are able to use the RPE scale in a reliable and valid manner. To date, no study examined the construct validity of the session-RPE method for quantifying internal TL in young Taekwondo athletes where the operational definition of the construct is the internal TL. Therefore, the aim of the present study was to evaluate the convergent validity between the session-RPE and two HR-based methods described by Edwards and Banister et al for assessing the internal TL in a variety of training modes with young Taekwondo athletes.

Methods

Participants

Ten male youth competitive Taekwondo athletes, aged between 10 and 15 y (mean ± SD: age, 13.1 ± 2.4 y; height, 1.53 ± 0.15 m; body mass, 46.1 ± 12.7 kg; HRmax, 201.0 ± 8.1 bpm, and HRrest, 53.1 ± 8.8 bpm) belonging to the largest classical Taekwondo club in the area of Manouba, Tunis, Tunisia, volunteered to participate in this study. All athletes had more than 2 y of experience with participation in
national competitions. Athletes’ typical training regimen before the training camp included set training sessions of 3 d/wk, approximately 2 h in duration, and often with the inclusion of further sessions of personalized work when necessary (range, 6–10 h/wk). During this typical training, the first 45 min of training (including 15 min dedicated for a warm-up) were generally designed to focus on fitness development and the remainder of the session was devoted to technical and tactical aspects of Taekwondo with approximately 5 min of cool-down at the end. Before the study, athletes received a letter with written information about the study design, the experimental risks, and a request for consent from the parents to allow their children to participate in the study. Parental and athlete informed consent was taken before the children could take part in the experiment. The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the Clinical Research Ethics Committee and the Ethic Committee of the National Centre of Medicine and Science of Sports of Tunis before the commencement of the assessments. All athletes were fully accustomed to the procedures used in this research and were informed they could withdraw from the study in any time without penalty.

**Procedures**

**Field Data Collection.** Subjects took part in a 2-wk Taekwondo training camp consisting of one to three daily sessions planned by the team coach (see Table 2). Before the camp, all athletes completed a shuttle run test to determine baseline endurance and maximum heart rate. At the time of the study, all athletes trained under the supervision of the same coach preparing for the upcoming national Taekwondo championship. Throughout the camp, training sessions included a combination of the following typical activities: basic techniques, technical combinations, predetermined sequence of movements (forms), breaking techniques, self-defense techniques, step sparring, sparring (skill) drills, and free sparring. Additional cardiovascular training and low-impact plyometric training were incorporated within these training sessions. Both the training volume and intensity were relatively high. A model Taekwondo competition was programmed on each Sunday. The Taekwondo competition constituted of several Taekwondo fights varied from 1 to 4 Taekwondo fights (ie, two rounds of 90 s with 30 s of recovery according to the internal rules of the Tunisian Taekwondo Federation with young Taekwondo athletes). In total, 35 training sessions were performed during the training camp including two formal Taekwondo competitions.

**Monitoring Training Loads.** Daily individual training load was calculated using the Foster’s session-RPE procedure. This method involved multiplying the training duration in minutes by the mean training intensity. The session-RPE scale is based on the Borg category ratio (CR-10) RPE scale and then modified by Foster et al, which translates the athlete’s perception of effort into a numerical score between 0 and 10. This test is designed to ask the athlete to respond to a simple question—How was your workout?—with the goal of getting an uncomplicated response that reflects the athlete’s global impression of the workout. In the present study, the French version of the CR10-scale cited by French researchers and coaches was used. All athletes had been familiarized to this scale before the start of the study (2 wk preceding the training camp) and followed standardized instructions for RPE.
Each athlete’s RPE was collected approximately 30 min after each Taekwondo session to ensure that the perceived exertion referred to the whole session rather than the most recent (end-of-session) exercise intensity. During the Taekwondo competition, athletes’ RPEs were collected after each Taekwondo fight to ensure that the perceived effort referred to the Taekwondo fight only. Fight session-RPE was calculated by multiplying this fight RPE by Taekwondo fight duration.

**Criterion Methods for Quantifying Physical Training Loads.** Two HR-based training load methods were used to measure internal TL: Banister TRIMP and Edwards TL. The Banister TRIMP tries to weight the duration using an exponential factor, as in the following formula:

\[
TD \cdot HR_R^0 \cdot 64e^{1.92\cdot HR_R}
\]

In which TD is the effective training session duration expressed in minutes and HR_R is determined with the expression \([\frac{HR_T S - HR_B}{HR_{\text{max}} - HR_B}]\), where HR_T S is the average training-session heart rate and HR_B is the heart rate measured at rest.

The HR-based method proposed by Edwards was also used as a common indicator of internal TL in various disciplines. The criterion-related validity between Banister’s TRIMP and Edwards’s TL was verified in many studies, such as that of Borresen and Lambert, who found high significant correlation between these two HR-based methods \((r = .98; 95\% \text{ CI:} 0.96 \text{ to} 0.99)\). Recently, this method was published in a review article of Borresen and Lambert as an index of training stress like Banister’s TRIMP and Lucia’s TRIMP. Indeed, practically all the research analyzing the ecological validity of session-RPE has used this HR-based method, such as Impellizzeri et al in soccer and Wallace et al in swimming. We also used it with a recently published paper on basketball. However, Edwards’s TL may have been derived theoretically and not through experimentation, raising the question of the legitimacy of validating the session-RPE method against this HR-based method. This method determines internal load by measuring the product of the accumulated training duration (minutes) in five HR zones by a coefficient relative to each zone (50–60% of HR_{\text{max}} = 1, 60–70% of HR_{\text{max}} = 2, 70–80% of HR_{\text{max}} = 3, 80–90% of HR_{\text{max}} = 4, and 90–100% of HR_{\text{max}} = 5), and then summing the results.

**HR Measurements and Calculations.** Training intensity during each Taekwondo training session was recorded using Polar Team System HR monitors (Polar, Kempele, Finland), with HR recorded every 5 s. After each training session, HR data were downloaded to a computer using Polar Advantage Software (Polar Electro, Oy, Finland). To assess resting HR, athletes lay on a bed for 10 min at 5:30 AM. The resting HR value corresponded to the minimal HR observed during this 10 min period. The 20 m shuttle run test according to Léger and Gadoury was used to measure the HR_{\text{max}}. The highest average value from three consecutively recorded HRs (15 s) was considered as HR_{\text{max}}.

**Statistical Analysis**

The results are expressed as means ± standard deviation (SD). Before using parametric tests, the assumption of normality was verified using the Shapiro-Wilk W
test. Pearson product-moment correlation coefficients were calculated to determine whether session-RPE and the various HR-based TL methods were convergent. The magnitude of the correlations was determined using the modified scale of Hopkins: \( r < .1, \) trivial; \( 0.1–0.3, \) small; \( 0.3–0.5, \) moderate; \( 0.5–0.7, \) large; \( 0.7–0.9, \) very large; \( >0.9, \) nearly perfect; and \( 1 \) perfect. Significance and meaningful acceptance of the correlation were set at \( 5\% \) (\( P \leq .05 \)) and \( 0.5 \) (large to perfect), respectively.

### Results

#### Individual Correlations

The HR and RPE were collected from 308 training sessions. Individual correlations were determined on a minimum of 22 to a maximum of 35 training sessions’ data. Significant relationships were found between individual session-RPE and all the HR-based TLs (\( r \) values from 0.55 to 0.90; \( P < .001 \)). Individual correlations are presented in Table 1.

#### Group Correlation

The pattern of session-RPE and Banister’s TRIMP during the 2 wk of the intensive training camp is shown in Figure 1.

#### Exercises Mode Correlations

The mean session-RPE values and correlations in each exercise mode between session-RPE and HR-based TLs (ie, Edwards’s TL and Banister’s TRIMP) are reported in Table 2. A significant correlation was observed in all modes of training. Lower, although significant, meaningful correlations were observed in intermittent, speed, and plyometric training. Significant correlations were found between the fight session-RPE method and HR-based methods (ie, Edwards’s TL, \( r = .68; \) 95% CI: 0.46 to 0.82 and Banister’s TRIMP, \( r = .74; \) 95% CI: 0.55 to 0.86, \( n = 14 \)) during the two model competitions.

### Discussion

This is the first study that investigated the construct validity of session-RPE as indicator of internal TL in young Taekwondo athletes. Specifically, we determined the correlations (convergent validity) between session-RPE and two HR-based methods commonly considered as valid indicators of internal TL during training and competitions. In the present investigation, large correlations were found between session-RPE and HR-based methods (ie, Banister’s TRIMP, \( r \) values from 0.56 to 0.90; Edwards’s TL, \( r \) values from 0.55 to 0.86). The magnitude of correlations between session-RPE method and the HR-based methods were similar to those reported by previous investigations, such as in swimming (\( r \) values from 0.55 to 0.92) adult athletes (ie, age 22.3 ± 3.1 y),\(^{16}\) endurance adult athletes (\( r \) values from .75 to 0.90),\(^{6}\) and young soccer players aged 17.6 ± 0.7 y (\( r \) values from 0.50 to 0.85).\(^{8}\) All these studies have used the session-RPE as described by Foster et al.\(^{7}\)
### Table 1  Individual correlations between session-RPE and various HR-based training loads

<table>
<thead>
<tr>
<th>Subject</th>
<th>Number of Sessions</th>
<th>Banister’s TRIMP</th>
<th>CI (95%)</th>
<th>Edwards’s TL</th>
<th>CI (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lower limit</td>
<td>Upper limit</td>
<td>Lower limit</td>
</tr>
<tr>
<td>S1</td>
<td>30</td>
<td>0.60***</td>
<td>0.31</td>
<td>0.79</td>
<td>0.56***</td>
</tr>
<tr>
<td>S2</td>
<td>30</td>
<td>0.74***</td>
<td>0.52</td>
<td>0.87</td>
<td>0.80***</td>
</tr>
<tr>
<td>S3</td>
<td>25</td>
<td>0.77***</td>
<td>0.54</td>
<td>0.89</td>
<td>0.77***</td>
</tr>
<tr>
<td>S4</td>
<td>35</td>
<td>0.74***</td>
<td>0.55</td>
<td>0.86</td>
<td>0.77***</td>
</tr>
<tr>
<td>S5</td>
<td>34</td>
<td>0.90***</td>
<td>0.89</td>
<td>0.95</td>
<td>0.78***</td>
</tr>
<tr>
<td>S6</td>
<td>34</td>
<td>0.67***</td>
<td>0.43</td>
<td>0.82</td>
<td>0.55***</td>
</tr>
<tr>
<td>S7</td>
<td>32</td>
<td>0.56***</td>
<td>0.26</td>
<td>0.76</td>
<td>0.66***</td>
</tr>
<tr>
<td>S8</td>
<td>33</td>
<td>0.82***</td>
<td>0.66</td>
<td>0.91</td>
<td>0.86***</td>
</tr>
<tr>
<td>S9</td>
<td>33</td>
<td>0.86***</td>
<td>0.73</td>
<td>0.93</td>
<td>0.82***</td>
</tr>
<tr>
<td>S10</td>
<td>22</td>
<td>0.81***</td>
<td>0.59</td>
<td>0.92</td>
<td>0.77***</td>
</tr>
</tbody>
</table>

***Significant at $P < .001$. 
Table 2  Mean training load and correlation coefficients for the session-RPE method and HR-based methods separated by training session mode for the combined group of young Taekwondo athletes

<table>
<thead>
<tr>
<th>Mode of Training</th>
<th>Number of Sessions</th>
<th>Mean TL (Session-RPE), AU</th>
<th>Edwards’s TL</th>
<th>CI (95%)</th>
<th>Banister’s TRIMP</th>
<th>CI (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower limit</td>
<td>Upper limit</td>
<td>Lower limit</td>
</tr>
<tr>
<td>Aerobic Training</td>
<td>107</td>
<td>134 ± 60</td>
<td>0.57***</td>
<td>0.43</td>
<td>0.69</td>
<td>0.60***</td>
</tr>
<tr>
<td>Tec/Tac</td>
<td>105</td>
<td>398 ± 173</td>
<td>0.61***</td>
<td>0.47</td>
<td>0.72</td>
<td>0.60***</td>
</tr>
<tr>
<td>Intermittent Exercises / Plyometric Training / Speed</td>
<td>72</td>
<td>257 ± 113</td>
<td>0.31**</td>
<td>0.09</td>
<td>0.51</td>
<td>0.32**</td>
</tr>
<tr>
<td>Total</td>
<td>308a</td>
<td>263 ± 169</td>
<td>0.63***</td>
<td>0.56</td>
<td>0.69</td>
<td>0.67***</td>
</tr>
</tbody>
</table>

*Note. Significant at *P < .05, **P < .01, and ***P < .001. AU = arbitrary unit. Tec/Tac = technical and tactical Taekwondo training.

*aIncluding 14 data values of Taekwondo completion and 10 data values from shuttle run test.
Figure 1 — Profile of the session rate of perceived exertion training load (TL) vs Edwards’s TL method across the training sessions examined during the training camp (35 training sessions including 2 competitions). The training session number 36 represents the TL of the shuttle run test, 20 m (n = 308).
RPE During Aerobic Training

In the present study, the magnitude of the association between session-RPE and HR-based methods (Table 2) is strong enough to provide confirmation that session-RPE can be a valid alternative indicator for quantifying measures during aerobic training in young Taekwondo athletes. These results are consistent with the study of Foster et al., where individual correlations between session-RPE method and Edward’s TL ranged between $r = .75$ and 0.90, but no statistical methods were explained in this study. The authors concluded that session-RPE was a valid and reliable measure of exercise intensity in aerobic exercise when compared with Edward’s TL. Also, Foster et al. found that although Edward’s TL gave lower scores than the session-RPE method (because of differing units), the pattern of differences between the two methods was very consistent; however, no correlation coefficients were provided by Foster et al. The only use of Edward’s TL to establish this pattern is not sufficient since this HR-based method has not been fully validated through experimentation (for a review, see Borresen and Lambert). In the present study, a similar consistent pattern of differences between session-RPE method and Banister’s TRIMP is shown in Figure 1.

RPE During High-Intensity Exercises

Ratings of perceived exertion have been shown to offer a simple and valid method for quantifying whole-training-session intensity in high-intensity intermittent exercise, and speed and plyometric training in young and adult athletes. In the present study, the magnitude of the association between session-RPE and Banister’s TRIMP is low, as are both confidence limits observed in this mode of exercise ($r = .32; 95\% CI = 0.10$ to 0.51) (Table 2). These weak correlations indicate that session-RPE and HR-based methods are not convergent. The results of the present study are similar to those of previous studies examining the relationship between RPE and HR measures during intermittent exercise. For example, in a meta-analysis, Chen et al. demonstrated that the 95% confidence interval of validity coefficients between HR and RPE was $r = .39–0.61$ during intermittent exercise. The resulting lower association between session-RPE and Banister’s TRIMP may be the result of the dependence on a large contribution from oxygen-independent metabolism rather than oxygen-dependent mechanisms during high-intensity exercises, which lead to the increased internal TL through increased RPE without a concomitant increase of HR. Therefore, HR may not be an appropriate global measure of high-intensity exercises. This is supported by a previous study that reported an increased subject’s RPE during intermittent protocols in comparison with a steady-state exercise session matched for total work, despite no differences in mean VO$_2$ and HR between the two exercise protocols.

Since HR-based methods are considered relatively poor methods of evaluating very-high-intensity exercises such as speed training, plyometric exercise, and high-intensity interval training, it seems that using HR-based methods as the criterion measure of exercise intensity is a limitation. Furthermore, additional factors other than HR have been suggested to contribute to the perception of exertion following high-intensity exercise. In this regard, Robertson and Noble have suggested that such psychobiological factors as metabolic acidosis, ventilatory drive, respiratory gases, catecholamine, $\beta$-endorphins, and body temperature are related to the percep-
tion of exertion. The HR-based methods are not sensitive enough to reflect these factors. It is possible that other markers of exercise intensity, such as blood lactate measures taken during high-intensity exercise, may better relate to session-RPE measures than HR measures per se.24 In agreement with previous research,8,24 the present results suggest that the session-RPE method is a good practical means for quantifying internal TL in high-intensity exercises with young Taekwondo athletes.

**RPE During Specific Taekwondo Training and Taekwondo Competition**

In Taekwondo, technical and tactical sessions significant correlations were observed between session-RPE and Edwards’s TL ($r = .61$; $95\%$ CI = 0.47 to 0.72) (Table 2). These values are in accordance with the results reported with other athletes, such as young soccer players.8 The moderate correlation found in this mode of exercise can be explained by the characteristic of technical and tactical training in Taekwondo, which requires different amounts of energy expenditure, making it dependent on a combination of aerobic and anaerobic pathways.1,2 The different perceived exertion with similar mean HR may explain the reduced magnitude of the correlation between the session-RPE and HR-based TL as compared with previously reported adult endurance athletes.6 The correlation observed in the present study can be influenced by the young age of athletes11,26 or the level of their skills.27 The scale used in the present study (ie, Borg’s CR-10 scale) may also have influenced the results but, in spite of all these possible influence factors, session-RPE can provide a valuable measure of TL in technical and tactical sessions of Taekwondo with young athletes. During the Taekwondo competition, the large correlation between RPE-session and Edwards’s TL ($r = .68$; $95\%$ CI: 0.46 to 0.82) persisted. The peak HR reported during a Taekwondo competition in a previous study was high,2 and when it is expressed in percentage of age-predicted maximal HR, the value was 99%. The lack of a steady state showed that the energetic demand during competition surpassed the potential of the aerobic metabolism and solicited anaerobic glycolysis. A limitation of the present study is that blood lactate concentration was not taken into account during Taekwondo competition to determine the correlation of RPE and blood lactate concentration. Various researchers have shown that the combination of HR and blood lactate concentration predicts RPE more accurately than either measure taken alone.24,28 These previous studies suggest that RPE may be a more reliable measure of exercise intensity when both anaerobic and aerobic systems are appreciably activated, such as during Taekwondo competition.2

**Practical Applications and Conclusions**

The results of the present study provide evidence that the session-RPE method is quantifying the similar internal TLs assessed by the HR-based methods during such exercises in young Taekwondo athletes. However, the magnitude of the correlation between session-RPE TL and HR-based TL is less meaningful during high-intensity exercises for which RPE is not a valid substitute for HR. These types of exercise depend on a large contribution from oxygen-independent metabolism rather than oxygen-dependent mechanisms and therefore HR may not be an appropriate global measure of high-intensity exercises.5 In conclusion, session-RPE is a measure of
both physiological and psychological factors and would allow young Taekwondo athletes’ coaches to evaluate and monitor the global training stress imposed upon each athlete. The use of the session-RPE method provides a practical, low-cost, and noninvasive mean for quantifying training load in Taekwondo, thus making it a valuable tool for athletes, coaches, and sport scientists.

Acknowledgments

The authors acknowledge the young Taekwondo athletes involved in this investigation. This study was financially supported by the Tunisian Ministry of Scientific Research.

References