VALIDITY OF A PEDIATRIC RPE SCALE WHEN DIFFERENT EXERCISE INTENSITIES ARE COMPLETED ON SEPARATE DAYS

Jacob E. Barkley1, James N. Roemmich2
1Exercise Science, The School of Health Sciences, Kent State University, Kent, Ohio, USA
2Division of Behavioral Medicine, Department of Pediatrics, State University of New York at Buffalo, Buffalo, New York, USA

Typically pediatric-specific ratings of perceived exertion (RPE) validation studies have utilized a perceptual estimation paradigm consisting of a single exercise test that incrementally increased in intensity. This may result in an overestimation of concurrent validity as the increases in exercise intensity and participant recall of their previous RPE likely encourages participants to respond with increases in RPE. The purpose of the present study was to assess the concurrent validity of the Cart and Load Effort Rating (CALER) RPE scale in children exercising either above or below the ventilatory threshold (>VT, <VT, respectively) on separate days. Thirty-two children performed 5 minutes of continuous cycle ergometer exercise at 20% < VT on 1 day and 5% > VT on another day. Heart rate (HR) and RPE were recorded during the final 20 seconds of each minute of exercise. HR and RPE increased from < VT to > VT (p < 0.001). Univariate correlations demonstrated a moderate relationship between HR and RPE (r = 0.50). Multilevel model regression demonstrated that RPE scores were positively associated with HR (estimate = 2.06 CALER, p < 0.01). Pediatric RPE scores assessed on separate days appropriately increased with exercise intensity and were positively associated with HR. However, the RPE–HR relationships are lower than for research that used exercise tests that incrementally increased in intensity within the same session. [J Exerc Sci Fit • Vol 9 • No 1 • 52–57 • 2011]

Keywords: child, intensity, perceived exertion, validity

Introduction

Several rating of perceived exertion (RPE) scales that cover a variety of exercise modalities have been developed for the pediatric population (Eston et al. 2009, 2000, 1994; Barkley & Roemmich 2008; Suminski et al. 2008; Parfitt et al. 2007; Roemmich et al. 2006; Robertson et al. 2005a, 2005b, 2002, 2000; Faigenbaum et al. 2004; Leung et al. 2002; Pfeiffer et al. 2002; Utter et al. 2002; Yelling et al. 2002; Williams et al. 1994). These scales are typically designed with a combination of simple numeric scales, verbal descriptors and pictorial illustrations of effort to increase the likelihood that children will better understand the scales than they would a traditional adult RPE scale such as the scale developed by Borg (Gros lambert & Mahon 2006; Eston et al. 2000, 1994; Robertson et al. 2000; Borg 1970). Multiple studies have demonstrated that, when assessing children, pediatric-specific RPE scales are more strongly associated with measures of physiologic effort and may be more reliable than the Borg RPE scale (Leung et al. 2002; Pfeiffer et al. 2002). The Cart and Load Effort Rating (CALER) scale is an example of a validated pediatric-specific RPE scale (Barkley & Roemmich 2008; Parfitt et al. 2007; Eston et al. 2000). The CALER scale consists of line drawings of a boy pedaling a bicycle across a flat surface towing a wagon that is increasingly filled with bricks over a numeric range of 1 to 10 with verbal descriptors ranging from “very, very easy” to “so hard I’m going to stop” (Figure). Previous evidence has
indicated that the CALER scale is a valid tool for regulating exercise intensity in children (Parfitt et al. 2007; Eston et al. 2000) and that it possesses both concurrent validity when compared to heart rate ($r = 0.88$) and $\text{VO}_2$ ($r = 0.92$) and construct validity when compared to a previously validated pediatric RPE scale ($r = 0.93$) (Barkley & Roemmich 2008).

The majority of the pediatric-specific RPE validation studies, including those to establish the validity of the CALER scale, have utilized a perceptual estimation paradigm consisting of an exercise test that incrementally increased in intensity and is completed during a single session (Barkley & Roemmich 2008; Roemmich et al. 2006; Utter et al. 2002; Yelling et al. 2002; Robertson et al. 2001, 2000). Assessing the validity of RPE scales in this manner may result in an overestimation of concurrent validity as the stepwise increases in exercise intensity and participant recall of their previous effort estimation likely encourages participants to respond with stepwise increases in RPE. We, along with other researchers, have previously noted this potential problem in assessing concurrent validity of pediatric RPE scales utilizing an incrementally increasing exercise test (Barkley & Roemmich 2008; Eston & Lamb 2000). We have also suggested that exposing children to multiple exercise intensities that are not incrementally increasing in intensity could solve this problem by reducing the ability of children to recall their previous RPE for a given intensity (Barkley & Roemmich 2008).

The purpose of this investigation was to utilize a perceptual estimation paradigm to assess the concurrent validity of the CALER RPE scale when children performed an exercise session 5% above the ventilatory threshold (VT) on 1 day and 20% below VT on another day in counterbalanced order. We hypothesized that even with the two exercise intensities tested on separate visits separated by at least 2 days, there would be concurrent validity of the CALER scale as evidenced by a positive association between CALER RPE and heart rate.

**Methods**

**Participants**

Participants included boys ($n = 16$) and girls ($n = 16$) aged 8 to 12 years. The children were recruited through posted flyers and a database of individuals who had previously contacted the Behavioral Medicine Laboratory at the University at Buffalo for unrelated studies. Children were excluded if they had any contraindications to physical activity including; cardiovascular, cognitive, orthopedic, neuromotor and/or metabolic disorders. Children also had not had prior experience with RPE scales. Prior to participation, informed assent and consent was obtained from the child and their parent respectively. This study was approved by the University at Buffalo School of Medicine Institutional Review Board.

**Procedures**

Children meeting the entry criteria were invited to the Behavioral Medicine Laboratory for a total of three visits. After obtaining child assent and parent consent, a trained anthropometrist measured participants for height and weight with a stadiometer (Seca, Hamburg, Germany) and a digital scale (Tanita, Arlington Heights, IL, USA), respectively. Participants then completed a progressive maximal exercise test on a magnetically-braked cycle ergometer (model EC-1600, Cateye Fitness, Dallas, TX, USA). Children became familiar with the cycle ergometer by pedaling at 50 revolutions·min$^{-1}$ and a resistance of 0.6 kg for 2 minutes. The initial workload was set at 30 watts and increased by 10 watts·min$^{-1}$ each minute until participants could not maintain a pedaling cadence of 50 revolutions·min$^{-1}$. This protocol has previously been utilized to establish
VT in children (Mahon et al. 1997). Throughout the exercise test, heart rate (beats·min⁻¹) and oxygen consumption (VO₂ mL·kg⁻¹·min⁻¹) were recorded via a telemetry monitor (Polar Electro, Inc., Woodbury, NY, USA) and indirect calorimetry using a calibrated metabolic cart (Sensormedics, Yorba Linda, CA, USA), respectively.

During the next two laboratory visits, children pedaled on the same cycle ergometer for a period of 5 minutes at a workload that elicited a VO₂ 20% below VT on 1 day and 5% above VT on the other in a counterbalanced fashion. Specifically, the 20% below VT intensity was selected as it is a moderate intensity which is similar to the intensity that children spend the majority of their leisure-time physical activity (Gilliam et al. 1981). The 5% above VT intensity was selected as it is a vigorous intensity that children can maintain for at least 5 minutes (Barkley et al. 2009). The range between the two intensities was intentionally large in an effort to best allow children to perceive the workloads as different from one laboratory visit to the next. Heart rate was recorded during the final 20 seconds of each minute. To assure achievement of steady-state, only the heart rate from the 5th (final) minute of each exercise session was used in the analyses. Children reported their undifferentiated (total body) RPE using the CALER scale at the conclusion of each minute of exercise. Only the RPE from the 5th minute of each exercise session was used in the analyses. The cycle ergometer seat height and handle bar position were kept constant for the progressive maximal exercise, exercise below VT and above VT for each child. All participants reported to the laboratory in the late afternoon for each laboratory visit to control for time of day as effort perception may differ for exercise performed in the morning versus the afternoon (Hill et al. 1989).

Measurement
Ventilatory threshold
VT was identified as the workload from the progressive cycle ergometer test immediately before the ventilatory equivalent for oxygen (V̇E/VO₂) begins to increase without a corresponding increase in the ventilatory equivalent for carbon dioxide (V̇E/VCO₂). The VO₂ corresponding to VT was then determined as was the workload required to elicit a VO₂ 20% below and 5% above VT. The plots were examined independently by three investigators with agreement between at least two required to establish VT. This method is considered the standard for assessing VT in children (Amann et al. 2004; Gaskill et al. 2001; Cheatham et al. 2000; Hebestreit et al. 2000; Mahon et al. 1997).

Ratings of perceived exertion
Immediately before each 5-minute exercise bout, children were shown and instructed how to use the CALER scale. Instructions for the use of the RPE scale for total body (undifferentiated) RPE were provided as previously described (Barkley & Roemmich 2008). Children were asked to visualize an intensity that would be similar to the minimum and maximum ends of each scale; a boy with a wagon that was empty or full of bricks. The process of establishing cognitive anchors were modified from previous research (Robertson et al. 2000) to account for the pictorial descriptors in the CALER scale. Children verbally indicated their RPE during each minute of exercise.

Data analysis
Subject characteristics including height, weight, BMI, age and VO₂ peak were compared between boys and girls using independent samples T-tests. Two sexes (boys, girls) by two exercise intensities (above VT, below VT) ANOVA with repeated measures on the second factor were utilized to examine differences in heart rate and CALER RPE.

Concurrent validity of the scale was assessed by testing the relationships between RPE scores and heart rates using both univariate correlation (r) and a multilevel regression model (MLM). Univariate coefficients were calculated for each child by individually correlating their two CALER RPE scores from the above and below VT workloads with their two heart rates from the same two workloads. The coefficients from all children were then averaged and reported as a single mean r for each relationship. A probability value could not be calculated for these average correlations, but this analytic plan is similar to earlier studies and allowed for comparisons with previous research. An overall correlation coefficient and probability for the entire group could not be determined because each subject had multiple scores in the data set, which violates the assumption of independent scores when using univariate correlation. MLM was utilized to establish the overall significance of the relationship between the RPE scores and heart rate. MLM allows for the analysis of the relationship between dependent and independent variables when data from the same subject are represented more than once in the data set by adjusting for the nonindependence or nesting of these scores. For each model, a “subject” variable was
included to identify nesting of scores from the same subject. Linear relationships were tested with the time variant predictor of exercise intensity and a random intercept. Sex was included as a time invariant fixed effect, but it was not a significant predictor and therefore not included in the final models. Because sex was not a significant predictor in the multiple linear regression model, data from boys and girls were also pooled for the univariate correlation analysis. Finally, tests of proportion were utilized to compare the average proportion of maximal CALER RPE scale indicated to the average proportion of maximal heart rate achieved at exercise intensities above and below VT.

Results

Subject characteristics are illustrated in Table 1. Boys had a greater VO2 peak than girls \(t(31) = 2.1, p < 0.05\). There were no other sex differences in subject characteristics \(t(31) ≤ 1.7, p ≥ 0.10\) for all. Heart rate and CALER RPE increased \(F(1,30) ≥ 20.8, p < 0.001\) for all from the below VT exercise intensity to the above VT exercise intensity (Table 2). RPE and heart rate results are presented with boys and girls data pooled (Table 2) because there were no significant main \(F(1,30) ≤ 3.6, p ≥ 0.07\) for all or interaction effects \(F(1,30) ≤ .5, p ≥ 0.12\) for all of sex. Univariate correlation analysis demonstrated a positive relationship between the CALER RPE scale and heart rate \(r = 0.31\) across the above and below VT intensities. The CALER RPE scale increased in concert with heart rate from the below VT to the above VT intensity. In addition to the positive univariate correlation, multilevel regression analysis demonstrated that over the two exercise intensities, the CALER scale was significantly \((estimate = 2.22, p < 0.01)\) associated with heart rate. Tests of proportions demonstrated that the proportion of maximum RPE indicated was significantly \(z(31) ≥ 2.8, p ≤ 0.005\) less than the proportion of maximum heart rate achieved for intensities both above and below VT (Table 3).

Discussion

The present investigation, which assessed RPE and heart rate over two different exercise intensities performed on separate days, demonstrated evidence of concurrent validity for the pediatric CALER RPE scale. Heart rate and CALER RPE scores increased from the below VT to the above VT intensity and the increase in heart rate was positively associated with RPE scores. However, the correlation coefficient between RPE and heart rate \(r = 0.30\) was three-fold lower \(r = 0.88\) than research evaluating concurrent validity of the CALER RPE scale utilizing an incrementally increasing exercise test completed during a single session (Barkey & Roemmich 2008; Robertson et al. 2000). The lower concurrent validity in the present study provides evidence that having a previous reference point to contextualize the exercise intensity immediately preceding subsequent exercise intensities during an incremental exercise test paradigm may result in an overestimation of concurrent validity. However, the number of different exercise intensities children completed in the present study is fewer than the number of intensities a child would complete during a more typical incrementally increasing exercise test completed on a single day. Having children complete additional exercise intensities would have produced a greater number and range of scores likely increasing the

Table 1. Subject characteristics

<table>
<thead>
<tr>
<th></th>
<th>Boys ((n = 16))</th>
<th>Girls ((n = 16))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>9.5 ± 0.7</td>
<td>9.4 ± 0.8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>141.3 ± 6.4</td>
<td>137.7 ± 5.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>33.3 ± 4.5</td>
<td>32.7 ± 5.3</td>
</tr>
<tr>
<td>BMI [kg (m²)⁻¹]</td>
<td>16.5 ± 1.1</td>
<td>17.1 ± 1.8</td>
</tr>
<tr>
<td>VO₂ peak (mL·kg⁻¹·min⁻¹)†</td>
<td>40.8 ± 10.9</td>
<td>34.9 ± 3.3</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± standard deviation; †average proportion of maximum heart rate significantly greater \(p < 0.005\) than below VT for each variable.

Table 2. Average ratings of perceived exertion (RPE) and heart rate

<table>
<thead>
<tr>
<th></th>
<th>Below VT</th>
<th>Above VT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALER RPE</td>
<td>3.3 ± 0.4</td>
<td>4.7 ± 0.4</td>
</tr>
<tr>
<td>Heart rate (beats·min⁻¹)</td>
<td>150.1 ± 1.9</td>
<td>173.2 ± 1.8</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± standard error; †above VT significantly greater \(p < 0.001\) than below VT for each variable.

Table 3. Average proportion of maximum ratings of perceived exertion (RPE) and maximum heart rate'+

<table>
<thead>
<tr>
<th></th>
<th>Below VT</th>
<th>Above VT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALER RPE</td>
<td>32.5 ± 3.7</td>
<td>47.2 ± 3.7</td>
</tr>
<tr>
<td>Heart rate (beats·min⁻¹)</td>
<td>75.0 ± 0.9</td>
<td>86.6 ± 0.9</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± standard error; †average proportion of maximum heart rate achieved significantly greater \(p < 0.005\) than average proportion of maximum CALER RPE scale indicated both below and above VT.
strength of the relationships between the RPE scales and heart rate. Keeping subject burden in mind, future research should consider utilizing a greater number of exercise intensities performed on separate days in an effort to better match the number of intensities a child would be exposed to during an incrementally increasing exercise test completed on a single day.

In addition to lower correlation coefficients, the proportions of maximal RPE scale indicated were significantly less than the proportion of maximal heart rate achieved during both exercise intensities. Previous investigations, utilizing progressive exercise tests in children, noted that the proportion of maximal RPE scale indicated was 20% less than the proportion of maximal heart rate achieved (Barkley & Roemmich 2008; Roemmich et al. 2006). In the present investigation, the proportion of maximal CALER RPE was approximately 50% less than the proportion of maximal heart rate achieved for exercise both above and below VT. These lower proportions suggest again that a progressive exercise test conducted in a single session, relative to the current methodology, may lead to an overestimation of concurrent validity for this type of RPE scale.

The novel Eston-Parfitt curvilinear RPE scale (E-P scale), which consists of verbal, numeric and pictorial descriptors similar to the CALER scale, may offer an alternative to traditional pediatric RPE scales (Lambrick et al. 2011; Eston & Parfitt 2007). Instead of a straight line, the E-P scale utilizes a concave slope with an increasing gradient at greater intensities and progressively shorter distances between numeric descriptors of effort. Recent evaluations of the E-P scale have reported strong concurrent validity (relative to heart rate) in children completing a progressive exercise test ($r = 0.93–0.96$) (Lambrick et al. 2011; Eston & Parfitt 2007). This previous study, like the present one, also indicated that the reported RPE was less than the physiologic effort achieved in children at a maximal workload. However, while previous evaluations of linear RPE scales during progressive exercise have also noted a discrepancy between RPE and physiologic effort (20% gap), there was only a 4% gap between physiologic effort and RPE in children using the E-P scale. This suggests that the E-P scale may be more closely related to physiologic effort than its linear counterparts; therefore, additional research examining the E-P scale is warranted (Faulkner & Eston 2008).

It would be particularly interesting to examine the E-P scale’s effectiveness in predicting physiologic effort over multiple intensities conducted on separate days to determine if the E-P scale is more successful in predicting physiologic effort than a linear RPE scale similar to the one utilized in the present study.

In conclusion, this study was the first to demonstrate concurrent validity for the CALER RPE scale utilizing a perceptual estimation paradigm with different exercise intensities performed on separate days. The scale was significantly associated with a physiologic measure of effort. However, despite utilizing verbal instructions for the scale’s use which were identical to previous RPE validation studies, the relationship between RPE and heart rate was not as strong as previous evaluations of concurrent validity that utilized an incrementally increasing exercise test completed on the same day. This weaker association may be due to a fewer number of exercise intensities and therefore smaller range of scores than what is typically used during a progressive exercise test. It is also possible that the weaker association is because without a previous reference point to contextualize the exercise intensity immediately preceding subsequent intensities, perceived effort does not match physiologic effort as closely as what is seen during a single progressive exercise test. Future studies should include a greater number of exercise intensities again conducted over separate days and also make comparisons between linear scales like the one utilized presently and the novel E-P curvilinear scale to determine if the curvilinear scale is more effective at predicting physiologic effort.

References


