The Relationship Between Perceived Exertion and Heart Rate in Children and Adults

Mary C. Gillach, James F. Sallis, Michael J. Buono, Patricia Patterson, and Philip R. Nader

This study examined the relationship between heart rate (HR) as a measure of physiological strain and ratings of perceived exertion (RPE) in 193 children (mean age = 11 yrs) and 188 adults (mean age = 36 yrs) during submaximal cycle ergometry. Two methods of correlating HR and RPE were compared. Computing correlations (r) for each individual's data and then taking the group mean produced very high rs, ranging from 0.92 to 0.95. Correlating HR and RPE for the entire group at all powers simultaneously produced much lower rs, ranging from 0.63 to 0.65. Correlations were essentially the same for children and adults, and there was no evidence of a practice effect. The results indicated that (a) children in this age group were as capable of expressing RPE as adults, and (b) absolute levels of perceived exertion were not predictive of physiological strain (as indicated by heart rate).

Exercise intensity is reflected in the response of many physiological processes including oxygen consumption, blood pressure, blood lactate levels, and heart rate (HR). Because HR is linearly related to power and oxygen consumption (VO2) in adults (1, 18, 27), it is accepted as an accurate index of physiological strain.

An alternative method of monitoring exercise intensity is ratings of perceived exertion (RPE). These ratings, obtained from subjects during testing, are subjective estimates of strain that simultaneously reflect both physiological and psychological variables. The most commonly used RPE scale is the 15-point scale by Borg (6). This scale, which ranges from 6 to 20, was constructed to correspond with the normal HR range for most healthy middle-aged subjects. Thus, a given RPE value multiplied by 10 should approximate exercising HR (7, 8). Several studies by Borg and others have confirmed this 1:10 ratio of RPE to exercise HR in adults (6, 9, 13, 14, 17, 27) while others have not (12, 28). One study found this ratio to be accurate in adults but not in children (2). Whether HR can be reliably estimated by RPE remains unclear.

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The positive linear relationship between HR and RPE over a range of powers is well documented in adults (6, 11, 24, 25, 28, 29). Numerous studies report correlations ($r$) ranging from 0.77 to 0.90 (4, 6, 10, 27). Based on these high correlations, subjective ratings are presumed to accurately reflect physiological strain in adults. However, the statistical methodology used to calculate $r$s in these studies is often inadequately described. Few authors specified whether $r$s for individual subjects were used to calculate group mean $r$s or if $r$s were calculated from the simultaneous analysis of all subjects’ HR and RPE data. Most studies that reported their methodology used the former method, which is likely to inflate the correlation. It appears that the latter correlation method, which considers all variables at each power, is more appropriate.

Few studies have examined how children perceive their physiological strain. It is difficult to compare existing studies of adults and children because of differences in methodology. Studies of adults usually correlate absolute HR with RPE while few studies in children did so (2, 3). Most studies of children correlate percent HR max with RPE, with resulting $r$s ranging from 0.69 to 0.94 in children over 9 years of age (22, 30). Nevertheless, several investigators suggest that the reliability and validity of RPE may be just as high in children as in adults (2, 22, 30). Test-retest reliabilities of the use of RPE by children have ranged from 0.37 to 0.89 (19, 22, 30) while reliabilities in adults have ranged from 0.78 to 0.98 (20, 21, 28). Although a few studies have indicated that children are able to use RPE, no studies have compared the validity of RPE scales in children and adults from the same population using the same methods. The purpose of the present study was to assess age-related differences in the relationship of RPE to physiological strain (HR).

Methods

**Subjects**

The subjects for this study were drawn from 95 Anglo and 111 Mexican American families ($N=623$) who were participating in the San Diego Family Health Project (23). Families with fifth- or sixth-grade children were recruited from 12 elementary schools. For this analysis, 283 children ages 10 to 14 years (mean age = 11 yrs) and 295 adults ages 22 to 55 (mean age = 36 yrs), who completed two submaximal cycle ergometer testing sessions 1 year apart, were studied. Subject characteristics for adults and children, by gender, are displayed in Table 1.

**Procedure**

Assessments were conducted by pairs of exercise physiology graduate students who were thoroughly trained and certified in the protocols. Testing was conducted on calibrated Monark cycle ergometers using a modified Astrand-Ryhming protocol of gradually increasing power (26). Subjects pedaled at 50 rpm at an initial power of 25 watts (W), and the power was increased 25 W every 2 minutes. Most subjects completed three to five workloads. HR was assessed at the end of each 2-min stage with a cardiotachometer and photoplethysmograph attached to the earlobe (CIC Instruments, Hempstead, NY, Model 60200). Radial palpation was used in rare instances when the cardiotachometer malfunctioned. RPE was measured at rest and at the end of each 2-min stage with Borg’s original 15-point scale (6) (see Figure 1). Brief standard instructions in the use of the
Table 1
Characteristics of Subjects in the San Diego Family Health Project (means and SD)

<table>
<thead>
<tr>
<th></th>
<th>Boys N=144</th>
<th>Girls N=139</th>
<th>Men N=100</th>
<th>Women N=195</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>41.0</td>
<td>40.7</td>
<td>81.3</td>
<td>67.4</td>
</tr>
<tr>
<td>(11.9)</td>
<td>(10.3)</td>
<td>(13.8)</td>
<td>(15.0)</td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>145.3</td>
<td>145.7</td>
<td>174.5</td>
<td>159.6</td>
</tr>
<tr>
<td>(9.1)</td>
<td>(9.0)</td>
<td>(7.0)</td>
<td>(7.7)</td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>19.2</td>
<td>18.9</td>
<td>26.7</td>
<td>26.4</td>
</tr>
<tr>
<td>(3.7)</td>
<td>(3.3)</td>
<td>(4.6)</td>
<td>(5.5)</td>
<td></td>
</tr>
<tr>
<td>Resting heart rate</td>
<td>74.7</td>
<td>80.2</td>
<td>63.9</td>
<td>71.2</td>
</tr>
<tr>
<td>(10.8)</td>
<td>(10.6)</td>
<td>(9.6)</td>
<td>(8.8)</td>
<td></td>
</tr>
<tr>
<td>VO₂ max (ml/kg/min)</td>
<td>50.8</td>
<td>48.2</td>
<td>35.3</td>
<td>25.5</td>
</tr>
<tr>
<td>(11.6)</td>
<td>(12.0)</td>
<td>(5.9)</td>
<td>(5.1)</td>
<td></td>
</tr>
</tbody>
</table>

RPE scale were provided before the test. Subjects were instructed to say or point to the number on the scale that described how they were feeling at the time. Subjects' understanding of the scale was tested by asking for a rating at rest and during their most vigorous exercise. Instructions and the Borg scale were available in Spanish when needed. Tests were preceded by a standardized screening form on which subjects reported history of cardiovascular and other diseases, relevant symptoms, and medication use. Exercise tests in adults were terminated at 70% age-predicted HR max or at an RPE of 15. The endpoint criterion for children was 85% age-predicted HR max.

Two procedures were used to compute rs between HR and RPE in both children and adults. The first method involved calculating the correlation across powers for each subject and then deriving a group mean. This was the method most often reported in the literature. The second method simultaneously considered each HR–RPE pair at all powers for all subjects in the group. For both methods, a Fisher z test was employed to test for differences between groups and between trials.

Results

Table 2 presents correlations between HR and RPE based on the mean of individual correlations across powers. The extremely high correlations in all groups indicated a strong association between HR and RPE. At Test 1 only, there was a statistically significant difference between correlations for children and adults. However, given the magnitude of the difference, it is of little practical significance. There were no differences between correlations at Test 1 and Test 2. Table 3 presents correlations between HR and RPE based on the entire group. There are nonsignificant differences between adults and children and between Test 1 and Test 2. These correlations are consistently much lower than those in Table 1.
Table 2
Correlation ($r$) Between HR and RPE in Children and Adults Based on the Mean of Individual Correlations

<table>
<thead>
<tr>
<th>Subject</th>
<th>Test 1</th>
<th>Test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>.92</td>
<td>.94</td>
</tr>
<tr>
<td>Adults</td>
<td>.94*</td>
<td>.95</td>
</tr>
</tbody>
</table>

*Significant difference between children and adults, $p<.05$; 
*Note: All correlations were significant at $p<.001$. 

Table 3
Correlation ($r$) Between HR and RPE in Children and Adults Based on Simultaneous Analysis of the Entire Group

<table>
<thead>
<tr>
<th>Subject</th>
<th>Test 1</th>
<th>Test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>.64</td>
<td>.65</td>
</tr>
<tr>
<td>Adults</td>
<td>.63</td>
<td>.64</td>
</tr>
</tbody>
</table>

*Note: All correlations were significant at $p<.001$. 

Figure 1 — Borg’s RPE scale (6).
Correlations were conducted separately for boys, girls, men, and women. Within age groups, correlations were essentially identical for both gender groups.

Figures 2 and 3 further clarify the correlations in Table 2. These scatterplots from Test 1 indicate that, in general, there is a positive linear association between HR and RPE, and the relationships are similar in children and adults. However, at any given RPE value there is a wide range of HRs such that the prediction of HR from RPE is very imprecise.

**Discussion**

This study clearly indicated that the type of statistical method used greatly influences one's conclusions regarding the relationship between HR and RPE. Previous investigators have tended to rely on the method of calculating correlations for each individual subject and then generating a group mean. This method produces high correlations because as power and HR increase, RPE also increases. In all individual subjects there was a linear association. This suggests that children

**Figure 2** — The relationship between submaximal exercise heart rates and ratings of perceived exertion in adults.
Figure 3 — The relationship between submaximal exercise heart rates and ratings of perceived exertion in children.

and adults are able to discriminate changes in physiological strain. Thus the RPE scale can be used to properly monitor changes in exercise intensity since each subject reported increases in RPE as exercise intensity increased over several powers.

However, the RPE scale was also designed to reflect the level of physiological strain such that RPE could be used to estimate exercise HR. For example, Bar-Or (2) found that RPE × 10 estimated HR adequately for middle-aged and older adults but not for younger subjects. This use of RPE was clearly not supported in either children or adults in the present study. Figures 2 and 3 indicate that the range of HRs at every level of RPE was very large for children and adults. Since each RPE value was associated with HRs that ranged over 40 to 100 bpm, there is no useful predictive power of RPE. Since these correlations were based on submaximal tests, the distribution of HRs was truncated. This restriction of range could have suppressed the correlations. In addition, RPE–HR correlations may be lower than correlations between RPE and other physiological indicators in children (3). Thus, present methods could have underestimated the associations.
The confidence in these results is increased since almost identical results were found for children and adults and for males and females. There were no indications that practice improved the HR–RPE association. It is reasonable to hypothesize that the ability of a 35-year-old subject to accurately report his or her level of exertion would be better than that of a 10-year-old, given differences in cognitive abilities. However, no such differences were found. Given that very few subjects had previous experience with exercise testing or rating their exertion level, improvement with practice could be expected. This was tested by evaluating subjects’ first exercise test and later their third test. A second test was conducted at the 3-month point but those data were not analyzed for this paper. Although the practice hypothesis was not supported by the present study, the measurement schedule was not optimal for testing the hypothesis. For maximal effect, a practice session should probably be held a few days prior to the testing session.

Ratings of perceived exertion are commonly used as indices of exercise intensity when prescribing exercise regimens (5, 15, 16). This practice is based on the assumption that RPE reflects physiological strain, but it appears that such an assumption is unwarranted because many previous studies may have overestimated associations between RPE and physiological strain. The results of the present study suggest that, while RPE–HR associations may be reliable over testing sessions in adolescents (19), RPE does not accurately reflect HR in either children or adults. These findings are essentially in agreement with the conclusion of Bar-Or (2), who found high RPE–HR associations only in middle-aged and older adults. Adults in the present study averaged 36 years of age. Using RPE to prescribe and monitor exercise intensity is therefore a questionable practice, since at any given RPE, HR may vary by 40 to 100 bpm. In healthy individuals this degree of error would render RPE useless. In clinical populations, basing exercise intensity on RPE could be dangerous.

The primary conclusion from this study is that RPE is useful for tracking changes in exercise intensity within a session, but that absolute levels of perceived exertion are not related to indices of physiological strain. Therefore, using RPE \( \times 10 \) as an estimate of heart rate may be dangerously misleading. Ratings of perceived exertion should not be used as substitutes for heart rate or other physiological measures. The associations between RPE and HR were similar in children and adults.

References


