Rate of Perceived Exertion as a Tool to Monitor Cycling Exercise Intensity in Older Adults

Ryosuke Shigematsu, Linda M. Ueno, Masaki Nakagaichi, Hosung Nho, and Kiyoji Tanaka

The purpose of this study was to determine the efficacy of rate of perceived exertion (RPE) to monitor exercise intensity in older adults. Middle-aged (46.9 ± 7.0 years, n = 24) and older women (75.5 ± 3.8 years, n = 29) performed a graded maximal exercise test on a cycle ergometer while RPE, oxygen uptake, heart rate, and blood lactate levels were measured. The Pearson’s product–moment correlation coefficient between RPE and oxygen uptake for each stage of the graded exercise test was calculated for each participant. The mean coefficient for the older group (r = .954) was similar to that of middle-aged group (r = .963). The autocorrelation coefficient was much lower (r = .411) in the older group than in the middle-aged group (r = .871). Variability in RPE through the graded exercise test was similar between the two groups. In conclusion, RPE was strongly associated with oxygen uptake in the older group. These results indicate that RPE is effective in monitoring exercise intensity in older adults.

Key Words: RPE, prescription, oxygen

The rate of perceived exertion (RPE) is defined as a subjective scale of how hard individuals feel they are working (Borg, 1973). RPE is commonly used during graded exercise tests, which are often performed to establish safe levels of exercise prescription and to assess disease severity and prognosis (American College of Sports Medicine [ACSM], 2000). During exercise testing, both objective and subjective variables were measured (ACSM). The objective variables included electrocardiogram, blood pressure, ventilation, oxygen uptake, and respiratory rate. The subjective variable, RPE, was used to allow the exerciser to rate his or her feelings (ACSM) and indicates the degree of heaviness and strain experienced in physical work (Borg, 1998).
Many previous studies have confirmed the validity and usefulness of RPE to measure exercise intensity not only for healthy adults but also for children and some clinical populations (Borg, 1998). There are few reports, however, on the usefulness of RPE during graded exercise testing for older adults. Because cognitive functioning decreases with age (Spirduso, 1995), it is important to verify that RPE can be used to monitor exercise intensities in older adults.

Some previous studies have assessed the relationship between RPE and selected physiological variables. For example, Shono et al. (2000) studied the correlation between heart rate (HR) and RPE in water exercise. In this study, they tested the relationship among these variables in middle-aged and older women who were asked to walk while immersed in water. Nakanishi, Kimura, and Yokoo (1999) also found that HR and RPE could be effective indices of exercise intensity during underwater treadmill walking in middle-aged men.

In order to confirm the applicability of RPE to older adults during exercise on land, this study assessed the relationship between RPE and HR or VO2 during a graded cycling test.

**Methods**

**PARTICIPANTS**

Through public-service announcements in the local paper (Toride City, Ibaraki prefecture, Japan), 24 middle-aged women (46.9 ± 7.0 years) and 29 older women (75.5 ± 3.8 years) were recruited as participants for this study. The study was approved by the Tsukuba Health Fitness Ethics Committee, which was established in the Division of Cardiology in Higashi Toride Hospital. All participants gave informed consent. The participants’ physical characteristics are shown in Table 1. The mean body weight, height, and body fat of the middle-aged group were significantly higher than those of the older group. Exclusion criteria included communication impairments (i.e., hearing, speaking, or reading), diabetes mellitus, or severe neuropathies. Individuals who were taking one or more medications for hypertension (e.g., beta-receptor blockers, calcium blockers) were also excluded. Fourteen women (48%) in the older group regularly participated in gateball or walking. In the middle-aged group, 10 women (42%) regularly participated in walking or volleyball. The others had no exercise habits and were classified as sedentary.

**EQUIPMENT**

A cycle ergometer (813E, Monark, Sweden) that was operated on a belt-braked system and had strap belts fitted on the pedals was used in this study.

A Japanese version of Borg’s standard 6–20 RPE scale (Onodera & Miyashita, 1976) was used to assess exertion. The validity of this scale has been confirmed in Japan (Nakanishi et al., 1999; Onodera & Miyashita; Shono et al., 2000). The RPE scale was written on a 30- by 43-cm piece of thick paper using a 36-point font for easy reading. The scale was usually mounted between the handlebars of the cycle ergometer, but participants who had hyperopia or myopia were allowed to place it where they preferred. RPEs were collected at the 55th second of each stage.
Table 1  Physical Characteristics and Cardiorespiratory-Fitness Data for Older and Middle-Aged Women, $M \pm SD$

<table>
<thead>
<tr>
<th></th>
<th>Older group, $n = 29$</th>
<th>Middle-aged group, $n = 24$</th>
<th>$t$ value</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>75.5 ± 3.8</td>
<td>46.9 ± 7.0</td>
<td>38.3</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>48.6 ± 8.7</td>
<td>71.3 ± 6.7</td>
<td>12.1</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Height, cm</td>
<td>147.3 ± 4.6</td>
<td>156.2 ± 6.0</td>
<td>8.3</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>24.8 ± 6.4</td>
<td>37.0 ± 4.1</td>
<td>8.1</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Exercise time, s</td>
<td>409 ± 58</td>
<td>704 ± 77</td>
<td>9.3</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Workload$_{\text{max}}$, W</td>
<td>76.0 ± 16.0</td>
<td>146.9 ± 19.3</td>
<td>14.3</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>HR$_{\text{max}}$, beats/min</td>
<td>136.4 ± 17.2</td>
<td>164.1 ± 9.9</td>
<td>7.0</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>HR$_{\text{LT}}$, beats/min</td>
<td>106.0 ± 14.4</td>
<td>118.3 ± 16.6</td>
<td>2.7</td>
<td>.01</td>
</tr>
<tr>
<td>VO$_{2\text{max}}$, ml · kg · min$^{-1}$</td>
<td>20.1 ± 3.9</td>
<td>27.0 ± 3.4</td>
<td>7.9</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>VO$_{2\text{LT}}$, ml · kg · min$^{-1}$</td>
<td>13.4 ± 2.4</td>
<td>15.8 ± 2.4</td>
<td>7.0</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>RPE$_{\text{max}}$</td>
<td>17.2 ± 1.6</td>
<td>18.5 ± 1.4</td>
<td>4.6</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>RPE$_{\text{LT}}$</td>
<td>12.8 ± 1.7</td>
<td>13.1 ± 1.6</td>
<td>0.8</td>
<td>.20</td>
</tr>
<tr>
<td>Lactate level$_{\text{LT}}$, mmol</td>
<td>0.89 ± 0.23</td>
<td>1.16 ± 0.34</td>
<td>10.1</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>

*Note.* Exercise time includes the 2-min warm-up period. HR = heart rate; VO$_{2}$ = oxygen uptake; RPE = rating of perceived exertion; LT = lactate threshold.

participants pointed to the ratings while they continued pedaling, using the index finger of the arm in which the needle was not injected.

Ventilation, oxygen uptake (VO$_{2}$), and carbon-dioxide output (VCO$_{2}$) were measured using an open-circuit spirometer and a gas analyzer with Oxycon alpha (Mijnhardt, Netherlands). The system was calibrated before the start of each test using a 3-L syringe and known gases for O$_{2}$ and CO$_{2}$. VO$_{2}$ and VCO$_{2}$ were collected breath by breath and computed every minute during the test. Heart rate (HR) was monitored continuously and recorded at the 55th second of each workload (Dinascope 501, Fukuda Denshi, Japan).

Lactate threshold (LT) was defined as the point at which blood lactate concentration exhibited a systematic increase above a resting baseline and was determined from the individual plots of blood lactate concentration against the workload (Beaver, Wasserman, & Whipp, 1985). During the last 10 s of each workload stage, 0.5 ml blood was collected from an antecubital vein.

**TESTING PROTOCOL**

The two-step testing protocol (Buckley, Eston, & Sim, 2000) was used. In the first step, each participant was familiarized with the whole testing procedure. A full description of the testing was given, including detailed instructions on using the 15-point Borg scale (Noble & Robertson, 1996). The participants were given the
opportunity to read over the RPE scale until they stated that they had a clear understanding of both the numerical and the verbal statements that make up the scale. They were then guided through the recommended and standardized procedure for familiarization with the RPE scale (Borg, 1998; Noble & Robertson), including, for example, understanding the definition of RPE and “anchoring” the top and bottom ratings to previously experienced sensations of no exertion at all and extremely hard or maximal exertion.

In the second step, all participants performed a graded maximal exercise test on the cycle ergometer to determine maximal \( \text{VO}_2 \) \( (\text{VO}_{2\text{max}}) \), maximal HR (\( \text{HR}_{\text{max}} \)), oxygen uptake at the lactate threshold (\( \text{VO}_{2\text{LT}} \)), and HR at the lactate threshold (\( \text{HR}_{\text{LT}} \)). The exercise test started with a 2-min warm-up while pedaling with no load (other than slight resistance at a zero dial setting). After the warm-up, the workload was set at 15 W and then increased by 15 W every minute until the participant showed indications for terminating the exercise test. Participants were notified verbally if they exceeded a pedal-speed range of 55–65 rpm. The pedal speed was monitored by electronic meter, which was attached to the ergometer. A plateau in \( \text{VO}_2 \) with increasing exercise intensity, a HR equal to the age-predicted maximum (220 – age), and a respiratory exchange ratio > 1.0 were used as criteria for attaining \( \text{VO}_{2\text{max}} \) and terminating the test (Demello, Cureton, Boineau, & Singh, 1987). All participants met at least one criterion.

STATISTICAL ANALYSES

The unpaired \( t \) test and the \( F \) test were used to compare the differences in means and deviations, respectively, for each variable. To determine a relationship between two variables (e.g., \( \text{VO}_2 \) and RPE) in each group, the Pearson’s product–moment correlation coefficient was used. In contrast to previous studies that calculated the coefficient using group data (Borg, 1973; Shone et al., 2000), we calculated the coefficient for each participant and then averaged them. This was done because the procedure used in previous studies does not control for extreme RPE responses and might overestimate the correlation coefficient.

In addition, the autocorrelation coefficient was calculated, because the Pearson’s correlation can be identified as a result of testing across multiple stages of exercise. When a participant gives an RPE score at each workload, the scores usually increase with increasing workloads. Autocorrelation coefficients are used to show the overestimated margin of this relationship (Kadzin, 1982).

If a participant gives the same RPE score at two or more consecutive stages, it suggests that the RPE is less sensitive. In order to assess this, “repeat ratios” were calculated as follows: the number of repeated RPE scores was divided by the number of total RPE scores. For example, the response of 11, 13, and 15 was scored as 0; the response of 11, 11, and 13 was scored as 1; and the response of 11, 11, and 11 was scored as 2. When a participant gave RPE scores of 9, 11, 11, 11, 13, 15, 17, and 19, the repeat ratio was .25 (2 divided by 8). A low repeat ratio indicates that the participant did not give the same RPE score and is an indication of sensitivity to exercise intensity.

Data are presented as means ± standard deviations. Statistical significance was accepted when the \( p \) value was less than .05.
Results

Tests were terminated at 409 ± 58 s in the older group and 704 ± 77 s in the middle-aged group (these data included a 120-s warm-up). At the end of the test, peak values in workload increased to 76.0 ± 16.0 W in the older group and to 146.9 ± 19.3 W in the middle-aged group; the difference between the mean values was statistically significant. Table 1 shows the cardiorespiratory-fitness data (HRmax, HRLT, VO2max, VO2LT, RPEmax, and RPELT). All cardiorespiratory-fitness variables except RPELT in the older group were significantly lower than those in the middle-aged group. The RPELTs in both groups were similar, scoring approximately 13 (equivalent to “somewhat hard”). Lactate levels at LT were, however, significantly different: 1.16 ± 0.34 mmol in the middle-aged group and 0.89 ± 0.23 mmol in the older group. Standard deviations of RPELT and RPEmax in the older group were not significantly different than those in the middle-aged group. This suggests that RPE in older adults has variability similar to that in middle-aged adults.

The individual Pearson’s correlation coefficients between VO2 and RPE were statistically significant and ranged from .774 to .998. The mean correlation coefficient in the older group (r = .954) was similar to that in the middle-aged group (r = .963). Correlation coefficients between HR and RPE were .964 in the middle-aged group and .956 in the older group. The means of individual RPE autocorrelation coefficients were .411 in the older group and .871 in the middle-aged group. The difference in these two correlation coefficients was statistically significant (p < .05). The “repeat ratio” in the older group was 0.31 ± 0.18, which was not significantly different from the repeat ratio (0.26 ± 0.17) in the middle-aged group (Table 2).

Discussion

The results obtained in the present study suggest that RPE is useful for monitoring exercise intensities during graded cycling in older adults. This conclusion stems

<table>
<thead>
<tr>
<th>Table 2</th>
<th>RPE Responses During the Graded Cycling Test for Older and Middle-Aged Women, M ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Older group</td>
</tr>
<tr>
<td>Number of all RPE, a</td>
<td>5.6 ± 1.8</td>
</tr>
<tr>
<td>Number of the same RPE, b</td>
<td>1.8 ± 1.2</td>
</tr>
<tr>
<td>Repeat ratio: b divided by a</td>
<td>0.31 ± 0.18</td>
</tr>
</tbody>
</table>

Note. RPE = rate of perceived exertion. The repeat ratio was calculated as follows: The number of repeated RPE values that were successively assigned was divided by the number of all RPE scores.
from the following three findings: (a) the Pearson’s correlation coefficient between RPE and VO\textsubscript{2} was high (\(r = .954\)), (b) the RPE value was not affected by the previous RPE value throughout the graded exercise (the autocorrelation coefficient was low, .411), and (c) older adults did not tend to repeat the previous RPE value (repeat ratio was low, 0.31).

The usefulness of RPE during graded cycling exercise has been reported in several studies. Myers et al. (1987) reported that, using patients with chronic atrial fibrillation, the Pearson’s correlation coefficients between RPE and VO\textsubscript{2} were .81, .86, and .88 in the conditions of taking a β-adrenergic blocker, a calcium-channel antagonist, and a placebo, respectively. Borg (1973) reported a correlation coefficient of .72 between RPE and HR. In the present study, we found a higher correlation coefficient (\(r = .956\)) between RPE and HR.

We are aware that no studies have reported either the autocorrelation coefficient or the repeat ratio. We believe that these additional measures add to our understanding of the validity of the RPE. The importance of the autocorrelation coefficient was to examine the time-series analysis (relationship) of two variables after reducing the effect of previous data (Kadzin, 1982). The mean autocorrelation coefficient for older adults was significantly lower than that for middle-aged adults. This result suggests RPE scores in older adults as a function of increasing workload and not as a function of increased exercise time. The low repeat ratio suggests that participants did not give the same RPE score. The ratio of 0.31 ± 0.18 in the older adults was not significantly higher than that of 0.26 ± 0.17 in the middle-aged adults. This result also suggests that older adults could assign an RPE score according to each workload.

The findings obtained in the present study suggest that RPE\textsubscript{LT} appears to correspond to an RPE score of approximately 13 (“somewhat hard”) regardless of the participant’s chronological age. Although using only RPE is not the best method to prescribe or monitor exercise intensity, an RPE range of 12–16 is considered appropriate for the development of both health-based and rehabilitative cardiovascular fitness (ACSM, 2000). In summary, Borg’s standard 6–20 RPE scale was found to be a useful tool for monitoring cycling exercise intensity and might be helpful in exercise prescription for unimpaired older adults.

References


