Comparison of the relation with muscle activity (facial and leg) between Borg- and facial pictorial-RPE scale for perceived exertion

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The aims of this study were 1) to determine the relation between facial pictorial RPE and facial EMG 2) to compare the correlation with facial muscle activity and active muscle activity between Borg and facial pictorial RPE scale. A cross-sectional, perceptual estimation design was used to assess exertional perceptions during a load-incremented cycle ergometer. Forty volunteers, including 22 males and 18 females were recruited. The effects of exercise intensity on EMG activity of the corrugator supercilii (CS), masseter and vastus lateralis (VL) muscles, heart rate (HR) and the rating of perceived exertion (RPE) derived from Borg and facial pictorial RPE were investigated, and the correlations among these parameters were determined. The relation between facial pictorial RPE and facial EMG was determined. The result of this study suggested that the facial RPE scale was as good as Borg RPE for self-report perceived exertion and highly correlated with active muscle activity. However, the facial RPE scale did not show the evidence that was more correlated with facial muscle activity than the Borg RPE scale.

Practitioner Summary: Our findings confirm a relationship between the facial expression of effort and physical effort. The facial pictorial RPE scale could be used to rate the perceived exertion to control intensity during cycling exercise, proving an indirect measure of the muscle activity.

Keywords: muscle activity, electromyography, RPE

1. Introduction

Some studies have indicated that rating of perceived exertion (RPE) is associated with primary active muscle strain, as measured using electromyography (EMG), during various type of exercise (Duncan et al., 2006; Fontes et al., 2010; Lagally et al., 2004; Lagally et al., 2002; Macdonald et al., 2008). Recent studies have shown that muscle activity, not only active muscle but unrelated to the task, such as frowning and jaw clenching, has also been shown to be associated with RPE (de Morree and Marcora, 2010, 2012; Huang et al., 2014), de Morree and Marcora (2010, 2012) first demonstrated a positive correlation between the perception of exertion and the corrugator supercilii (CS) muscle activity (associated with frowning) during leg extension exercise and constant-load cycling exercise. Unless frowning muscle activity, Huang et al. (2014) also showed that a progressive and systematic increase in a workload forcing function on the EMG activity both of the CS and masseter (associated with clenching) muscles increased concomitantly with overall RPE. Especially, the jaw clenching facial expression can thus be considered an important factor that determines the perception of effort and estimates the intensity of effort during incremented workload exercise. These studies reveal that facial EMG maybe a valid psychophysiological measurement based on the facial expression of effort for measuring perceived effort.

A newly developed pictorial rating of perceived exertion (RPE) scale that focuses on the facial expression of effort for assisting to evaluate physical tasks (Huang and Chiou, 2013). The visual information on the pictorial faces were the primary cues emphasizing on the scale instructions. Both concurrent and construct evidence supported the use of the facial pictorial RPE scale by males and females to estimate RPE during the incremental cycle ergometer test (Huang and Chiou, 2013).

The correlation between Borg RPE or OMNI RPE and facial EMG was validated (de Morree and Marcora, 2010, 2012), however the relation between facial pictorial RPE and facial EMG has yet not been investigated. Do facial RPE scale was as good as Borg for self-report perceived exertion and highly correlated with active muscle activity? Otherwise, whether the facial RPE scale is more correlated with facial muscle activity than the formal Borg RPE scale should be determined. To answer these questions therefore,
the aims of this study were 1) to determine the relation between facial pictorial RPE and facial EMG 2) to compare the correlation with facial muscle activity and active muscle activity between Borg and facial pictorial RPE scale.

2. Method

2.1 Subjects
Forty volunteers, including 22 males (age: 23.1 ± 3.0 years; height: 173.6 ± 5.0 cm; weight: 68.8 ± 8.9 kg) and 18 females (age: 21.2 ± 2.7 years; height: 159.6 ± 3.6 cm; weight: 53.6 ± 6.3 kg) were recruited from a university population to participate in the study. All participants were reported as being physically active, healthy, and asymptomatic of illness and pre-existing injuries. Written informed consent was obtained from all participants after they were informed of the study purpose and protocol. The experimental procedures were approved by the Institutional Review Board of Chang Gung Medical Foundation.

2.2 Experiment design
A cross-sectional, perceptual estimation design was used to assess exertional perceptions during a load-incremented cycle ergometer protocol that terminated at peak task intensity. Each participant performed a continuous incremental workload cycling exercise on an electromagnetically braked cycle ergometer (Corival 906900, Lode BV, Groningen, The Netherlands). The exercise included a 5-minute warm up at 0 watts (W), the initial power output was 50 W for women and 75 W for men. Power outputs were incremented in continuous 3-min test stages by 25 W and 50 W, respectively, for women and men. Participants were instructed to maintain a cycling cadence between 60–70 rpm throughout the exercise test. When a participant experienced volitional exhaustion or an inability to sustain a cadence greater than 55 rpm for a period of 5 seconds, the exercise test was terminated.

Throughout the test CS and masseter muscle activities were continuously recorded using EMG during exercise. For details about the recording method, please see our previous publication on facial EMG (Huang et al., 2014). To avoid bias from mimicry effects on facial EMG measurements, the experimenter stood behind participants and remained silent during data collection (Tassinary et al., 2007).

HR was monitored continuously using a wireless chest strap telemetry system (Polar WearLink System and Polar FT4 HR monitor, Polar Electro Oy, Kempele, Finland) during the task. During the final 30 s of each stage of cycle ergometer exercise, participants were asked to report their feeling of exertion through the Borg 6-20 scale (Borg, 1998) and Facial pictorial RPE (Huang and Chiou, 2013). The order of presentation of the two scales was counterbalanced across subjects.

2.3 Data analysis
Surface EMG signals were amplified by the NeXus-10 system (Mind Media, The Netherlands). Signals were acquired at 1024 samples per second, bandpass filtered (20–500 Hz; IIR filter, Butterworth 4th order) and sent via Bluetooth to a laptop for data visualization, storage and pre-processing (BioTrace Software, Mind Media, The Netherlands). EMG amplitudes were calculated (root mean square, epoch size: 1/16 s, 32 samples per second). The raw EMG values were normalized against a reference voluntary contraction (RVC) and presented as a percentage for each muscle. Normalized EMG (NEM) values were obtained using the following equation: %RVC = (EMGmeasured - EMGrest)/(EMGreference - EMGrest) × 100%.

Perceived exertion and physiologic responses to ergometer testing were tested with separate two-factor ANOVA, with sex as a between-subjects factor and ergometer test stage as a within-subjects factor. Changes in perceived exertion and physiologic responses between successive stages were tested for statistical significance with planned post hoc analysis. To directly compare Borg and facial pictorial RPE data, subject scores at each stage were converted to a percentage of the maximal score for the perceived exertion scale. Significance was set at 0.05 (two-tailed) for all analyses, which were conducted using SPSS version 20 (SPSS Inc., Chicago, IL).
3. Result

Table 1 lists the physiology responses and perceived exertion scores for males and females across the 4 stages of the cycle ergometer test. No sex difference were found in leg muscle activity, Heart rate, Borg and facial pictorial RPE scores but all significantly increased from one stage to the next successive stage across all stages of the cycle ergometer test. The facial activity of the masseter muscle was significantly greater at stage 4 compared with those at the other three power outputs for male and female subjects. CS muscle activity was only significantly greater at a workload of stage 4 compared with stage 1 for males. For females, CS muscle activity was not significantly different between each stage.

### Table 1. Ratings of perceived exertion and physiological variables of the males and females

<table>
<thead>
<tr>
<th>Gender</th>
<th>Stage</th>
<th>CS muscle (%)</th>
<th>Master muscle (%)</th>
<th>VL muscle (%)</th>
<th>HR</th>
<th>Facial RPE Borg RPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1</td>
<td>6.7±5.1%</td>
<td>4.7±5.6%</td>
<td>24.6±7.4%</td>
<td>112.4±12.5</td>
<td>3.2±1.3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>10.3±6.8%</td>
<td>8.0±7.0%</td>
<td>36.4±10.5%</td>
<td>136.6±15.2</td>
<td>5.4±1.0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>15.7±10.7%</td>
<td>15.9±12.4%</td>
<td>51.1±15.1%</td>
<td>160.0±17.4</td>
<td>7.4±1.3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>21.8±15.8%</td>
<td>25.2±18.6%</td>
<td>60.9±13.5%</td>
<td>173.6±15.7</td>
<td>8.7±1.1</td>
</tr>
<tr>
<td>Female</td>
<td>1</td>
<td>15.6±16.4%</td>
<td>4.6±5.3%</td>
<td>27.0±6.2%</td>
<td>118.2±16.2</td>
<td>3.7±1.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>16.0±14.2%</td>
<td>6.2±5.0%</td>
<td>35.3±7.7%</td>
<td>139.4±16.0</td>
<td>5.2±1.5</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>17.1±15.9%</td>
<td>13.1±10.2%</td>
<td>48.4±9.8%</td>
<td>157.9±15.5</td>
<td>6.8±1.4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>18.6±14.8%</td>
<td>19.7±12.2%</td>
<td>62.4±10.8%</td>
<td>169.1±12.5</td>
<td>8.0±1.5</td>
</tr>
</tbody>
</table>

Pearson correlations for physiological variables are summarized in Table 2. Correlations were comparatively high for the relation between RPE and HR, leg muscle activity. Correlation between RPE and facial muscle activity was relatively low.

### Table 2. Correlation coefficients for rating of perceived exertion (RPE), heart rate (HR), facial normalised electromyographic (NEMG) values and lower limb NEMG values.

<table>
<thead>
<tr>
<th>Type of scale</th>
<th>CS muscle (%)</th>
<th>Master muscle (%)</th>
<th>VL muscle (%)</th>
<th>HR</th>
<th>RPE_Borg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>RPE_Borg</td>
<td>0.453**</td>
<td>0.535**</td>
<td>0.765**</td>
<td>0.806**</td>
</tr>
<tr>
<td></td>
<td>RPE_Facial</td>
<td>0.446**</td>
<td>0.569**</td>
<td>0.792**</td>
<td>0.850**</td>
</tr>
<tr>
<td></td>
<td>RPE_Borg</td>
<td>-0.066</td>
<td>0.484**</td>
<td>0.789**</td>
<td>0.787**</td>
</tr>
<tr>
<td></td>
<td>RPE_Facial</td>
<td>0.018</td>
<td>0.478**</td>
<td>0.851**</td>
<td>0.791**</td>
</tr>
<tr>
<td></td>
<td>RPE_Borg</td>
<td>0.177</td>
<td>0.515**</td>
<td>0.774**</td>
<td>0.798**</td>
</tr>
<tr>
<td>Female</td>
<td>RPE_Facial</td>
<td>0.208*</td>
<td>0.533**</td>
<td>0.815**</td>
<td>0.824**</td>
</tr>
</tbody>
</table>

The relationships between mean % of total RPE of Borg or facial pictorial RPE scores and mean % RVC of muscle activity or mean heart rate are shown in Figure 1 and 2. Figure 1 illustrated both scales were linearly related with heart rate (Figure 1 A) and leg muscle activity (Figure 1B) across cycle ergometer test stages for male and female. In figure 2 (a) both gender and RPE scales showed significant linear relationship between masseter muscle activity and % of total RPE score. In figure 2 (b) RPE scales showed significant linear relationship between CS muscle activity and % of total RPE score for males but there was no relation for females.
Figure 1. Response linearity of perceived exertion of the Borg scale and facial pictorial RPE scale when plotted against heart rate (HR) and vastus lateralis (VL)
4. Discussion

The present study demonstrated that CS and masseter muscle activity were significantly correlated with facial pictorial RPE scores and increased with power output during incremental workload cycling unless CS muscle activity of female subjects. The result was in line with previous studies, de Morree and Marcora (2010, 2012) demonstrated a positive correlation between Borg RPE and CS muscle activity during leg
extension exercise or constant workload cycling. (Huang et al., 2014) also showed that not only CS muscle but masseter muscle activity was associated with RPE derived from OMNI scale during incremental workload cycling test.

The correlation between both RPEs and HR, leg muscle activity was strongly high. These results are consistent with previous studies that have shown positively correlated increases in RPE and lower limb EMG activity (Macdonald et al., 2008; Perry et al., 2001) and in RPE and HR (Borg et al., 1987; Robertson et al., 2004). However, the correlation between RPEs and two facial muscle activities was relatively lower. This maybe explained that RPEs, HR and lower limb EMG activity were all significantly different and demonstrated uniform increases among all stages, unlike facial EMG activity. The facial muscles of the CS (associated with frowning) and the masseter contracted significantly but only at a higher stage (de Morree and Marcora, 2012; Huang et al., 2014).

Both scales provided valid estimates of submaximal effort perception as demonstrated by robust correlations (Table 2) and linear regressions with physiologic measures of effort, including heart rate and leg muscle activity (Figure 1). Comparison of the correlation between and two RPE scales, the results indicated that facial pictorial RPE scale has slightly higher correlation coefficient with masseter, VL and HR than Borg RPE for male subjects. For female subjects, facial pictorial RPE has slightly higher correlation coefficient with VL and HR than Borg RPE. Overall the facial RPE scale was as good as Borg RPE for self-report perceived exertion and highly correlated with active muscle activity. However, the facial RPE scale did not show the strong evidence that was more correlated with facial muscle activity than the formal Borg RPE scale.

References