Perceived Exertion: Applications for Testing and Exercise Prescription

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Rating of Perceived Exertion Scale

- Frame of reference to subjectively rate the intensity of exercise.

- RPE x 10 provides an approximation of HR (± 10 b/min)
  
  e.g., 13 = 130 ± 10 b/min;

  Typically monitored during exercise tests

Borg 6-20 Rating of Perceived Exertion Scale
Factors affecting the RPE

**Psychological**
e.g., Cognition, Understanding, Mood, Motivation

**Physiological**
e.g., Cardiorespiratory, Metabolic, Temperature

**Situational**
e.g., Preferred or imposed; Audience; Competition; Mode, Knowledge of end-point
e.g., knowledge of endpoint is important

Assessment of Cardiorespiratory Fitness

WHY?
To assess health and fitness status
To quantify and prescribe appropriate intensity ranges

Direct
Maximal

Methods

Indirect
Physiological Responses to Graded Exercise Test

Oxygen uptake

Ventilation

Blood lactate

Heart rate

GXT protocol

Gradient (%)

Time

Gradient: 0%

Gradient: 1%

Gradient: 2%

Gradient: 3%

Gradient: 4%

Gradient: 5%

Gradient: 6%

Gradient: 7%

Gradient: 8%

Gradient: 9%

Gradient: 10%

Plateau (VO₂ max)

66 ml/kg/min

Aerobic threshold

Anaerobic threshold

10

9

8

7

6

5

4

3

2

1

0

L/min

beats/min

mmol/L
Submaximal Exercise Test

- strong linear relationship between HR and VO$_2$
- allows submaximal HR to be used to estimate fitness
- need to know maximal HR

Maximal HR is influenced by:
- Fitness and health
- Mode of exercise
- Age (maximal HR decreases $\approx$7 b/min every 10 years)
Simple linear regression models

e.g. HRmax = 220 - age
HRmax = 208 - (0.7 x Age)
HRmax = 208 – (0.7 x age) ± 10 b/min

Prescribing an exercise intensity at 75% HRmax

30 year-old
HRmax = 208 – (0.7 x 30) = 187 b/min

.75 x 187 = Target HR = 141 b/min

95% confidence interval? = 187 ± 20 b/min = 167 – 207 b/min!
5% will be above or below this!

Target HR 141/208 = 68% HRmax
Target HR 141/166 = 85% HR Max
Oxygen uptake

Ventilation

Heart rate

GXT protocol

Rating of perceived exertion

Gradient (%)

Time

Plateau (VO_{2max}) 66 ml/kg/min

Ventilatory threshold

Rating of perceived exertion

0                  2                  4                  6                  8                 10

minutes

0                2                4                6                8               10

minutes

6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

No exertion at all
Extremely light
Very light
Light
Somewhat hard
Hard (heavy)
Very hard
Extremely hard
Maximal exertion

6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Rating of perceived exertion

0                  2                  4                  6                  8                 10

Rating of perceived exertion

0                2                4                6                8               10

Rating of perceived exertion

0                2                4                6                8               10
Rating of perceived exertion

- RPE
- Oxygen uptake (ml/kg/min)

Heart rate

- Beats/min
- Oxygen uptake (ml/kg/min)

Measured max = 66 ml/kg/min

Theoretical maximum = 68 ml/kg/min

Age predicted maximum (208 - (0.7 x age)) = 61 ml/kg/min
Student laboratory data

Prediction of max work rate from HR

At 21 y; age-predicted max HR = 193
\[ y = (2.53 \times 193) - 189 = 299 \text{ W} \]

Prediction of max work rate from RPE

\[ Y = (15.1 \times 20) - 64 = 238 \text{ W} \]
\[ Y = (15.1 \times 19) - 64 = 223 \text{ W} \]

Max power output achieved = 220 W!
Prediction of VO₂peak in obese women (BMI >38)

50-y old women exercised until RPE15. (n = 43)
Estimated and measured VO₂max were similar
15 ± 3 vs 14 ± 3 ml/kg/min
Prediction of VO₂ peak in patients with chronic obstructive pulmonary disease

‘Healthy’ middle-aged

COPD

Prediction of VO2peak from RPE during a graded and ramp exercise test in able-bodied and paraplegic participants

Fig 1. Prediction of VO2peak from RPEs prior to and including RPE 17 when extrapolated to RPE 20 from a ramp exercise test for a person with paraplegia.

Prediction of VO$_2$peak in wheelchair athletes (extrapolated from RPE 9-15)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TETRA</th>
<th>PARA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured $\dot{\text{VO}_2}$peak (L min$^{-1}$)</td>
<td>1.50 ± 0.39</td>
<td>2.74 ± 0.48</td>
</tr>
<tr>
<td>RPE$_C$</td>
<td>1.47 ± 0.43</td>
<td>2.71 ± 0.63</td>
</tr>
<tr>
<td>RPE$_P$</td>
<td>1.52 ± 0.45</td>
<td>2.73 ± 0.57</td>
</tr>
<tr>
<td>RPE$_O$</td>
<td>1.50 ± 0.44</td>
<td>2.68 ± 0.57</td>
</tr>
<tr>
<td>HR</td>
<td>1.54 ± 0.38</td>
<td>2.97 ± 0.70</td>
</tr>
</tbody>
</table>

Prediction of VO₂max from RPE during shuttle run

Fit women aged 28 ± 7 years, performed 3 maximal tests in random order

**Figure 1** An example of VO₂max prediction using submaximal RPE 9–17 data obtained during the multistage fitness test.
Relationship between Lactate, RPE and heart rate

RPE …affordable, practical and valid tool for monitoring and prescribing exercise intensity, independent of gender, age, exercise modality, physical activity level and CAD status.

RPE of 11–13 recommended for less trained individuals, RPE of 13–15 recommended when more intense aerobic training is desired.


70 W for 5 min, followed by 30 W increase every 3 min until exhaustion.

Table 1. Mean (SD) of the relevant physiological and training variables across lactate and RPE thresholds.

<table>
<thead>
<tr>
<th>Methods</th>
<th>$\dot{V}O_2$ (mL.min$^{-1}$)</th>
<th>%$\dot{V}O_2_{max}$</th>
<th>HR (bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D$_{MAX}$RPE</td>
<td>2717.6 ± 470.9</td>
<td>78.8 ± 5.8</td>
<td>169.7 ±</td>
</tr>
<tr>
<td>D$_{MAX}$La</td>
<td>2719.4 ± 504.1</td>
<td>78.7 ± 6.1</td>
<td>169.7 ± 13.8</td>
</tr>
</tbody>
</table>
Perceptually-regulated training at RPE 13 is pleasant and improves physical health.

After 8 weeks, participants exercised at a higher intensity at RPE 13.

(and it still felt good!)

Mean (±SD) oxygen uptake values (ml kg⁻¹ min⁻¹) at each RPE for active (n = 49) and sedentary (n = 26) participants across both PRET trials

<table>
<thead>
<tr>
<th>RPE level</th>
<th>PRET 1</th>
<th>PRET 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>˙VO₂</td>
<td>% ˙VO₂peak</td>
</tr>
<tr>
<td>Active</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>26.7 (4.8)</td>
<td>50.0 (9.5)</td>
</tr>
<tr>
<td>11</td>
<td>31.1 (4.8)</td>
<td>58.3 (9.2)</td>
</tr>
<tr>
<td>13</td>
<td>37.5 (5.6)</td>
<td>70.1 (8.8)</td>
</tr>
<tr>
<td>15</td>
<td>43.4 (5.6)</td>
<td>81.0 (6.9)</td>
</tr>
<tr>
<td>Sedentary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>9.8 (2.3)</td>
<td>29.5 (8.7)</td>
</tr>
<tr>
<td>11</td>
<td>12.3 (3.2)</td>
<td>36.9 (10.8)</td>
</tr>
<tr>
<td>13</td>
<td>18.1 (5.9)</td>
<td>52.9 (14.3)</td>
</tr>
<tr>
<td>15</td>
<td>24.9 (6.4)</td>
<td>72.3 (9.2)</td>
</tr>
</tbody>
</table>

Power output during handcycling at moderate (A) and vigorous (B) intensities between imposed and RPE-regulated trials.

~55% VO₂peak  RPE 12 ± 1

~75% VO₂peak  RPE 16 ± 1

Perceptually-regulated exercise test (PRET)

- Individual is in control;
- Replicates method of exercise intensity regulation;
- Ecologically valid;

Perceptually-regulated exercise test

- Individual is in control;
- Replicates method of exercise intensity regulation;
- Ecologically valid;

Oxygen uptake (ml/kg/min)

<table>
<thead>
<tr>
<th>RPE</th>
<th>9</th>
<th>11</th>
<th>13</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>9</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Increased Rs between trials provide evidence of learning across low and high intensity levels.
A perceptually regulated, graded exercise test predicts peak oxygen uptake during treadmill exercise in active and sedentary participants.
A submaximal, perceptually-regulated exercise test is sensitive to increases in aerobic fitness.
Perceptually-regulated exercise testing (PRET)

To predict $\text{VO}_{2\text{max}}$

- Eston and Thompson, 1997: *Br J Sports Med* (cardiac patients, cycling)
- Eston et al., 2005 *Eur J Appl Physiol* (sports science students, cycling)
- Eston et al. 2006 *Eur J Appl Physiol* (sports science students, cycling)
- Faulkner et al 2007 *Eur J Appl Physiol* (active and sedentary men and women, cycling)
- Eston et al. 2012 *Eur J Appl Physiol* (active and sedentary men and women, treadmill)
- Morris et al; 2009; *J Exerc Sci Fitness* (sports science students, cycling)
- Morris et al. 2011; *Eur J Appl Physiol* (sports science students, treadmill)
- Evans et al., 2013, *Eur J Appl Physiol* (Sedentary men and women, cycling)
- Coquart et al 2014; *Sports Med* (Review of methods to date)
- Smith et al 2015, *J Aging Phys Act* (Older persons 60-74 y active, Treadmill)

To measure $\text{VO}_{2\text{max}}$ (compared to standard GXT or ramp test)

- Mauger and Sculthorpe, 2012, *Br J Sports Med* (sports sci students, cycling), Higher in PRET$_\text{max}$
- Mauger et al, 2013, *Appl Physiol Nutr Metab* (sports sci students, treadmill) Higher in PRET$_\text{max}$
- Chidnok et al., 2013, *Eur J Appl Physiol* (sports sci students, cycling) No Difference
- Poole 2014 *Appl Physio Nutr Metab* (questions credibility of Mauger et al 2013)
- Straub 2014 *Eur J Appl Physiol* (trained cyclists) No Difference
- Hogg et al. 2015. *Int J Sports Physiol* (distance runners, treadmill incline) Higher in PRET$_\text{max}$
To measure VO$_{2}^\text{max}$

**Maximal perceptually-regulated exercise test**

- **Individual is in control**
- **Ecologically valid self pacing method**

**Disagreement in literature**

- Mauger and Sculthorpe, 2012, *Br J Sports Med* (sports sci students, cycling), **Higher in PRET$_{\text{max}}$**
- Mauger et al, 2013, *Appl Physiol Nutr Metab* (sports sci students, non-mot treadmill), **Higher in PRET$_{\text{max}}$**
- Chidnok et al., 2013, *Eur J Appl Physiol*(sports sci students, cycling), **No Difference**
- Evans et al. 2013, *Eur J Sports Sci.* (sports sci students, recumbent cycling), **No Difference**
- Eston et al. 2014 *Appl Physio Nutr Metab* (questions credibility of Mauger et al 2013), **No Difference**
- Poole 2014 *Appl Physio Nutr Metab* (questions credibility of Mauger et al 2013), **No Difference**
- Straub et al. 2014. Eur J Appl Physiol. (sports sci students, cycling), **No Difference**
- Hogg et al. 2015. Int J Sports Physiol (distance runners, treadmill incline), **Higher in PRET$_{\text{max}}$**

**Known end point of exercise test RPE 20**
Use of maximum PRET to measure VO$_2$max
VO$_2$max is not altered by self-pacing during incremental exercise.

SPT bouts regulated at 8, 10, 12, 14, 16, 18, 20 equal timed

No significant difference!
Maximal values recorded during the PRETmax and the ramp test

<table>
<thead>
<tr>
<th></th>
<th>PRETmax</th>
<th>Ramp Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{VO}_{2}\text{max} \text{ (ml kg}^{-1} \text{ min}^{-1})$</td>
<td>$43.5 \pm 4.1$</td>
<td>$44.3 \pm 4.9$</td>
</tr>
<tr>
<td>$\text{HR}_{\text{max}} \text{ (b min}^{-1})$</td>
<td>$183 \pm 10$</td>
<td>$187 \pm 13$</td>
</tr>
<tr>
<td>$\text{RER}_{\text{max}}$</td>
<td>$1.11 \pm 0.09$</td>
<td>$1.16 \pm 0.07$</td>
</tr>
<tr>
<td>$\text{PO}_{\text{max}} \text{ (W)}$</td>
<td>$279.1 \pm 70^*$</td>
<td>$257.7 \pm 54.2$</td>
</tr>
</tbody>
</table>

16 active participants (18-22 y)
Recumbent cycle ergometer,
3-min continuous bouts at RPE 9, 11, 13, 15, 17 and 20

Oxygen uptake at each RPE during PRETmax and a Ramp test

<table>
<thead>
<tr>
<th>RPE</th>
<th>PRETmax</th>
<th>Ramp</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>13.5 ± 1.0</td>
<td>16.3 ± 4.5</td>
</tr>
<tr>
<td>11</td>
<td>18.5 ± 1.8</td>
<td>20.0 ± 4.9</td>
</tr>
<tr>
<td>13</td>
<td>24.1 ± 2.3</td>
<td>25.0 ± 5.0</td>
</tr>
<tr>
<td>15</td>
<td>30.9 ± 3.1</td>
<td>30.9 ± 5.5</td>
</tr>
<tr>
<td>17</td>
<td>36.8 ± 3.5</td>
<td>37.1 ± 4.7</td>
</tr>
<tr>
<td>20 / End</td>
<td>43.5 ± 3.9</td>
<td>44.3 ± 4.7</td>
</tr>
</tbody>
</table>

Affect was recorded in the last 15s of each minute for both tests

Affect Scale:  -5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5

Affective response

When matched for RPE, participants felt more positive (p<0.05) during PRET compared to GXT.
The mean power output (a) and VO$_2$ (b) in the ramp-incremented and RPE-clamped VO$_{2max}$ test protocols.

Straub et al 2014 Ramp-incremented and RPE-clamped test protocols elicit similar VO$_{2max}$ values in trained cyclists. *Eur J Appl Physiol* 114, 1581-1590
Measurement of RPE in children
## Children’s Effort Rating Table (1994)

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very, very easy</td>
</tr>
<tr>
<td>2</td>
<td>Very easy</td>
</tr>
<tr>
<td>3</td>
<td>Easy</td>
</tr>
<tr>
<td>4</td>
<td>Just feeling a strain</td>
</tr>
<tr>
<td>5</td>
<td>Starting to get hard</td>
</tr>
<tr>
<td>6</td>
<td>Getting quite hard</td>
</tr>
<tr>
<td>7</td>
<td>Hard</td>
</tr>
<tr>
<td>8</td>
<td>Very hard</td>
</tr>
<tr>
<td>9</td>
<td>Very, very hard</td>
</tr>
<tr>
<td>10</td>
<td>So hard I’m going to stop</td>
</tr>
</tbody>
</table>

*References*


Better validity and test-retest reliability compared to the Borg 6-20 RPE Scale.
Developments in child-specific rating scales


Fig. 3. Traduction française [17,18] de l’échelle de perception de l’effort de l’enfant (CERT) de Williams et al. [57]. French translation [17,18] of the Children’s Effort Rating Table (CERT) of Williams et al. [57].
Validation of a pictorial curvilinear ratings of perceived exertion scale

Eston, Lambrick and Rowlands (2009) The perceptual response to exercise of progressively increasing intensity in children aged 7–8 years: Validation of a pictorial curvilinear ratings of perceived exertion scale. Psychophysiology, 46, 843-851
Validation of the E-P Scale and Marble Quantity task for Treadmill running in 7-8 year old children

Summary

• RPE is highly related to exercise intensity
• RPE can be used to predict VO$_2$$_{\text{max}}$ and prescribe intensity
• RPE can be used to assess effects of training
• Perceptually regulated exercise tests can be used to estimate VO$_2$$_{\text{max}}$
• Training at RPE 13 leads to increases in fitness and it feels ‘good’
• RPE increases linearly with time and has potential to be used to predict the time (or distance) remaining to exhaustion
• Children can use RPE provided it is understandable to them