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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

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Abstract

This study assessed the validity of the Eston-Parfitt (E-P) curvilinear Ratings of Perceived Exertion (RPE) Scale and a novel marble quantity task to provide estimates of perceived exertion during cycle ergometry. Fifteen children aged 7–8 years performed a discontinuous incremental graded-exercise test, and reported exertional ratings at the end of each minute. Significant increases in physiological and perceptual data were observed with increasing work rate. The relationship between work rate and marbles was curvilinear (mean $R^2 = .94$), supporting the theoretical justification for the E-P Scale. Strong linear ($R^2 = .93$) and curvilinear ($R^2 = .94$) relationships between RPE from the E-P Scale and work rate confirmed the robustness of the E-P Scale. Valid exertional ratings may be obtained using the E-P Scale with young children. The novel marble quantity task offers an alternative method of deriving perceived exertion responses in children.

Descriptors: Children, Perceived exertion, GXT, Validity, Curvilinear scale

Most research on perceived exertion in children has focused on the suitability of methods of assessing exercise effort, with a great deal of attention paid, in particular, to the appropriateness of the perceptual scales employed (Barkley & Roemmich, 2008; Eston & Lamb, 2000; Eston & Parfitt, 2007; Roemmich et al., 2006). As consideration of age and the cognitive developmental level of the child are fundamental for assessing perceived exertion in children (Eston, 2009), a number of child-specific ratings scales have been developed in the last 20 years.

Nystad, Oseid, and Mellbye (1989) attempted to improve children's understanding of Borg 6-20 Ratings of Perceived Exertion (RPE) Scale (Borg, 1998) through the addition of pictorial descriptors, but the children in their study continued to experience difficulties in interpreting the scale to estimate and produce exercise effort. The authors attributed this to the children's comparatively underdeveloped cognitive ability. Following a suggestion by Williams, Eston, and Stretch (1991) that a 1–10 scale would be more appropriate for assessing perceived exertion in children, the authors developed and validated the Children's Effort Rating Table which uses verbal anchors generated by children (CERT; Eston, Lamb, Bain, Williams, & Williams, 1994; Williams, Eston, & Furlong, 1994). The CERT is considered to be a significant advancement in the study of perceived exertion in children (Bar-Or & Rowland, 2004; Mahon, 1997; Robertson & Noble, 1997).

More recently, a number of derivatives of the 10-point scale have been developed to incorporate simplified numerical, verbal, and pictorial descriptors of perceived exertion. Abridged and pictorial versions of the CERT include the Cart and Load Effort Rating (CALER) Scale (Eston, Parfitt, Campbell, & Lamb, 2000) that depicts a child pulling a cart along flat terrain which is progressively laden with bricks, and the Bug and Bag Effort (BABE) Scale (Parfitt, Shepherd, & Eston, 2007), which portrays a Disney animation of an ant performing a stepping exercise onto a bench whilst wearing a backpack of increasing load. A further pictorial version of the CERT (P-CERT; Yelling, Lamb, & Swaine, 2002) uses all 10 original verbal descriptors of the CERT and depicts a child ascending a flight of steps. The Omnibus (OMNI) Scale (Robertson et al., 2000) illustrates a child riding a bicycle up a 45° incline. A more recent pictorial version of the Borg 6-20 RPE Scale, the RPE-C (Groslambert, Hintzy, Hoffman, Dugue, & Rouillon, 2001), also depicts a character in various stages of exertion ascending a vertical numerical scale.

The aforementioned child-specific scales have been shown to possess concurrent validity in prepubescent children and adolescents. The relationships between perceived exertion and various cardiorespiratory measures such as heart rate (HR; $b \cdot min^{-1}$)

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and the rate at which oxygen is consumed (oxygen uptake, $\dot{V}O_2$; $ml \cdot kg^{-1} \cdot min^{-1}$) are comparable to those observed when employing the Borg 6-20 Scale with adults, and indicate how closely perceived exertion in children matches the physiological changes throughout exercise. For example, for the OMNI Scale, the correlations of RPE with HR range from $r = .40$ to $r = .93$ ($p < .01$, Utter, Robertson, Nieman, & Kang, 2002; $p < .001$, Barkley & Roemmich, 2008, respectively). For $\dot{V}O_2$, these range from $r = .32$ to $r = .94$ ($p < .01$; Utter et al., 2002; Robertson et al., 2000, respectively). Barkley and Roemmich (2008) also provided evidence that the CALER scale is linearly related to HR and $\dot{V}O_2$ during cycle ergometry ($r = .92$, and $r = .88$, $p < .001$, respectively) in 9-year-old children. The concurrent validity of the P-CERT has also been confirmed by Roemmich et al. (2006) who reported strong linear relationships with HR ($r = .86$ and $r = .92$, $p < .001$, for boys and girls, respectively) and $\dot{V}O_2$ ($r = .86$ and $r = .94$, $p < .001$, for boys and girls, respectively). In addition to the above studies which reported RPE during an estimation paradigm, Parfitt et al. (2007) also showed high intraclass correlations (R) for HR ($R = .90$ and $R = .87$, $p < .001$) for cycling and stepping exercise, respectively, when the BABE scale was used as the independent variable to regulate exercise intensity at RPE 3, 5, and 8 in a triple-repeated, randomized, intermittent production paradigm.

The commonly employed Borg 6-20 Scale assumes a linear function between perceptual and physiological ($\dot{V}O_2$, HR) or physical (work rate) parameters (Borg, 1998). Similarly, the CERT was founded on the basis of a linear relation between CERTand HR (Eston et al., 1994; Williams et al., 1994). Indeed, all currently validated pictorial child-specific rating scales depict a child at varying stages of exertion on either a horizontal line or a linearly increasing gradient, to express the relationship between a child's perception of exertion and increasing exercise intensity.

It is feasible to consider that ventilation ($\dot{V}_E$) may be a mediating factor in respiratory-metabolic signals of exertion in children, such as in adults, particularly at higher intensities of exercise (Noble & Robertson, 1996). At lower work loads, $\dot{V}_E$ tracks metabolic demand, or $\dot{V}O_2$, in a linear fashion (Rowland, 2005). As work load increases, above approximately 60% $\dot{V}O_2max$, $\dot{V}_E$ rises according to a positively accelerating function to compensate for metabolic acidosis and bicarbonate buffering of lactic acid (Orenstein, 1993; Rowland, 2005). It has been suggested that between 45–70 % $\dot{V}O_2max$, $\dot{V}_E$ provides strong sensory signals of exertion (Robertson, 1982). Indeed, in adults it has been proposed that ventilatory function and discomfort are the only central signals of exertion that are consciously monitored, whereas HR does not appear to be associated with strong sensations of effort (Robertson, 1982).

If $\dot{V}_E$ is a central signal of exertion and this increases in a positively accelerating fashion above work rates of 60% $\dot{V}O_2max$, it follows that the RPE will also increase in a positively accelerating manner at high intensities. Indeed, following the original suggestion by Eston and Lamb (2000) that children will readily conceive that the steeper the hill, the harder it is to ascend, a pictorial scale that depicts a curvilinear relationship rather than a linear relationship between RPE and exercise intensity has been proposed to assess RPE in young children (Eston & Parfitt, 2007; Faulkner & Eston, 2008). The Eston-Parfitt (E-P) Scale utilizes a similar numerical range and verbal anchors abridged from the CERT, and depicts a character at various stages of exertion on a concave slope with a progressively increasing gradient at the higher intensities. Accordingly, the distance between each numbered increment on the horizontal axis (0–10) is increasingly reduced in relation to its antecedent (Figure 1). The area under the curve is also progressively shaded from light to dark from left to right, respectively.

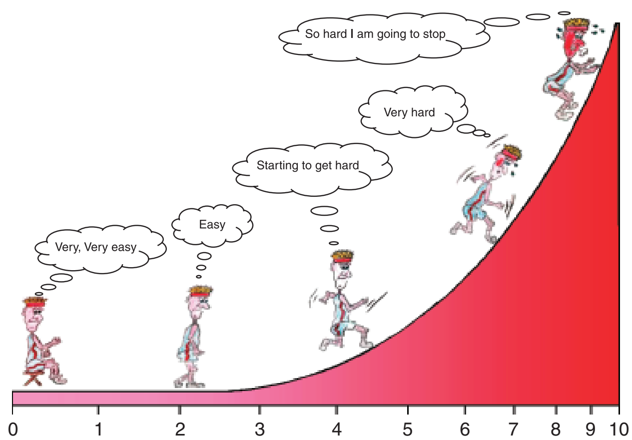

Figure 1. The Eston-Parfitt (E-P) curvilinear Ratings of Perceived Exertion (RPE) Scale.

Encouraging pilot data using the E-P Scale in the production mode has previously been reported (Eston & Parfitt, 2007). In their study, healthy boys and girls (aged 8–11 years) were required to bench step continuously for 3-min at self-regulated exercise intensities corresponding to RPE levels 2, 5, and 8. High intraclass correlations of $R = .71$, .75, and .76 ($p < .01$) were reported between HR and RPE levels 2, 5, and 8, respectively, across 6 experimental trials. Data from a recent study by Barkley and Roemmich (2008) on 9–10-year-old children have indicated that a scale which depicts a curvilinear rise in the RPE response may be warranted. They observed that children indicated RPE scores that were 75 ± 20% and 74 ± 19% of the total scale (for CALER and OMNI, respectively) compared to a corresponding heart rate response of 94.5% of the age-predicted maximal heart rate, during the final stage of a progressive maximal cycle ergometer test. They speculated that, if children were to indicate a maximal score on the ratings of perceived exertion scale at predicted maximal HR or $\dot{V}O_2$, then the rise in RPE would have to increase at a faster rate than had occurred at the lower workloads.

The purpose of this study was to assess the validity of the E-P Scale during an incremental graded-exercise test (GXT) on a cycle ergometer against continual measurement of HR, $\dot{V}O_2$, $\dot{V}_E$, and work rate in healthy children, aged 7–8 years. To further investigate the notion that a child's effort perception increases curvilinearly with linear increases in work rate, a novel psychophysical marble quantity task was implemented. We hypothesized that children would readily understand and utilize the E-P scale and the marble task to provide valid estimates of their perception of exertion in relation to increases in exercise intensity. We also hypothesized that the number of marbles taken from one container and placed into another with increasing exercise intensity would increase disproportionately in relation to HR, $\dot{V}O_2$, and work rate.

Method

Participants

Fifteen healthy children (six boys; age: 7.5 ± 0.5 years; height: 1.29 ± 0.03 m; seated height: 0.69 ± 0.01 m; body mass:

25.8 ± 2.5 kg, and nine girls; age: 7.6 ± 0.5 years; height: 1.29 ± 0.04 m; seated height: 0.70 ± 0.02 m; body mass: 27.3 ± 2.1 kg) were recruited for this study from a local independent school in the Exeter area. Participants completed a current health questionnaire prior to participating. All participants were asymptomatic of illness or disease and free from any acute or chronic injury. This information was gathered by means of a general health questionnaire, completed by the parents/guardians of each child. Each participant signed an informed assent form, and parents/guardians provided written informed consent to their child's participation prior to the commencement of the study. The study was approved by the ethics committee of the School of Sport and Health Sciences at the University of Exeter.

Procedures

Height, seated height, and body mass (Seca, Hamburg, Germany) were recorded for each participant prior to the exercise test. Each participant then performed a single graded exercise test (GXT) to volitional exhaustion on an electronically braked cycle ergometer (Lode Excalibur Sport V2, Lode BV, Groningen, The Netherlands). Seat height, handle bar, and pedal position were adjusted accordingly for each participant. Resistance on the cycle ergometer was manipulated automatically via the Lode workload programmer, accurate to ± 1 W, which was linked to the Cortex software (Cortex Metalyzer II, Biophysik, Leipzig, Germany) that utilized a previously programmed exercise protocol. All information screens displaying power output or any other physiological data were masked from the participant during the test. Revolutions per minute ($rev \cdot min^{-1}$) were visible to the participant on the Lode display screen, and it was expressed that the desired pedal cadence of 70 $rev \cdot min^{-1}$ was to be maintained throughout the test. This was to reduce the potential effect of low pedal cadence (<60 $rev \cdot min^{-1}$) and therefore greater resistance per pedal revolution, on the overall sensation of exertion (Jameson & Ring, 2000). Respiratory gas analysis ($\dot{V}O_2$, $\dot{V}_E$, RER) was performed continuously using breath-by-breath sampling (Cortex Metalyzer II, Biophysik, Leipzig, Germany). The system was calibrated prior to each test following the manufacturers' guidelines, with ambient air measurements calibrated against known concentrations of gas, and volume calibrations performed using a 3-litre syringe (Hans Rudolph Inc., Kansas City, MO). A large pediatric facemask (Hans Rudolph Inc.) was used to collect expired air, and assisted in allowing participants to verbally communicate with the experimenters. Heart rate was recorded throughout the test using a pediatric wireless chest strap telemetry system (Wearlink+, Polar Electro Oy, Kempele, Finland).

Each child had been given a copy of the E-P Scale to take home several weeks in advance of the start of the study, at which time they also received a full verbal explanation as to how to use the scale. No active familiarization with the scale was given prior to the test. However, the children were given further standardized instructions on how to implement the scale during their test session. The scale remained in full view of the child for the duration of the test. The children were similarly given standardized instructions on how to perform the marble task, which involved grasping a preferred number of marbles (out of a possible 50) from a container and placing them into another container, according to their current perception of effort. The harder the exercise felt to the participant, the more marbles they collected from the container, and vice versa. The instructions for both the E-P Scale (modified from Robertson et al., 2000) and the marble quantity task are as follows:

"Whilst you are exercising on the bicycle, we would like you to use this scale to tell us how your body feels. You can point to a number or slide the marker along the scale to tell us how you feel. Please look at the person on the left (point to the left pictorial). If you feel like this person whilst riding the bicycle, it will feel *very, very easy* to you. Please look at the person on the right (point to the right pictorial). If you feel like this person whilst riding the bicycle, then you will feel that it is '*so hard I am going to stop.'* If you feel somewhere in between *very, very easy* (0) and *so hard I am going to stop* (10), then point or slide the marker to a number between 0 and 10.

"We would also like you to use these marbles to tell us how you feel whilst you are cycling. The harder the exercise feels to you, the more marbles you take from this container and place into the empty container. If you feel that the exercise is *very, very easy* to you, then you should take a few marbles and place them into the empty container. If the exercise feels *so hard that you are going to stop*, then you may place lots of marbles into the empty container. If you feel somewhere in between *very, very easy* and *so hard I am going to stop*, then you may choose any number of marbles to place into the empty container.

"We would like you to *really* think about how your whole body feels when you are riding the bicycle—how your legs feel and how your breathing (chest) feels. Try to answer as honestly as possible. There are no right or wrong answers."

Children were informed that fifty marbles were available in the container for the purpose of estimating their RPE. As such, children had an upper reference in the marble task, similar to the E-P Scale, to which they could anchor their perceptions. The order in which each method was implemented was randomized between participants but remained consistent during each test. Any queries regarding the application of the scale or the procedure for the marble task were resolved before the start of the exercise test.

Graded Exercise Test (GXT) to $\dot{V}O_2$peak

All participants completed a 3-min warm-up on the cycle ergometer at a resistance of 15 W, followed by a 2-min rest where the procedural instructions were briefly repeated. A discontinuous GXT protocol was then applied, which commenced at 10 W for 1-min, followed by an intervening 1-min period of unloaded cycling. The work rate was then increased by 10 W for 1 min, and the procedure was repeated until the participant attained maximal oxygen uptake ($\dot{V}O_2$peak). During the final 15 sec of each minute of loaded cycling throughout the exercise test, participants were asked to report their perception of exertion using two methods. The E-P Scale was placed in front of the participant whilst cycling; the participant then moved the sliding marker along the numerical scale to the number that satisfied their level of exertion at that specific exercise intensity, or pointed to a corresponding place on the slope. If the participant had pointed to a place on the slope, a perpendicular line was drawn down from this point to obtain a corresponding numerical value. The equivalent number was recorded and/or the marker was returned to the starting position on the scale (zero). Immediately after (or prior to the E-P Scale being employed) participants selected any number of marbles (out of a possible 50) from a container and placed them into an identical container, adjacent to the first. The number of marbles placed into the adjacent container was recorded, after which the marbles were returned to the original container. The question, "*How hard does the exercise feel to you?*" was asked prior to each method being implemented.

Criteria for terminating the exercise test included exhaustion, in association with HR $\geq$ 195 $b \cdot min^{-1}$; respiratory exchange ratio (RER)1.02; an evident plateau or peak in $\dot{V}O_2$, or <2.1 $ml \cdot kg^{-1} \cdot min^{-1}$ increase in $\dot{V}O_2$ in the final stage of exercise; pedal cadence <70 $rev \cdot min^{-1}$ for a period greater than 5 sec (Rowland, 1996). At the end of the exercise test, participants cycled against a light resistance to aid recovery.

Data Analysis

Physiological ($\dot{V}O_2$, HR, V_E) and perceptual (E-P Scale, marbles) data, recorded in the final 15 sec of each active exercise bout, were collated and used in the subsequent analyses. Due to the nature of the cycling protocol, which implemented fixed, absolute increments in work rate, variable maximal work rates were attained by participants in this study (70–120 W). As such, repeated measures ANOVA assessed the change in $\dot{V}O_2$, HR, $\dot{V}_E$, RPE from the E-P Scale and marble response with increasing exercise intensity across the first seven stages of the exercise test. If data violated assumptions of sphericity using the Mauchly test, the Greenhouse-Geisser epsilon (ε) correction factor was applied to improve the validity of the F ratio. In such cases, the uncorrected degrees of freedom are reported in conjunction with the respective epsilon value. Furthermore, where significant differences were observed, paired samples t-tests with Bonferroni adjustment ($p<.025$) were employed to investigate where the differences lay. To account for the decreasing number of participants at the higher intensities of exercise, the remaining data from stages 8–12 (80–120 W) were subsequently analyzed using a series of paired t-tests. Similarly, Bonferroni adjustment ($p<.025$) was applied to increase the stringency of the analysis and to protect against type I error.

To test the curvilinear properties of the E-P scale and the marble task, individual regression analyses, using Microsoft Office Excel software (Microsoft Office Excel, 2003, version 11), were conducted using both linear and curvilinear ('exponential') lines of best fit on the perceptual data (dependent variable) in relation to work rate (independent variable). Individual coefficients of determination (R squared; R^2) were calculated across relative maximal work rates (i.e., 10–120 W). To approximate the normality of the sampling distribution, all individual R^2 values were converted into Zr values using Fisher's Zr transformation. A mean Zr value was then calculated and re-converted into a mean R^2 for all participants in this study. An identical procedure was employed between the RPE data measured by the E-P Scale and the marble task with $\dot{V}O_2$. To investigate whether HR or V_E was a significantly stronger mediator of the perceptual responses (E-P Scale, marbles), both linear and curvilinear least squares models were similarly performed via individual regression analysis for the ventilatory and perceptual responses, and HR and the perceptual responses. The resultant R^2 values were then analyzed using paired samples t-tests (with Bonferroni adjustment; $p<.025$) to obtain the four 'best-fit' relationships (those with significantly higher R^2). The four best-fit relationships were subsequently analyzed using paired samples t-tests ($p<.025$) to investigate whether any differences were apparent.

To investigate the consistency of pedal cadence throughout exercise tests, particularly during the period of rating perceived exertion (during the final 15 sec of each active bout of exercise), a coefficient of variation analysis was performed on the pedal revolution data ($rev \cdot min^{-1}$). A paired t-test was also utilized between the two randomly allocated groups of participants who either rated their perceived exertion using the E-P Scale first or the marble task first. This was to investigate whether the visibility of the E-P Scale for the duration of the test for all participants had marked influence on the exertional ratings provided when using the marble task.

Alpha was set at 0.05, and adjusted accordingly. All analyses were performed using the statistical package SPSS for Windows, version 13.0.

Results

Fifteen children completed the first seven stages (70 W) of the exercise test, 14 completed stage 8, 10 completed stage 9, 6 completed stage 10, 3 completed stage 11, and 2 completed stage 12 (120 W). Repeated measures ANOVA, employed on data from the initial seven stages, revealed highly significant increases in $\dot{V}O_2$ ($F(6,84) = 272.19$, $p<.001$, $\eta^2 = .623$), HR ($F(6,84) = 469.9$, $\varepsilon = .432$, $p<.001$, $\eta^2 = .747$), $\dot{V}_E$ ($F(6,84) = 110.3$, $\varepsilon = .356$, $p<.001$, $\eta^2 = .666$), E-P Scale RPE ($F(6,84) = 50.1$, $\varepsilon = .328$, $p<.001$, $\eta^2 = .593$), and marble task RPE ($F(6,84) = 29.6$, $\varepsilon = .294$, $p<.001$, $\eta^2 = .555$) with successive increases in exercise intensity. In consideration of children reaching maximal volitional exhaustion at different stages of the exercise test, a series of paired t-tests with Bonferroni adjustment ($p<.025$) were utilized on the remaining data from stages 8 to 12 to allow exploration of the widest range of physiological and perceptual data collected. For all variables, further significant increases ($p<.025$) were observed across stages 7 to 8 ($t(13) = -5.01$, $t(13) = -16.61$, $t(13) = -4.28$, $t(13) = -4.58$, and $t(13) = -3.98$ for $\dot{V}O_2$, HR, $\dot{V}_E$, E-P Scale RPE, and marbles, respectively) and stages 8 to 9 ($t(9) = -7.75$, $t(9) = -9.54$, $t(9) = -2.97$, $t(9) = -4.39$, and $t(9) = -3.22$ for $\dot{V}O_2$, HR, $\dot{V}_E$, E-P Scale RPE, and marbles, respectively). In addition, significant increases ($p<.025$) in HR were observed across stages 9 to 10 and 10 to 11 ($t(5) = -3.49$, and $t(2) = -14.00$, respectively). At the higher exercise intensities, and between stages 3 and 4 for the RPE measured by the E-P Scale, no significant increases ($p>.025$) were observed with increasing power output (see Figures 2, 3, 4, 5, & 6 for $\dot{V}O_2$, HR, $\dot{V}_E$, E-P Scale RPE, and marble task RPE, respectively).

No significant differences between the strength of the relationships between RPE and work rate were observed ($t(6) = 0.67$, $p>.05$) between the children who rated their perception of exertion using the E-P Scale first ($R^2 = .94$) or those

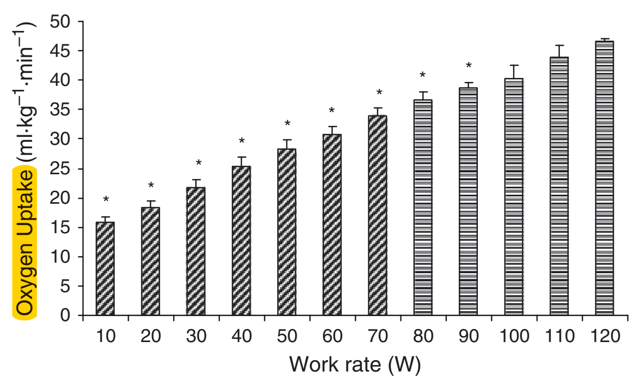

Figure 2. Increases in oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$) with incremental exercise (W). Values are Mean $\pm$ SEM. $R^2 = .99$ for work rate 10–120 W. *Significant ($p<.01$) increases in $\dot{V}O_2$ with exercise intensity.

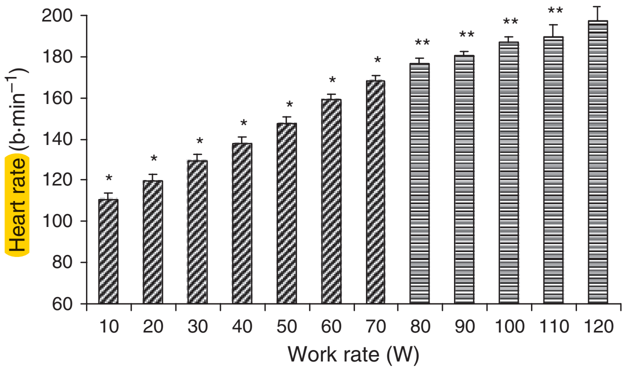

Figure 3. Increases in heart rate ($b \cdot min^{-1}$) with incremental exercise (W). Values are Mean ± SEM. $R^2 = .98$ for work rate 10–120 W. *Significant ($p < .001$) increases in HR with exercise intensity. **Significant ($p < .025$) increases in HR with exercise intensity.

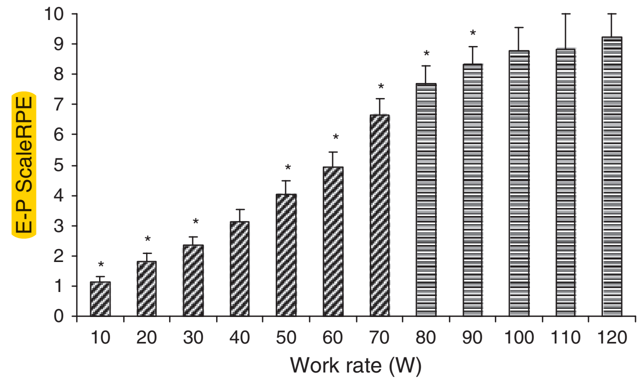

Figure 5. Increases in the ratings of perceived exertion using the Eston-Parfitt Scale, with incremental exercise (W). Values are Mean ± SEM. $R^2 = .93$ for work rate 10–120 W. *Significant ($p < .025$) increases in RPE with exercise intensity.

who used the marbles first ($R^2 = .93$). When utilizing individual data across the full range of relative work rates (i.e., 10–120 W), average Fisher *Zr* correlations were significantly higher ($t(14) = -4.15$, $p < .01$) for the curvilinear relationship compared with the linear relationship between the marble quantity task and work rate ($R^2 = .94$ and $R^2 = .80$, respectively). For the E-P Scale, no significant differences ($p > .025$) were noted between the mean linear and curvilinear R^2 values ($R^2 = .93$ and $R^2 = .94$, respectively) for the RPE and work rate. Similarly, no significant differences ($p > .05$) were observed between the mean linear and curvilinear relationships between the RPE from the E-P Scale and $\dot{V}O_2$ ($R^2 = .88$ and $R^2 = .92$, respectively). However, a significantly stronger ($t(14) = -7.468$, $p < .001$) curvilinear relationship was apparent between the RPE from the marble task and $\dot{V}O_2$ ($R^2 = .77$ and $R^2 = .92$ for linear and curvilinear, respectively).

Paired sample *t*-tests of the relationships (Fisher *Zr*) between the $\dot{V}_E$ and the RPE, measured by the marble task using both curvilinear and linear trend lines, revealed a significantly stronger ($t(14) = -3.01$, $p < .025$) curvilinear relationship ($R^2 = .92$ and $R^2 = .86$, respectively). However, no significant differences ($p > .05$) were observed between the curvilinear or linear relationship between $\dot{V}_E$ and the RPE from the E-P Scale ($R^2 = .88$ and $R^2 = .90$, respectively). Similarly, the curvilinear model was significantly stronger ($t(14) = -5.31$, $p < .025$) than the linear model for HR and marble quantity task ($R^2 = .93$ and $R^2 = .79$, respectively). There was also no significant difference ($p > .05$) in the strength of the linear and curvilinear relationships between HR and the RPE from the E-P Scale ($R^2 = .92$ and $R^2 = .88$, respectively). Further analysis utilizing the lines of 'best fit' data revealed no significant differences ($p > .05$) between the R^2 values for $\dot{V}_E$ and the marble quantity task, or HR and the marble quantity task ($R^2 = .92$ and $R^2 = .93$, respectively). Similarly, no significant differences ($p > .05$) were noted between the R^2 values for $\dot{V}_E$ and RPE from the E-P Scale, or HR and RPE from the E-P Scale ($R^2 = .90$ and $R^2 = .92$, respectively).

With regard to the variation in pedal cadence for all children in this study, subsequent analysis of the collated pedal revolution data revealed that children cycled at an average of 72.4 ± 8.1 $rev \cdot min^{-1}$ throughout all exercise stages, and 71.7 ± 8.0 $rev \cdot min^{-1}$ during the final 15 sec of each exercise stage. This equated to a coefficient of variation range of 2.4–6.9% across exercise tests, for all participants in this study. Furthermore, no significant differences were observed ($t(6) = 0.67$, $p > .05$) between the children who rated their perception of exertion using the E-P Scale first ($R^2 = .94$) or those who used the marbles first ($R^2 = .93$).

Discussion

This study assessed the validity of the E-P Scale during an incremental GXT to volitional exhaustion on a cycle ergometer

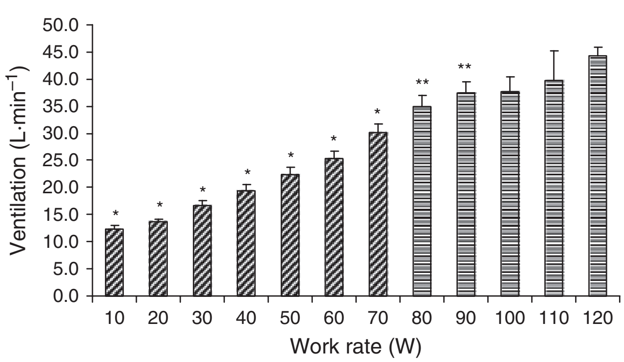

Figure 4. Increases in ventilation ($L \cdot min^{-1}$) with incremental exercise (W). Values are Mean ± SEM. $R^2 = .96$ for work rate 10–120 W. *Significant ($p < .01$) increases in ventilation with exercise intensity. **Significant ($p < .025$) increases ventilation with exercise intensity.

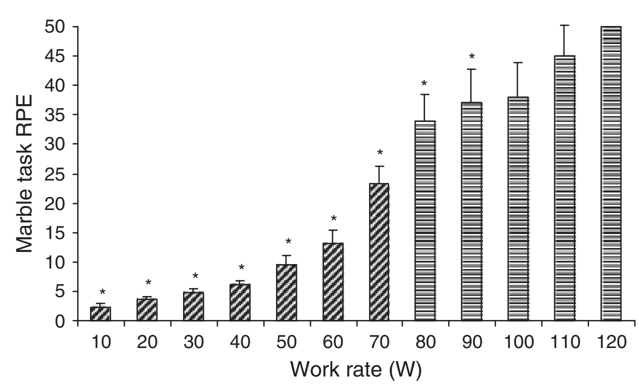

Figure 6. Increases in the number of marbles chosen, using the psychophysical marble quantity task, with incremental exercise (W). Values are Mean ± SEM. $R^2 = .94$ for work rate 10–120 W. *Significant ($p < .025$) increases in number of Marbles with exercise intensity.

with healthy 7–8-year-old children. The successive increases in perceived exertion with increments in exercise intensity indicate that children readily understood the nature and purpose of the E-P Scale. Furthermore, without a prior active familiarization bout of exercise, the children were able to use the scale to accurately estimate their perception of exertion throughout the exercise test. Equally strong linear and curvilinear coefficients of determination (R^2) were observed between the E-P Scale and work rate ($R^2 = .93$ and $R^2 = .94$, respectively). The young children in this study were also able to comprehend and apply the novel perceptual marble task effectively, providing an accurate indication of their perception of effort for the duration of the test. The strong curvilinear relationship demonstrated between the marble quantity task and work rate ($R^2 = .94$) provides further support for the use of a curvilinear rating of perceived exertion scale with normal, healthy young children.

As the children understood from the outset that the stages in the exercise test would become progressively harder, it is plausible to assume that the rise in their perceptual responses may have been the result of anticipatory bias. However, the equally high linear and curvilinear R^2 values, for the RPE reported through the E-P Scale and increasing exercise intensity (work rate, $\dot{V}O_2$, $\dot{V}_E$, HR), demonstrate that all the children understood and could utilize the E-P Scale to provide valid ratings of perceived exertion. Furthermore, our data demonstrate the robustness of the E-P Scale to detect both linear and curvilinear growth functions of the children's perceptual responses during incremental exercise.

The statistically higher curvilinear R^2 value ($R^2 = .94$) observed for the relationship between perceived exertion assessed from the marble task and work rate suggests that the perception of exertion for a child aged 7–8 years may rise in a curvilinear fashion in response to equal and gradual increments in work rate, which in this study equated to between 1–2 child-specific metabolic equivalents for this age range (5.92 $ml \cdot kg^{-1} \cdot min^{-1}$; Harrell et al., 2005). For the participants in this study, exponents in the range 0.58–1.98 were generated for the RPE response when this was calculated from the natural logarithmic values of the individual relationships between the RPE from the marble task and work rate. This equated to an average exponent of 1.3 ± .8, which is in accordance with previous research that has demonstrated exponents of approximately 1.6 in studies on short-term perceived exertion during cycle ergometry (Borg, 1998; Borg & Dahlström, 1959; Borg, Edström and Marklund, 1970). Indeed, it is important to recognize that prior to the formation of the Borg 6-20 RPE scale, upon which many of the subsequent (linear) child-specific RPE scales were based; psychophysical studies investigating subjective force and perceived exertion during cycle ergometry demonstrated nonlinear functions between the ratio data of perceived intensity and physical work load (Borg, 1970; Borg & Dahlström, 1960).

The slope of the E-P Scale was originally drawn by one of the authors (Eston) based on a simple power function ($R = c \cdot S^n$) as described by Borg (1998). As such, the slope of the hill (from number 2–10 on the horizontal axis), depicted pictorially in Figure 1, was designed with an exponent of approximately 3. This is in keeping with previous research that has yielded an exponent of 3 during treadmill walking and running (Borg 1973, 1998). However, the overall exponent for the E-P Scale, when calculated across the full numerical range (0–10), is 1.04. This is a consequence of the pictorial design, in that the exponent is reduced when the calculation takes into account the significant portion of the base of the hill (0–2.5) which is parallel to the horizontal axis. Individual analyses, comparable to those performed with the marble task data, between the RPE responses from the E-P Scale and work rate, revealed exponents in the range 0.53–1.69. This constitutes an average exponent of 1.03, which is appreciably similar to the exponent generated in the design of E-P Scale.

As in the familiar Borg Category-Ratio 10 (CR10) scale (Borg, 1998), the E-P Scale encompasses both category and ratio properties. However, unlike the CR10, the E-P Scale does not permit free magnitude estimation. Rather, it has a fixed end point, or an upper reference, to which participants can anchor their perceptions. The character utilized on the E-P Scale, depicted in rising stages of exertion on a progressively increasing gradient, complements the assumption that from prior learning and experience a child will readily conceive that the steeper the hill, the harder it is to ascend (Eston & Lamb, 2000). The distinct characteristic of the numerical range utilized on the E-P Scale similarly reflects the rise in the RPE during the higher intensities of exercise, corresponding with the pictorial descriptors. Furthermore, in the initial development of the E-P Scale, the locations of the stylized figures were chosen by children according to where they perceived they should be (Eston & Parfitt, 2007). On this basis, we believe the E-P Scale holds inherently obvious face validity.

It is unknown, however, if the ambulatory figure depicted in the E-P Scale was a primary focus of the child's attention. It is also unknown whether a 'cycling' figure may have led to even greater perceptual acuity of the exertion experienced by the child during the 'cycling' task in this study. Despite the modality of exercise depicted in the scale not being congruent with the exercise task, it has been observed by Parfitt et al. (2007) that a mode-specific stepping scale (BABE) and a mode-specific cycling scale (CALER) may be used interchangeably for intra- and intermodal regulation of effort production in young children aged 9–10 years. This infers that a mode-specific RPE scale may not be necessary for a child to accurately gauge the sensation of exertion. Further to this, the resultant exponents generated by the marble task in this study reflect rather more closely those observed during cycle ergometry exercise (exponent of approximately 1.6) than those observed during either walking or running exercise (exponent of approximately 3), as depicted on the E-P Scale. Prior research has also indicated that the gender of the pictorial descriptors does not systematically influence perceptual responses (Roemmich et al., 2006). However, the relative influence of the visual information (pictorial, numerical, or verbal descriptors) has yet to be established when determining a suitable perceptual rating using the E-P Scale.

Although this is the first study to utilize a curvilinear RPE scale for the purpose of estimating exercise effort in children, curvilinear relationships between perceived exertion and variables such as HR and power output have been previously documented in the pediatric literature. In a study by Lamb (1995), which utilized the CERT in a passive estimation mode, the HR data of 36 boys and girls aged 9–10 years manifested considerable disparity, particularly at higher exercise intensities, when compared against the linear conceptual model on which the CERT was originally based (Williams et al., 1994). Moreover, the author noted a similar, non-linear trend between the RPE data from the CERT and increasing power output. Accordingly, a curvilinear model was proposed to fit the data more suitably, and yielded stronger correlations than the original linear model (Lamb, 1995). Barkley and Roemmich (2008) have further corroborated these findings. In their study, boys and girls (aged 9.5 ± 0.7 years and 9.4 ± 0.8 years, respectively) performed a continuous, incremental exercise test to $\dot{V}O_2$peak on a cycle ergometer, and estimated RPE every minute using both the CALER and OMNI perceived exertion scales. They revealed that children reported terminal RPE values that were statistically lower ($p \leq .001$; 75 ± 20% and 74 ± 19% of theoretical maximal (RPE 10) for CALER and OMNI, respectively) than the proportion of predicted maximal heart rate (94.5 ± 3%) achieved during the final stage of the exercise test (Barkley & Roemmich, 2008). Moreover, a study by Roemmich et al. (2006) on boys and girls (aged 11.2 ± 1.6 years and 11.1 ± 1.4 years, respectively) has indicated similar findings, reporting that, at 82% of HR maximum and 70% $\dot{V}O_2$peak during a progressive, submaximal treadmill protocol, children corresponded with only 52% of the maximum value on the RPE scale. This infers that perceived exertion tracks according to a positively accelerated function, as has previously been suggested in the adult literature (Borg, 1998; Borg & Dahlström, 1959).

Despite continued increases in $\dot{V}O_2$, HR, $\dot{V}_E$, RPE from the E-P Scale and marbles during the latter stages of the exercise test (approximately 90–120 W), no statistical differences were noted between stages. This is likely attributed to the limited number of participants who continued to exercise to these higher exercise intensities, and the resultant decrease in statistical power of the analyses. Additionally, it may reflect similarities in the maximal physiological and perceptual responses obtained from each of these participants at the point of exhaustion. From the physiological data reported in Table 1, we are satisfied that all participants reached $\dot{V}O_2$peak at termination of the exercise test. Furthermore, the standardized instructions and anchoring of the perceptual responses for both the E-P Scale and the marble task were deemed sufficient to allow confidence in the maximal RPE responses of each child in this study.

In this regard, it is notable that the average terminal RPE (mean ± *SD*) reported at $\dot{V}O_2$peak for all participants was RPE 9.4 (± 1.1), which was slightly but significantly lower than the theoretical maximal RPE (10) according to the E-P Scale ($t(14) = -2.17$, $p < .05$). A similar finding was observed with the marble task, wherein the average terminal quantity of marbles (mean ± *SD*) selected by all 15 participants in this study (44.4 ± 9.6) was significantly lower than the theoretical maximal quantity of marbles (50; $t(14) = -2.25$, $p < .05$). These findings are in accordance with previous research conducted with adults, which have noted that the theoretical maximal RPE on the Borg 6-20 RPE Scale is infrequently reported at volitional exhaustion (Eston, Faulkner, St Clair Gibson, Noakes, & Parfitt, 2007; Faulkner, Parfitt, & Eston, 2007; Kay et al., 2001; St Clair Gibson, Lambert, Hawley, Broomhead, & Noakes, 1999). It is noteworthy that these findings are also in accordance with those of Barkley and Roemmich (2008), albeit to a lesser extent; in that the terminal RPE was lower than theoretical maximal RPE value at a similar maximal physiological output. However, as the proportional difference between the maximal RPE and maximal exercise intensity is much smaller in the current study (96% of total RPE scale reported) compared to the study by Barkley and Roemmich (75% and 74% of total RPE scale reported at 94.5% of predicted HRmax), we suggest that the curvilinear design of the E-P Scale may present a more appropriate tool to reflect the cognitive developmental characteristics of a child's perceived exertion response.

This study utilized participants of a young age range (7–8 years). It is clear that the children in this study were in the 'Concrete Operations Period' of their cognitive development, according to Piaget (1999), as they understood the three-dimensional aspects involved in the marble task (number, volume, and weight of the marbles) and simultaneously were able to interpret the two-dimensional curvilinear pictorial scale. This demonstrates the ability for 'conservation of quantity' and 'decentering,' which are fundamental to this phase of the child's development (Child, 1977).

In this study, the children were also able to cope with the process of estimating via the two distinct procedures whilst simultaneously maintaining a fixed pedal cadence. The possibility that 'dual loading' would influence pedal cadence was discounted on the basis of a low coefficient of variation of their pedal revolutions data throughout each test (2.4–6.9%). Similarly, as large intra-individual variation in pedal cadence throughout an exercise test may impede accurate determination of perceptual growth functions in relation to work rate (independent variable), the low coefficient of variation in pedal cadence reported in this study permits assurance that our overall interpretation of the perceived exertion response in relation to work rate is acceptable.

It is important to note that the E-P Scale was visible to all participants throughout the duration of the test. Despite randomizing the order in which each participant was presented with the methods of rating their perceived exertion (i.e., E-P Scale prior to marbles, marbles prior to E-P Scale), it is potentially feasible that the visibility of the E-P Scale may have influenced the subsequent selection of marbles. However, further analysis confirmed that no significant differences in the relationship between the RPE and work rate ($t(6) = 0.67$, $p > .05$) were observed between the children who rated using the E-P Scale first ($R^2 = .94$) or those who used the marbles first ($R^2 = .93$). Similarly, it is feasible to assume that intra-individual differences in RPE response may result from the alternate use of the point and slide procedures when using the E-P Scale. Although this was not formally assessed, it is noteworthy that all the children in the present study chose either to point to the scale *or* slide the marker when rating their perceived exertion, which they repeated through choice for the duration of their test.

Table 1. *Maximum Physiological Variables (oxygen uptake, $\dot{V}O_2$; $ml \cdot kg^{-1} \cdot min^{-1}$; heart rate, HR; $b \cdot min^{-1}$; ventilation, $\dot{V}_E$; $L \cdot min^{-1}$; respiratory exchange ratio, RER) and Terminal RPE (E-P Scale and marble task) Obtained at Termination of the Exercise Test (maximum work rate; W) for all Fifteen Children (aged 7–8 years). Values are Mean ± SD*

$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	HR ($b \cdot min^{-1}$)	$\dot{V}_E$ ($L \cdot min^{-1}$)	RER	Work rate (W)	RPE (E-P Scale)	RPE (Marbles)
53.5 ± 9.4	193 ± 8.1	60.7 ± 14.2	0.96 ± 0.07	92 ± 14	9.4 ± 1.1	44.4 ± 9.6

This study utilized the RPE in a passive estimation paradigm which is similar to many previous investigations on perceived exertion in children (Barkley & Roemmich, 2008; Groslambert & Mahon, 2006; Mahon & Ray, 1995; Marinov, Mandadjieva, & Kostianev, 2008; Robertson et al., 2000; Roemmich et al., 2006; Utter et al., 2002). However, the protocol employed in this study was discontinuous and incremental in style, which is unlike many previous studies in this area. Lamb, Trask, and Eston (1997) assessed the influence of protocol on the relationship between perceived exertion (CERT) in children (9–10 years) using a production paradigm. They reported significantly higher correlations ($p < .05$) between perceived exertion (CERT) and heart rate using a discontinuous protocol when compared to a continuous protocol ($r = .66$ and $r = .46$). Although somewhat limited, Eston and Parfitt (2007) have also provided evidence to suggest that an intermittent protocol may be preferable over a continuous protocol during a passive estimation procedure, for an 8-year-old child. As acceptable physiological and perceptual criteria for reaching $\dot{V}O_2$peak were elicited by each participant in this study (Table 1), we are satisfied that a discontinuous protocol was appropriate for this study.

The specific factors that affect RPE determination in children remain unknown (Mahon & Ray, 1995). Ventilation has been suggested as a potential cue for perceptual responses given that it is an accepted physiological mediator for respiratory-metabolic signals of exertion during endurance exercise (Eston & Parfitt, 2007). However, the preliminary results of this study suggest that neither heart rate nor ventilation is a statistically stronger mediator of perceptual responses in young children. Whether the integration of several cardio-respiratory and metabolic signals, in addition to peripheral mediators of exertion, act to constantly regulate perceived exertion in children, such as in adults, or whether one physiological mediator presides over all others is yet to be determined.

Despite the sample size (15 children) being large enough to exact statistical differences from the analyses, we acknowledge that a larger sample would aid in generalizing our findings to the wider population.

Conclusion

The results of this study provide evidence in support of the validity of the E-P Scale to provide estimates of perceived exertion in healthy children, aged 7–8 years. The novel psycho-physical marble task employed in this study offered a valuable and interesting insight into a child's method of deriving valid exertional ratings. These findings challenge conventional understanding and question available methods of assessing perceived exertion in children. The unique observations in this study are encouraging and indicate that a child's perception of exertion may rise curvilinearly with equal increments in work rate.

The findings of this study concur with the postulation that a curvilinear gradient may be more ecologically valid for use with children. The E-P Scale has such a gradient, and therefore has inherent face validity as such visual representation may facilitate a child's understanding and thus his or her ability to use the scale. A single exercise test was used for the purpose of estimation in this study, with no assigned period of habituation. Future studies are recommended to investigate the validity and reliability of the E-P Scale in both the passive estimation and active production paradigms, and the influence of familiarization on trial-to-trial variability of perceived exertion responses in children of this age.

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