The Influence of Exercise Test Protocol on Perceived Exertion at Submaximal Exercise Intensities in Children

Anthony D. Mahon, David M. Plank, and Molly J. Hipp

Catalog Data

Key words: ventilatory threshold, cardiorespiratory measures, exercise test, peak VO$_2$, cycle ergometry, RPE

Abstract/Résumé
This study examined ratings of perceived exertion (RPE) using Borg’s 6-20 scale at 50 W, 80 W, and ventilatory threshold (VT) in 10-year-old children (n = 15) during two different graded exercise tests. Power output was increased by 10 W·min$^{-1}$ in one protocol and by 30 W·3 min$^{-1}$ in the other. The cardiorespiratory responses at VT and peak exercise were similar between protocols. At 50 W and 80 W the cardiorespiratory responses were generally lower (P < 0.05) in the 10-W trial. However, RPE was 11.5 ± 2.9 and 12.1 ± 3.2 at 50 W and 15.1 ± 2.7 and 15.3 ± 2.8 at 80 W in the 10-W and 30-W trials, respectively (P > 0.05). The RPE at VT was 13.9 ± 2.4 in the 10-W trial and 12.4 ± 2.4 in the 30-W trial (P < 0.05). In that variations in submaximal RPE did not coincide with variations in central mediators of exertion, locals cues of exertion may have provided the dominate sensory signal.

Cette étude analyse la perception de l’intensité de l’effort (RPE) chez des enfants de 10 ans (n = 15) au moyen de l’échelle 6-20 de Borg au cours d’épreuves d’effort dont l’intensité est progressivement augmentée de 10 W par minute et, dans un deuxième temps, de 30 W.

The authors are with the Human Performance Laboratory, Ball State University, Muncie, IN.
toutes les 3 minutes; la RPE est évaluée aux intensités suivantes : 50 W, 80 W et au seuil ventilatoire (VT). Les ajustements cardiorespiratoires au seuil ventilatoire et à l’exercice de crête sont semblables d’une épreuve à l’autre. Aux intensités de 50 W et de 80 W, les ajustements sont généralement moins importants (p < 0,05) au cours de l’épreuve progressive par palier de 10 W. Les RPE sont de 11,5 ± 2,9 et 12,1 ± 3,2 à 50 W et 15,1 ± 2,7 et 15,3 ± 2,8 à 80 W dans les épreuves par palier de 10 W et de 30 W, respectivement (p > 0,05). Le RPE au seuil ventilatoire est de 13,9 ± 2,4 au cours de l’épreuve graduée par palier de 10 W et de 12,4 ± 2,4 dans l’épreuve graduée par palier de 30 W (p < 0,05). Les variations de perception de l’intensité de l’effort ne coïncident pas avec les variations des médiateurs centraux de l’effort; les signaux locaux associés à l’effort constituent fort probablement la principale dominante sensitive.

Introduction

During the course of a graded exercise test, the magnitude of the power output increment and the exercise test stage duration dictate the corresponding physiological responses. The physiological responses in turn provide the sensory signals underlying the perception of effort. A common scale used in the assessment of perceptual effort is the Borg 6-20 rating of perceived exertion (RPE) scale (Borg, 1972). On this scale RPE represents the combined influence of a collection of cardiorespiratory, metabolic and muscular sensations related to the exercise intensity (Robertson and Noble, 1997). Sensations arising from the cardiorespiratory and metabolic response to exercise are referred to as central or respiratory-metabolic signals of exertion, whereas the muscular sensations are termed local or peripheral signals of exertion (Pandolf, 1983; Robertson and Noble, 1997).

A number of studies examining overall RPE in children have focused on the ability of the child to estimate his or her effort during exercise (Bar-Or, 1977; Duncan et al., 1996; Lamb et al., 1995; Mahon et al., 1997, 1998; Robertson et al., 2000). These studies have established that children as young as eight years of age are able to use subjective rating scales in the assessment of perceptual effort. Despite this knowledge, it is unknown how manipulation of the exercise test protocol may alter the child’s perceptual framework at a given level of exercise. For example, an exercise test employing a relatively small increment rate may result in an less abrupt transition to the next level of exercise compared to the employment of larger increments in power output. With respect to stage duration, exercise tests with short stage durations may preclude the attainment of steady-state exercise responses compared to tests utilizing longer stage durations. Thus, an exercise test using relatively small increments in power output with short stage durations may alter the intensity of the various central and local mechanisms mediating perceived exertion compared to a protocol involving a larger increment rate and longer stage duration. In addition, if a child is able to provide similar ratings of effort at the same intensities, but under different exercise test conditions, the validity of assessing perception of effort in children is enhanced. Thus, the purpose of this study was to evaluate the effect of two different exercise test protocols using the same rate of increase in power output (10 W · min⁻¹ versus 30 W · 3 min⁻¹) on the overall RPE in children at submaximal levels of exercise.
Methods

SUBJECTS

Fifteen children (six girls and nine boys) participated in this study. Prior to the child’s participation, parental consent and child assent were provided in accordance with the policy of the Institutional Review Board at our university. The mean (± SD) age, height and weight of the children were 10.8 ± 0.6 yrs, 145.6 ± 6.8 cm, and 40.9 ± 8.6 kg, respectively. The child’s pubertal status, using Tanner’s stages for pubic hair development, was determined by each child’s parent using a standard rating form (Tanner, 1962). Nine children (six boys and three girls) were classified as Tanner stage 1; three children were classified as Tanner stage 2 (two boys and one girl); and two boys were classified as Tanner stage 3. Pubertal status was not obtained from one female subject. According to parental report, most of the children were participating in activities such as volleyball, soccer, basketball, swimming, and track and field at the time of their participation in this study. However, none of the children were engaged in heavy amounts of exercise training at the time of the study.

PROCEDURES

Each child was required to report to the laboratory on three separate days. Testing was separated by at least 48 hours and each child completed all phases of the testing within a 4-week period of time. On the first visit to the laboratory, the subject’s age was recorded, and height and weight were obtained. Height was measured using a tape measure secured to a wall in the laboratory, and weight was measured using a balance beam scale. The child then read a standardized set of instructions regarding the use of the Borg 6-20 RPE scale. After reading the instructions the child was asked a series of questions to verify how well the instructions were understood. This procedure has been found to be effective in teaching the concept of RPE (using the Borg 6-20 scale) to children in this age group (Mahon et al., 1998). A practice exercise test was then performed on a Lode electrically-braked cycle ergometer in order to fully acquaint each child with the procedures involved in assessing peak exercise capacity and to insure that the subjects properly applied the RPE scale to the range of physiological sensations commensurate with a graded exercise test. The practice test commenced at 25 W for 2 minutes and then increased by 25 W every 2 minutes until 100 W; thereafter, the power output increased by 10 W · min⁻¹ until a near-peak or peak effort was achieved. Determination of this effort was based on the proximity of the peak heart rate (HR) to age-predicted maximal HR. Every 2 minutes throughout this trial, RPE was assessed by having the subject point to the number of the scale corresponding to his or her effort. The 2-minute interval was selected to provide a general pattern of the child’s perceptual response to progressively increasing exercise intensities. A copy of the scale was kept in sight throughout the exercise test.

On a second and third day of testing each child reported to the laboratory and body weight was measured. The RPE instructions administered on the first day were read again by the child, however no questions were asked. The subject then performed a graded exercise test in order to measure submaximal and peak
cardiorespiratory and perceptual responses. On one day the protocol began at 20 W for 2 minutes and increased by 10 W · min⁻¹ until a peak voluntary effort was achieved. On the other day the protocol began at 20 W for 2 minutes and increased by 30 W · 3 min⁻¹ until a peak effort was achieved. These protocols were selected to insure that the overall increase in power output was constant and to provide a marked difference in the external loading regimen associated with each change in power output. The order of testing was alternately assigned in a counterbalanced manner by the principle investigator so that eight children performed the 10-W protocol first while the other seven children performed the 30-W protocol first. Ratings of perceived exertion were assessed at the end of the first stage and every minute thereafter in a manner similar to the practice trial. The one-minute interval was selected to facilitate comparisons between the two exercise test protocols (described below). A copy of the scale was in full view of the subject during the entire test.

During the practice trial as well as during the two exercise tests, a Hans Rudolph 2600 series non-rebreathing valve and nose clip were used. Respiratory gas exchange was measured continuously using open circuit spirometry. Pulmonary ventilation was measured during inspiration using a Parkinson-Cowan dry-gas meter. Expired gas concentrations were measured from a mixing a chamber using an Applied Electrochemistry S-3A oxygen analyzer and a Sensormedics LB-2 carbon dioxide analyzer which were calibrated prior to each exercise test. The dry-gas meter and the gas analyzers were interfaced to a personal computer, which recorded respiratory gas exchange variables at 15-second intervals using a rolling 60-second averaging method. Ventilatory threshold was identified as the point in which pulmonary ventilation increased out of proportion to the increase in VO₂ during the exercise tests (Davis, 1985), and was determined by a single investigator who was blinded to the identity of the subject and the test. Heart rate was measured using a Polar HR monitor. The transmitter was secured to the child’s chest using two electrocardiogram electrodes and fastened with tape. A receiving unit was taped to the back of the child’s shirt. The cardiorespiratory and RPE responses recorded at the fifth minute (50 W), eighth minute (80 W) and at VT during each exercise test were used in the submaximal exercise comparisons. The 50 W and 80 W power outputs were selected because these levels of exercise were common to both protocols and represent a submaximal level of exercise for most children in the age-range used in this study. Ventilatory threshold was selected for the relative intensity comparison because VT may represent an optimal level of exercise in which to equate central and local mediators of RPE more so than a given percentage of peak VO₂. The highest cardiorespiratory and RPE responses observed during the exercise tests were used in a comparison of the peak responses.

DATA ANALYSES

The physiological and perceptual responses were examined at 50 W, 80 W, VT, and at peak exercise. Initially, the RPE data were subjected to a two-way ANOVA (gender by protocol). This analysis was performed separately for the 50 W and 80 W power outputs and at VT. As there were no gender differences (gender main effect or interaction) the data were treated as one group. At each exercise intensity (50 W, 80 W, VT, and peak) the effect of the test protocol on each dependent
variable was assessed using a one-way ANOVA with repeated measures. A P-value of < 0.05 was used to establish statistical significance.

Results

Ventilatory threshold was not identifiable in two female subjects during the 30 W protocol, thereby excluding their data from all analyses involving VT. In addition, one of these two subjects voluntarily terminated the 30-W test prior to achieving a peak level of exertion and her data was excluded in comparisons involving peak exercise responses. Examination of the individual responses at peak exercise indicated that the respiratory exchange ratio (RER) exceeded 1.00 in all children in both trials. Heart rate was greater than 195 b · min⁻¹ (Bar-Or, 1983) in 8 of 15 children in the 10-W test and in 8 of 14 children in the 30-W test, while RPE was greater than 18 in 14 of 15 children in the 10 W-test and 13 of 14 children in the 30-W test.

The cardiorespiratory responses at VT and peak exercise are outlined in Table 1. There were no statistical differences between tests for any of variables at VT ($F < 1.00; P > 0.05$ in all comparisons) and at peak exercise ($F < 1.00; P > 0.05$ in all comparisons). In contrast, the duration of the 10-W protocol (11.14 ± 1.78 min) was significantly longer ($F = 23.84; P < 0.05$) in comparison to the 30-W protocol (10.27 ± 1.98 min).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Protocol</th>
<th>M ± SD</th>
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<tbody>
<tr>
<td>VT ($n = 13$)</td>
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<tr>
<td>$V_O_2$ (L · min⁻¹)</td>
<td>10 W</td>
<td>1.15 ± 0.15</td>
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<td>30 W</td>
<td>1.16 ± 0.17</td>
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<tr>
<td>$V_O_2$ (mL · kg⁻¹ · min⁻¹)</td>
<td>10 W</td>
<td>28.2 ± 3.9</td>
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<td></td>
<td>30 W</td>
<td>28.2 ± 4.3</td>
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<tr>
<td>HR (b · min⁻¹)</td>
<td>10 W</td>
<td>160.0 ± 11.4</td>
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<td></td>
<td>30 W</td>
<td>158.0 ± 14.2</td>
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<tr>
<td>% Peak $V_O_2$</td>
<td>10 W</td>
<td>68.8 ± 6.1</td>
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<td></td>
<td>30 W</td>
<td>69.1 ± 5.8</td>
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<td>Peak Exercise ($n = 14$)</td>
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<tr>
<td>$V_O_2$ (L · min⁻¹)</td>
<td>10 W</td>
<td>1.67 ± 0.30</td>
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<td></td>
<td>30 W</td>
<td>1.66 ± 0.28</td>
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<tr>
<td>$V_O_2$ (mL · kg⁻¹ · min⁻¹)</td>
<td>10 W</td>
<td>41.2 ± 5.7</td>
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<td></td>
<td>30 W</td>
<td>41.0 ± 5.7</td>
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<tr>
<td>HR (b · min⁻¹)</td>
<td>10 W</td>
<td>193.6 ± 4.9</td>
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<td></td>
<td>30 W</td>
<td>194.6 ± 6.3</td>
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<tr>
<td>RER</td>
<td>10 W</td>
<td>1.11 ± 0.05</td>
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<td></td>
<td>30 W</td>
<td>1.12 ± 0.04</td>
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The cardiorespiratory responses at the 50 W and 80 W are displayed in Table 2. Data from two boys were excluded in 80 W analysis because this power output was equal to each child’s peak power output. Oxygen uptake (L · min⁻¹ and mL · kg⁻¹ · min⁻¹) and pulmonary ventilation (Vₑ) were significantly higher at both 50 W (VO₂ L · min⁻¹ F = 8.90; P < 0.05; VO₂ mL · kg⁻¹ · min⁻¹ F = 9.32; P < 0.05; Vₑ F = 11.15; P < 0.05) and 80 W (VO₂ L · min⁻¹ F = 7.88; P < 0.05; VO₂ mL · kg⁻¹ · min⁻¹ F = 8.26; P < 0.05; Vₑ F = 14.03; P < 0.05) during the 30-W protocol in comparison to the 10-W trial. At 50 W, HR tended to be higher in the 30-W trial, but the difference did not achieve statistical significance (F = 4.31; P = 0.058), whereas at 80 W HR during the 30-W protocol was significantly higher (F = 16.79; P < 0.05) than during the 10-W protocol. The relative intensities (% peak VO₂) at 50 W (F = 13.45; P < 0.05) and 80 W (F = 10.79; P < 0.05) were significantly higher in the 30-W test compared to the 10-W protocol.

The perceptual responses at the three submaximal intensities and at peak exercise during each protocol are depicted in Figure 1. RPE at 50 W (n = 15) was 11.5 ± 2.8 and 12.1 ± 3.2 on the 10- and 30-W protocols (F = 2.74; P > 0.05). At 80 W (n = 13) RPE was 15.2 ± 2.7 during the 10-W protocol and 15.3 ± 2.8 during the 30-W protocol (F = 0.06; P > 0.05). In contrast, the RPE at VT (n = 13) in the 10-W trial (13.9 ± 2.4) was significantly higher (F = 6.23; P < 0.05) than the RPE at VT in the 30-W trial (12.4 ± 2.4). At peak exercise (n = 14) RPE was 19.4 ± 1.3 and 19.5 ± 1.3 (F = 0.19; P > 0.05).

**Discussion**

The purpose of this study was to determine whether differences in the power output increment during a graded exercise test affected the overall RPE at submaximal intensity.
and peak exercise intensities in boys and girls. At both of the absolute submaximal
dower outputs (50 W and 80 W) examined in this study the cardiorespiratory re-
ponses tended to be attenuated somewhat during the 10-W trial compared to the
30-W trials. Despite these differences, RPE at each power output was unaffected.
At VT, the cardiorespiratory responses were unaffected by exercise test protocol,
however, the average RPE at VT was 1.5 units higher in the 10-W test compared to
the 30-W test. There were no differences in the physiological and perceptual re-
sponses at peak exercise.

The RPE responses recorded at 50 W and 80 W in the present study can be
compared to data reported by others in studies involving children similar in age to
those participating in this study. For example, Lamb et al. (1995) evaluated the
test-retest reliability of RPE at four submaximal power outputs (25 W, 50 W, 75 W
and 100 W) in nine-year-old boys and girls. At 50 W, RPE averaged 11.36 and
10.24 on the first and second tests, respectively. These values are only slightly
lower than the values reported in the present investigation. At 75 W, the mean RPE
was 13.33 and 13.45 on the two tests, respectively. These values are nearly two
units lower on the RPE scale from what was observed at 80 W in this study. The
small disparity in power output (75 W vs. 80 W) and possible differences in aero-
bic fitness levels between the subjects in this study and those of Lamb et al. may
account for the difference in RPE. The later point, though, is only speculative
because Lamb et al. did not measure aerobic capacity. In a study by Mahon et al.
(1997) RPE was examined at three different intensities spanning ranges in VO₂
that are similar to the present study. Ratings of perceived exertion ranged from
11.2 during the lowest intensity to 16.2 during the highest intensity which corre-
sponds favorably to the RPE responses observed at 50 W and 80 W in the present
study.

![Figure 1. Overall RPE at four exercise intensities (M ± SD; n = 15 at 50 W, n = 13 at
80 W, n = 13 at VT, and n = 14 at peak exercise). *P < .05](image)

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The RPE responses at VT during both exercise tests are similar with previous studies from our laboratory (Duncan et al., 1996; Mahon et al., 1998). Duncan et al. reported the RPE at VT during cycle ergometry was 11.6 in boys with a mean age of 10.2 years. Mahon et al. found RPE at VT was 13.6 in a group of boys and girls with an average age of 10.9 years. Although the RPE at VT was within the range of what has been previously reported, there was nonetheless a significant difference between protocols. Specifically, the RPE at VT was significantly higher in the 10-W protocol compared to the 30-W protocol despite the fact that VT occurred at the same HR, VO₂, and percentage of peak VO₂ in both tests. It is possible that variations in the subjective determination of VT contributed to the differences in RPE. However, in that the physiological responses were not different this does not seem like a plausible explanation. Moreover, the variation in the physiological responses (expressing the SD as a percentage of the M) appeared similar between trials and tended, for the most part, to be lower than the variation in RPE between subjects. As the children were likely unaware of the occurrence of VT during both tests, it is possible that the less frequent change in the power output in the 30-W trial versus the 10-W trial may have altered the child’s ability to gauge his or her effort. Similarly, it should be noted that RPE at the same relative intensity has been shown to vary in both children and adults during different exercise tests. Glass et al. (1991) reported that the RPE at ~65% of VO₂ max was significantly lower in adult men and women during a standard Bruce treadmill protocol compared to a modified Balke treadmill protocol. In addition, Mahon et al. (1992) reported that the RPE at VT in a group of children was significantly lower (1 unit on the Borg 6-20 RPE scale) on the second of two identical treadmill tests performed on separate days although there were no differences in VT.

The physiological sensations mediating perceived exertion during exercise arise from the various cardiorespiratory, metabolic and muscle responses relative to the intensity of exercise. Sensations arising from the cardiorespiratory and metabolic response to exercise are termed central signals of exertion, whereas signals arising from exercising muscle are referred to as local signals of exertion (Robertson and Noble, 1997). These signals are then integrated to form the overall RPE. Specific cardiorespiratory and metabolic signals include HR, VO₂, Vₑ (inclusive of tidal volume and respiratory rate) and blood lactate. However, of these signals, only the ventilatory parameters are likely to be consciously sensed by the individual. Moreover, Robertson (1982) has proposed that central signals of exertion begin to dominate the perception of effort only at relatively high intensities (>70% of peak VO₂).

In the present study, nearly all the cardiorespiratory responses at 50 W and 80 W were lower in the 10-W protocol compared to the 30-W protocol. Despite these differences, the overall RPE was unaffected. As the relative intensity (% peak VO₂) at 50 W was below Robertson’s suggested threshold of influence, any differences in central signaling brought on by the protocols likely was not influential. On the other hand, 80 W represented an intensity in excess of the 70% threshold, and according to Robertson’s model, the augmented cardiorespiratory responses observed in the 30-W trial should have elevated RPE. However, this was not the case. At VT, there was a significance difference in RPE between the two tests despite similar cardiorespiratory responses. The failure of overall RPE to co-vary with cardiorespiratory responses suggests that central mediators of perceived
exertion were not providing the primary stimulus for the child’s RPE selection across the three submaximal intensities examined in this investigation.

Specific mediators of exertion arising from exercising muscle include the sensations associated with the degree of muscle activity relative to the intensity of exercise. These factors include the sensations related to muscle force and frequency associated with the power output (Ekblom and Goldbarg, 1971). Since two of the submaximal RPE determinations were made at the same power output it seems logical to conclude that the factors associated with local signaling were similar in both exercise trials. Moreover, pedal rate did not vary between protocols as the children were required to maintain a pedal frequency in the range of 70-90 revolutions per minute. Similarly, the time into the test in which the RPE was assessed was constant (at 5 minutes for 50 W and 8 minutes for 80 W) in both trials so local fatigue theoretically should have been comparable. This was possible because at the rate in which the power output was changed was identical in both protocols. The consistency of both the local influence and the RPE responses during each protocol may not be coincidental, and is in accordance with the suggestion by Robertson (1982) that local factors may function as the dominate cue in shaping the perception of effort rather than central signals of exertion. On the other hand, this explanation does not entirely explain the findings regarding the RPE at VT. As the relative exercise intensity at VT was similar in both protocols one would expect the contribution of local signals to be consistent as well. Despite this viewpoint, the RPE at VT was different between tests. However, in the absence of any direct assessment of local mediators of perceived exertion, these conclusions should be viewed with caution.

For the most part, the cardiorespiratory responses at 50 W and 80 W were lower during the 10-W trial compared to the 30-W trial. Part of the difference is likely due to the short stage duration used in the 10-W trial. Although the rate in which the power output was incremented was similar in both protocols, changing power output on a minute-by-minute basis in the 10-W protocol likely prevented adequate response time to elevate the cardiorespiratory responses. In contrast, the 3-minute stage durations used in the 30-W protocol may have provided more time to augment the cardiorespiratory responses. However, the precise interaction of the rate of change and the stage duration in augmenting the cardiorespiratory responses is unknown. It is also interesting to note that the magnitude of the differences in the cardiorespiratory variables outlined in Table 2 tended to increase from 50 W to 80 W. This may have been due to the fact that the VO₂ at 80 W was above VT for most of our subjects. When exercise intensity exceeds ventilatory threshold, VO₂ kinetics are slowed and more time is required to reach a steady-state response (Wasserman, 1987).

The cardiorespiratory responses at VT and at peak exercise were similar between the two exercise test protocols. This finding is consistent with the results reported by Zhang et al. (1991) in adults. In their study, cardiorespiratory responses during a ramp protocol and three power output step protocols, incremented at 1-, 2-, and 3-min intervals, were examined at VT and at peak exercise. Similar to the present study, the tests were designed so that the rate of the power output increase was identical across the four protocols. A comparison of the four protocols revealed there were no differences in the cardiorespiratory responses at VT and at peak exercise. Collectively these results may indicate that the various neural and
humoral mediators of VT are unaffected by the exercise test protocol so long as the overall rate of increase in power output is similar, although it is important to note that this point is speculative in the absence of direct assessment of these stimuli.

There are several limitations in the present study which merit comment. First, although gender differences in perceived exertion were not apparent, the small number of girls participating in this study prevents an adequate assessment of male-female differences. Second, for reasons already outlined, not all of the subjects who participated in this study were included in each analysis. Whether or not this influenced the outcomes of this study is impossible to know. Third, variations in pubertal status among the study population may have affected the results. Fourth, as a result of equalizing the overall rate of increment in power output and the duration into the test, the amount of time spent exercising at 50 W and 80 W was different between the two protocols and may have confounded the results of the study.

In summary, the results of the present study indicate the perception of effort at a given submaximal power output in boys and girls is not affected by the manner in which the power output is incremented as long as the overall rate in which power output is increased is constant. In contrast, the RPE at VT was higher in the 10-W protocol compared to the 30-W protocol. Most of the cardiorespiratory responses at 50 W and 80 W ended to be attenuated in the 10-W protocol, while cardiorespiratory responses at VT and peak exercise were similar between the two trials. That there were differences in the cardiorespiratory responses at 50 W and 80 W, yet no differences in RPE; and that there were differences in RPE at VT despite similar cardiorespiratory responses, suggests that central signals of exertion were not making a substantial contribution to the overall perception of effort in these children. To what extent local factors known to mediate RPE were the predominate sensory cue used by these children remains uncertain. Further investigations that directly manipulate central and local sensory cues are needed to better understand the physiological basis for the child’s perception of effort during exercise.

References


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