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ORIGINAL ARTICLE

OMNI Scale of Perceived Exertion: mixed gender and race validation for Singapore children during cycle exercise

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Abstract The children's OMNI Scale of Perceived Exertion (RPE) has not been validated for children of Asian origin. The purpose was to validate the RPE for Singapore children, 12–15 years. 81 children of male and female of Chinese, Malay, and Indian ethnicities participated in the study. A cross-sectional, perceptual estimation paradigm using a multistage cycle ergometer protocol was used. Oxygen consumption ($\dot{V}O_2$; ml min^{-1}), heart rate (HR; beats min^{-1}), and RPE for the Overall body (RPE-O), Legs (RPE-L), and Chest (RPE-C) were determined at the end of each continuously administered 3-min power output stage (PO) starting at 25 W with 25 W increments until exhaustion. For validation, linear regression analysis for all PO revealed that RPE-O, RPE-L, and RPE-C for each of the six gender–race and combined cohort distributed as positive linear functions of both $\dot{V}O_2$ (ml min^{-1}, ml kg^{-1} min^{-1}) and HR (beats min^{-1}). All regression functions were statistically significant ($P < 0.01$). Differences between undifferentiated (RPE-O) and differentiated (RPE-L and RPE-C) at each PO stage were examined separately for the male (up to PO 8 [200 W]) and female (up to PO 5 [125 W]) cohorts. For the males, RPE-L was greater ($P < 0.05$) than both RPE-C and RPE-O only at PO 8. For the females, RPE-O was greater ($P < 0.05$) than RPE-C only at PO 3 and 4. OMNI Scale validity was established for male and female Asian children of Chinese, Malay, and Indian origin. Male and female children did not perceive the intensity of exertional perceptions to differ between the legs and the chest. As there were no differences between the undifferentiated and differentiated perceptual responses, a dominant signal was not observed.

Keywords Perceptual responses · Psycho-physiology · Ratings of perceived exertion · OMNI · Scale RPE · Exertion · Fatigue · Exercise prescription · Body composition

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Introduction

Regular physical exercise is critical to good health. According to the American College of Sports Medicine (ACSM 2000, p. 5) cardiorespiratory fitness obtained through habitual participation in vigorous physical activities is strongly associated with a reduced risk of death from coronary heart disease (CHD) as well as from all cause mortality. ACSM (2000, p. 145) guidelines recommend that in order to derive health benefits from aerobic exercise, an optimal level of physical exertion, or exercise intensity, needs to be maintained for a specified duration of time. This level of exertion should elicit a heart rate (HR) response in the range between 55 and 90% of maximum HR (ACSM 2000, p. 145).The HR range of 55–90% is intentionally broad so as to accommodate low-fit and high-fit individuals, when prescribing optimal exercise intensity to develop and maintain cardiorespiratory fitness.

For the adult population, ACSM (2000, p. 78 and 149) recommends the use of Borg's 15 category (6–20) rating of perceived exertion (RPE) scale as a method for monitoring and regulating exercise intensity for health benefits. The training zone identified for health-related fitness corresponds to numerical categories 12–16 on the Borg scale (ACSM 2000, p. 149; Watt and Grove 1993). The scale also includes verbal descriptors positioned along the response continuum to guide the user in making a subjective interpretation of the exertional level. Since the measure of RPE is non-invasive and easier to monitor and regulate than oxygen uptake ($\dot{V}O_2$), HR, or blood lactate (BLa) during exercise, it is a convenient tool for exercise prescription (Stoudemire et al. 1996). In addition, for the diseased individual where HR response may be affected by medication, the RPE method proves indispensable for regulating intensity in patients undergoing exercise rehabilitation (ACSM 2000, p. 149).

The RPE scale can be used to assess the undifferentiated estimate for the overall body. In addition, RPE can be differentiated to anatomically specific sites such as the chest (cardiorespiratory or aerobic metabolic strain) and the limbs (localized active musculature or peripheral strain). Differentiated signals of perceived exertion arising from the legs (RPE-Legs) and the chest (RPE-Chest) are presumed to be directly linked with the respective underlying physiological factors of strain of the exercising muscles and the cardiopulmonary systems, whereas the undifferentiated signal of exertion (RPE-Overall) for the whole body represents an integration of the perceptually weighted differentiated signals (Pandolf 1982; Robertson 1982; Watt and Grove 1993).

In practice, ACSM (2000, p. 78 and 149) recommends that an individual be instructed to self-regulate an exercise intensity that produces RPE responses that fall within the target range of 12–16 on the Borg Scale during such common health-related fitness activities as running, walking, or cycling. These levels of exertion, based on validation studies, are expected to bring about a physiological overload that results in cardiovascular fitness gains and other attendant health benefits. Both such exercise adaptations help to lower the risk of chronic and degenerative diseases (ACSM 2000, p. 5 and 145).

As a result of the widespread utility of Borg's RPE scale in health-related exercise applications with the adult population, there has been much recent interest in the study of perceived exertion and rating scale development in children (Duncan et al. 1996; Eston and Lamb 2000; Eston et al. 2000; Groslambert et al. 2001; Lamb and Eston 1997; Mahon et al. 1998; Mahon and Ray 1995; Pfeiffer et al. 2002; Robertson et al. 2000a, 2001; Utter et al. 2002; Balasekaran et al. 2003). Researchers realized that in many cases it was inappropriate to use the Borg RPE scale for children (Eston and Lamb 2000; Robertson et al. 2000a, 2001, 2004; Utter et al. 2002, 2004). It was noted that younger pediatric subjects were unable to consistently assign numbers to the words or phrases in adult-formatted scales to describe their perceived exertion during exercise (Robertson et al. 2000a, 2001, 2004). According to Eston and Lamb, the major consideration in measuring RPE for children is to have a scale that is easily assimilated by children based on their own experiences and their levels of physical and mental development.

In response to the limitations encountered when using existing RPE scales with children, Robertson et al. (2000a, b) developed the children's OMNI Scale of Perceived Exertion (OMNI Scale) (Fig. 1). The scale was developed with the expectation that a single format can be used across gender and race, hence the name, OMNI. The term OMNI, a contraction of the word omnibus, expresses the broadly encompassing properties in the scale format (Robertson et al. Robertson, 2001, 2004). The OMNI Scale has been validated for use with children over a range of ages from 6 to 18 years old. These include mixed gender and race validation with male and female African–American and Caucasian children 8–12 years old (Robertson et al. 2000a, 2001, 2004), a walking/running evaluation where a walk/run pictorial version of the OMNI Scale was developed and validated with children 6–13 years (Utter et al. 2002), and a concurrent validation on treadmill testing with 13- to 18-year-old adolescent girls (Pfeiffer et al. 2002).

There is a general lack of studies regarding the validity of the OMNI RPE scale involving children of other ethnicities. There are no studies available that have validated the OMNI Scale with Asian children, especially children in Singapore who are predominantly of Chinese, Malay, and Indian races in descending order of majority. These children of mixed races may have potential differences in the use and interpretation of words and phrases that describe physical exertion. Therefore, for the OMNI Scale to be generalizable in the Singapore school context, it must be systematically validated with children of these races. The validity of the OMNI Scale with children in Singapore will warrant its use as a convenient and appropriate tool in the regulation of suitable physical work intensities for outcome-based exercise programmes in Singapore schools, such as weight loss, fitness maintenance, and sports performance enhancement.

Methodology

Subjects

Eighty-one clinically normal, non-obese children ranging in age from 12 to 15 years participated as subjects. The cohort

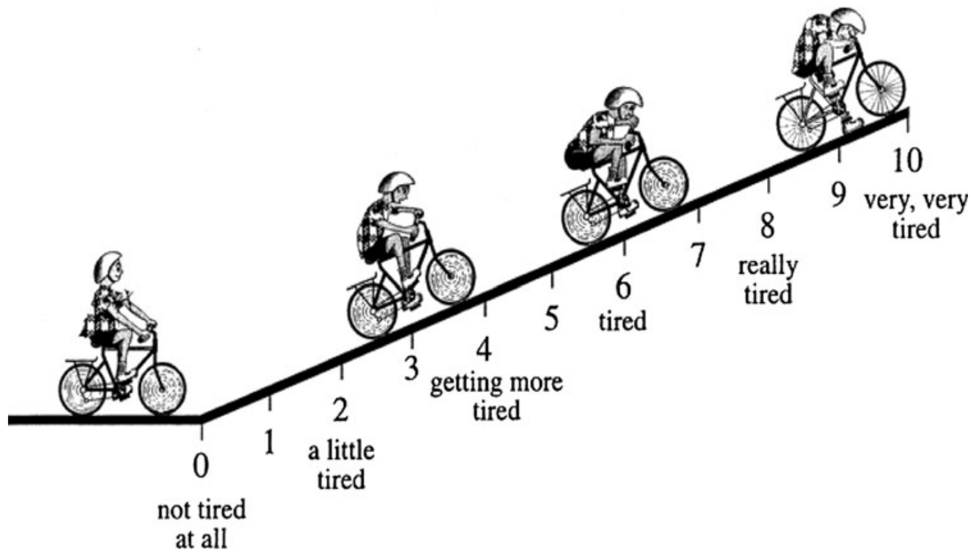

Fig. 1 Children's OMNI Scale of Perceived Exertion (Robertson et al. 2000a, b)

was further subdivided into 27 Chinese children (i.e., 15 males and 12 females), 27 Indian children (i.e., 15 males and 12 females), and 27 Malay children (i.e., 15 males and 12 females). Sample size was determined for the statistical power required for this study, using a power of 0.80, an α of 0.05 and an effect size of >1.1. Power analysis showed that nine subjects were required for each cohort for this study (Robertson et al. 2001). The within-subject factor of this power calculation assumed an intraclass correlation of $r = 0.80$ over the repeated measures and was derived from the report by Robertson et al. (2000a). The investigation was approved by the Ethical Review Board of the Physical Education and Sports Science academic group of the National Institute of Education, Nanyang Technological University, Singapore. All subjects and their parents/guardians were informed of the risks and benefits of the study, and gave their written consent to participate. The descriptive characteristics of the subjects are shown in Table 1.

Experimental design

The design employed a cross-sectional, perceptual estimation paradigm administered during a 30-min test session. These testing procedures were based on the experimental protocol developed by Robertson et al. (2000a). In this design, subjects first reported for pre-test assessments at the Exercise Physiology Laboratory, National Institute of Education, Singapore. Pre-test and exercise test assessment were all undertaken during a single session. The sequence of pre-test evaluations was as follows: (a) clinical and anthropometric measurements, (b) medical questionnaire, (c) physical maturity assessment (Tanner staging), and (d) body composition assessment by dual energy X-ray absorptiometry (DEXA). Subjects then reported for their functional exercise test. The exercise test was administered according to the following sequence: (a) orientation test procedures, and (b) load incremented cycle ergometer test to validate the OMNI Scale. Subjects were instructed to refrain from heavy physical exercise and caffeine consumption for 24 h prior to exercise testing.

Experimental variables

The experimental variables for this investigation were RPE, oxygen consumption ($\dot{V}O_2$; ml min^{-1}), and heart rate (HR; beats min^{-1}). Cohort classification variables were gender and race. Descriptive variables for each cohort were age (years), height (cm), body mass (kg), body fat (%), body mass index (BMI; kg m^{-2}), and physical maturity status (Tanner 1962, pp. 32–37, plates 5–7).

Tests and measurements

Anthropometric measures

Height (cm) of subjects was determined using a stadiometer (Harpendun Stadiometer, Holtein Limited, Britain). Body mass (kg) was measured using a digital scale [ID1Plus, Mettler-Toledo (Albstadt), Germany]. The BMI (kg m^{-2}) was calculated as the body mass (kg) divided by the square of the height (m).

Dual energy X-ray absorptiometry (DEXA)

Total percentage body fat of subjects was determined using DEXA (model QDR-4500 elite, Waltham, MA, USA). The assessment period was 7 min per subject with a radiation dose of ~0.03 millirem (mrem). Total body fat, fat free mass, and total body bone mineral content were calculated

Table 1 Descriptive characteristics of subjects listed by gender/race cohorts (mean ± SD)

Variables	Cohorts					
	MC ($n = 15$)	MM ($n = 15$)	MI ($n = 15$)	FC ($n = 12$)	FM ($n = 12$)	FI ($n = 12$)
Age (years)	13.9 ± 0.4	13.8 ± 0.5	14.1 ± 0.5	13.8 ± 0.6	13.8 ± 0.8	13.8 ± 0.8
Ht (cm)	166.6 ± 7.2	165.1 ± 8.4	166.4 ± 4.6	160.7 ± 9.1	160.7 ± 7.6	160.1 ± 6.3
Body mass (kg)	58.1 ± 10.1	56.0 ± 14.8	53.8 ± 10.7	49.6 ± 7.9	52.8 ± 11.2	47.4 ± 4.9
Fat (%)[a]	17.9 ± 7.3	15.6 ± 5.8	14.6 ± 6.3	22.7 ± 4.0	31.0 ± 4.2	23.7 ± 3.4
BMI (kg m^{-2})	20.8 ± 2.5	20.3 ± 3.8	19.4 ± 3.4	19.1 ± 2.0	20.3 ± 3.6	18.5 ± 1.9
Tanner[1]	3.7 ± 0.7	3.5 ± 0.6	3.6 ± 0.5	3.6 ± 0.5	3.9 ± 1.0	3.5 ± 0.5
Tanner[2]	3.8 ± 0.7	3.6 ± 0.6	3.7 ± 0.5	3.7 ± 0.5	3.6 ± 0.8	3.6 ± 0.5
$\dot{V}O_{2peak}$ (L min^{-1})[b]	2.31 ± 0.5	2.4 ± 0.61	2.31 ± 0.44	1.75 ± 0.35	1.66 ± 0.41	1.62 ± 0.34
$\dot{V}O_{2peak}$ (ml kg^{-1} min^{-1})[c]	40.1 ± 5.1	44.4 ± 12.0	43.4 ± 7.7	35.3 ± 4.2	32.1 ± 8.4	34.3 ± 6.6
HR_{peak} (beats min^{-1})	182.5 ± 18.1	179.7 ± 17.9	187.2 ± 14.8	182.4 ± 14.8	175.9 ± 12.7	176.5 ± 13.7

Cohorts: *MC* male Chinese, *MM* male Malay, *MI* male Indian, *FC* female Chinese, *FM* female Malay, *FI* female Indian, *Ht* height, *Wt* weight, *BMI* body mass index, *Tanner[1]* tanner stage for breast/genitalia growth, *Tanner[2]* tanner stage for pubic hair growth, $\dot{V}O_{2peak}$ peak oxygen uptake, HR_{peak} peak heart rate

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

[a] FM > MC**, FM > MM***, FM > MI***

[b] MC > FM*, MC > FI*, MM > FC*, MM > FM**, MM > FI**, MI > FM*, MI > FI*

[c] MM > FM*, MI > FM*

based on the attenuation of two photon beams and the known soft tissue and bone absorption characteristics for each energy level (Goran et al. 1995; Rico et al. 1993).

Physical maturity assessment

Tanner stages of sexual maturation were used to assess pubertal status with a parental supervised self examination. This was carried out by reference to a series of developmental diagrams with descriptions that correspond to Tanner Stages 1–5 (Tanner 1962, pp. 32–37, plates 5–7). Parent and child were instructed to verify the developmental stage of the child based on two series of diagrams illustrating sexual maturation stages with related descriptions. Girls were assessed by breast development and pubic hair growth and distribution. Boys were assessed by scrotal development and pubic hair growth and distribution. The five stages of development ranged from 1, which is the infantile stage until the onset of puberty, to 5, which is the mature adult stage.

Orientation procedure

During the orientation procedure, subjects were familiarized with (a) the perceived exertion rating scale to be validated, (b) rating scale instructions, (c) the cycle ergometer exercise test protocol, and (d) the heart rate monitor and the respiratory face mask and related components in the respiratory–metabolic system.

A standardized instructional set regarding the use of the OMNI cycle pictorial rating scale was explained to the subjects while they visually examined the scale (Noble and Robertson 1996, p. 61). The scale instructions specifically described exertional rating procedures for the legs, chest, and overall body. Procedures to establish the low and high perceptual anchors of the OMNI Scale were based on a visually interfaced cognitive procedure as reported by Robertson et al. (2000a). Scale anchoring procedures were standardized for all subjects and conformed to Borg's range model for rating interindividual differences in perceptual responsiveness (Noble and Robertson 1996, p. 61).

Exercise validation trials

The exercise validation trials were administered using a Monark cycle ergometer equipped with a plate-loading system to apply brake force (Model 834E, Varberg, Sweden).

The exercise protocol required power outputs to be presented in continuous 3-min test stages at a pedal rate of 50 rpm according to the following sequence: 25, 50, 75, and 100 W (Robertson et al. 2000a). Thereafter, the subjects continued for subsequent 3-min stages at increments of 25 W per stage until volitional termination owing to exhaustion, or when subjects were unable to maintain the pedal rate of 50 rpm for 15 consecutive seconds. The power output was adjusted at the beginning of each test stage with the absolute value unknown to the subject.

An electronic metronome was used to signal the pedal rate of the subject.

Rating of perceived exertion

Three separate OMNI Scale RPE were estimated in random order during the 30–60 s of the last minute of each power output test stage. Differentiated ratings were estimated for peripheral perceptions in the legs (RPE-Legs) and respiratory–metabolic perceptions in the chest (RPE-Chest). An undifferentiated rating for the overall body (RPE-Overall) was also estimated. A definition of perceived exertion specifically written for children and a standard set of instructions regarding the use of the OMNI Scale to rate perceptions of exertion were read to the subject immediately before the exercise test (Robertson et al. 2000a).

Heart rate

During the cycle ergometer test, a Polar Sports Tester system (Polar Electro Oy, Finland) consisting of a transmitter with an elastic belt and wrist monitor was used to measure heart rate. The Polar transmitter was attached to the elastic belt and secured around the chest of the subject below the pectoral muscles. The Polar wrist monitor was secured to the cycle ergometer in close proximity to the subject to ensure clear transmission of HR signals. HR was recorded during the last 15 s of each minute of the cycle ergometer test.

Aerobic metabolic measures

An open circuit respiratory–metabolic system was used to measure total body oxygen uptake ($\dot{V}O_2$; ml min^{-1}) from 0 to 60 s of the final minute of each power output test stage. Total body oxygen uptake was monitored continuously throughout the exercise test and expired gases were analyzed in a breath-by-breath mode using a portable gas analyzer (Cosmed K4RQ, Italy). After the manufacturer recommended warm-up period of 45 min, the O_2 and CO_2 sensors of the gas analyzer were calibrated before each test according to room and standard gases (16% for O_2; 5% for CO_2) of known concentrations. Subjects wore a specially designed pediatric facemask that incorporated a respiratory valve during the exercise test. The facemask contained a photoelectric turbine and a capillary gas sampling port within the turbine housing. Expired air was sampled at a rate proportional to ventilation, with the aid of a dynamic sampling pump, through a polymer sampling capillary of Nafion (Perma Pure), leading to a microchamber containing the O_2 (polargraphic) and CO_2 (infrared) electrodes. Daily variations of barometric pressure and humidity of the testing environment were also configured into the calibration of the O_2 and CO_2 sensors.

Data analysis

Descriptive data for perceptual and physiological variables were calculated as mean ± standard deviation (SD). Differences in descriptive data among the six gender–race stratified sample groups were examined by ANOVA (SPSS v11.5 for Windows). Evidence for OMNI Scale response validity was determined using simple linear regression analysis. These analyses separately regressed the criterion variables $\dot{V}O_2$ and HR against the predictor variables RPE-Overall, RPE-Legs, and RPE-Chest using data obtained in the final minute of each power output (PO) stage. Correlation coefficients (Pearson) and linear regression equations were calculated separately for each of the six gender–race cohorts, as well as for the combined cohort of all subjects.

OMNI Scale RPE were also examined using a four factor ANOVA having main effects on gender, race, RPE site (Overall, Legs, and Chest), and power output (PO) with repeated measures taken for the last factor. Follow-up analyses of significant interactions were performed by one-way ANOVA to determine differences among RPE-Overall, RPE-Legs, and RPE-Chest at each PO stage separately for the male and female cohorts. Planned post hoc comparisons were probed using a Scheffe analysis. Statistical significance was accepted at the $P < 0.05$ level.

Results

Perceptual and physiological responses

Tables 2 and 3 list the mean ± SD for perceptual (RPE-Overall, RPE-Legs, and RPE-Chest) and physiological responses (HR, beats min^{-1}; $\dot{V}O_2$, ml min^{-1}) for all power outputs (PO) within each of the gender–race stratified sample cohorts. The variation between the number of PO stages completed within the two gender groups was high. To test for the effect of variations in range of RPE responses, data for the male cohort were analyzed up to PO stage 8 (200 W), and for the female cohort, data were analyzed up to PO stage 5 (125 W). For the data points analyzed, 93.3% ($n = 42$) of the male cohort completed PO stage 5, 84.4% ($n = 38$) of the male cohort completed PO stage 6, 57.8% ($n = 26$) completed PO stage 7, and 31.1% ($n = 14$) completed PO stage 8. For the six PO stages, the mean RPE ranged from 0.8 ± 0.9 to 6.0 ± 2.4 for RPE-Overall, 0.6 ± 0.8 to 6.9 ± 2.2 for RPE- Leg, and 0.6 ± 0.7 to 5.9 ± 2.1 for RPE-Chest. The highest mean RPE attained for males was at PO stage 8: 7.6 ± 1.8 for

Table 2 Perceived exertion (OMNI Scale) and physiological responses during cycle exercise listed by cohort and power output for male subjects

Variables	PO (W)	Cohorts		
		MC	MM	MI
RPE-O	25	0.9 ± 0.9 ($n = 15$)	0.5 ± 0.6 ($n = 15$)	0.9 ± 1.2 ($n = 15$)
	50	1.6 ± 1.1 ($n = 15$)	0.7 ± 0.7 ($n = 15$)	1.3 ± 1.4 ($n = 15$)
	75	2.6 ± 1.4 ($n = 15$)	1.4 ± 1.1 ($n = 15$)	2.7 ± 2.2 ($n = 15$)
	100	3.5 ± 1.7 ($n = 15$)	2.7 ± 1.3 ($n = 15$)	4.2 ± 3.2 ($n = 15$)
	125	4.8 ± 2.1 ($n = 15$)	4.3 ± 2.1 ($n = 14$)	5.0 ± 3.1 ($n = 13$)
	150	6.7 ± 2.3 ($n = 13$)	5.7 ± 2.3 ($n = 12$)	5.5 ± 2.8 ($n = 13$)
	175	8.2 ± 1.9 ($n = 9$)	6.5 ± 2.4 ($n = 9$)	5.9 ± 2.4 ($n = 8$)
	200	10.0 ± 0.0 ($n = 5$)	6.7 ± 1.7 ($n = 5$)	6.2 ± 1.0 ($n = 4$)
RPE-L	25	0.9 ± 0.9 ($n = 15$)	0.3 ± 0.6 ($n = 15$)	0.6 ± 0.8 ($n = 15$)
	50	1.7 ± 1.3 ($n = 15$)	1.1 ± 0.5 ($n = 15$)	1.2 ± 1.5 ($n = 15$)
	75	2.7 ± 1.4 ($n = 15$)	2.1 ± 1.2 ($n = 15$)	2.8 ± 2.3 ($n = 15$)
	100	3.8 ± 1.8 ($n = 15$)	3.8 ± 1.4 ($n = 15$)	4.4 ± 2.9 ($n = 15$)
	125	5.2 ± 1.9 ($n = 15$)	5.5 ± 1.7 ($n = 14$)	5.6 ± 3.2 ($n = 13$)
	150	7.0 ± 2.2 ($n = 13$)	7.4 ± 1.9 ($n = 12$)	6.3 ± 2.6 ($n = 13$)
	175	8.2 ± 2.0 ($n = 9$)	7.9 ± 1.5 ($n = 9$)	7.4 ± 1.4 ($n = 8$)
	200	10.0 ± 0.0 ($n = 5$)	8.8 ± 1.0 ($n = 5$)	8.2 ± 1.0 ($n = 4$)
RPE-C	25	0.9 ± 0.8 ($n = 15$)	0.2 ± 0.4 ($n = 15$)	0.6 ± 0.8 ($n = 15$)
	50	1.7 ± 1.0 ($n = 15$)	1.1 ± 0.6 ($n = 15$)	1.4 ± 1.0 ($n = 15$)
	75	2.5 ± 1.2 ($n = 15$)	1.6 ± 1.0 ($n = 15$)	2.3 ± 1.7 ($n = 15$)
	100	3.4 ± 1.5 ($n = 15$)	3.0 ± 1.3 ($n = 15$)	3.9 ± 2.4 ($n = 15$)
	125	4.6 ± 1.6 ($n = 15$)	4.3 ± 1.6 ($n = 14$)	4.9 ± 2.7 ($n = 13$)
	150	6.3 ± 2.1 ($n = 13$)	5.9 ± 1.4 ($n = 12$)	5.6 ± 2.8 ($n = 13$)
	175	7.6 ± 2.7 ($n = 9$)	6.3 ± 1.2 ($n = 9$)	5.9 ± 2.2 ($n = 8$)
	200	9.0 ± 1.4 ($n = 5$)	7.0 ± 1.4 ($n = 5$)	6.2 ± 1.5 ($n = 4$)
$\dot{V}O_2$ (ml min^{-1})	25	719.8 ± 171.8 ($n = 15$)	726.6 ± 194.1 ($n = 15$)	698.2 ± 191.0 ($n = 15$)
	50	967.9 ± 237.4 ($n = 15$)	992.8 ± 266.3 ($n = 15$)	912.4 ± 230.7 ($n = 15$)
	75	1,331.6 ± 260.6 ($n = 15$)	1,224.7 ± 241.2 ($n = 15$)	1,180.8 ± 272.4 ($n = 15$)
	100	1,540.8 ± 304.9 ($n = 15$)	1,562.0 ± 279.5 ($n = 15$)	1,614.0 ± 706.2 ($n = 15$)
	125	1,837.6 ± 287.8 ($n = 15$)	1,843.9 ± 407.9 ($n = 14$)	1,785.1 ± 391.2 ($n = 13$)
	150	2,257.1 ± 252.7 ($n = 13$)	2,296.8 ± 388.6 ($n = 12$)	2,045.5 ± 296.7 ($n = 13$)
	175	2,400.9 ± 337.7 ($n = 9$)	2,552.4 ± 278.4 ($n = 9$)	2,466.6 ± 333.0 ($n = 8$)
	200	2,910.9 ± 162.0 ($n = 5$)	2,680.2 ± 445.4 ($n = 5$)	2,604.0 ± 205.4 ($n = 4$)
HR (beats min^{-1})	25	111.2 ± 17.3 ($n = 15$)	97.9 ± 12.5 ($n = 15$)	105.3 ± 16.1 ($n = 15$)
	50	119.5 ± 18.2 ($n = 15$)	109.6 ± 12.2 ($n = 15$)	118.3 ± 22.5 ($n = 15$)
	75	132.7 ± 22.2 ($n = 15$)	122.4 ± 15.9 ($n = 15$)	130.9 ± 25.7 ($n = 15$)
	100	146.7 ± 26.1 ($n = 15$)	138.9 ± 19.1 ($n = 15$)	149.1 ± 26.0 ($n = 15$)
	125	159.9 ± 24.5 ($n = 15$)	153.1 ± 20.8 ($n = 14$)	156.8 ± 25.2 ($n = 13$)
	150	165.1 ± 16.4 ($n = 13$)	161.8 ± 16.3 ($n = 12$)	167.1 ± 23.8 ($n = 13$)
	175	173.5 ± 19.7 ($n = 9$)	177.9 ± 13.0 ($n = 9$)	166.3 ± 32.5 ($n = 8$)
	200	175.2 ± 11.7 ($n = 5$)	187.0 ± 3.9 ($n = 5$)	166.0 ± 26.5 ($n = 4$)

Values are presented as mean ± SD

(n) subjects that completed the power output stage, $\dot{V}O_2$ oxygen uptake, *HR* heart rate, *RPE-O, L, and C* rating of perceived exertion Overall, Legs, and Chest

Cohorts: *MC* male Chinese, *MM* male Malay, *MI* male Indian

RPE-Overall, 8.7 ± 1.1 for RPE-Leg, and 7.4 ± 1.7 for RPE-Chest. However, the number of subjects who reached this stage was 14, which represented only 31.1% of total male cohort. For the data points analyzed for the female cohort, 88.9% ($n = 32$) had completed PO stage 4, and 55.6% ($n = 20$) had completed PO stage 5. The first four

Table 3 Perceived exertion (OMNI Scale) and physiological responses during cycle exercise listed by cohort and power output for female subjects

Variables	PO (W)	Cohorts		
		FC	FM	FI
RPE-O	25	1.6 ± 1.2 ($n = 12$)	1.4 ± 1.0 ($n = 12$)	0.8 ± 0.5 ($n = 12$)
	50	3.4 ± 1.2 ($n = 12$)	3.8 ± 1.4 ($n = 12$)	2.3 ± 1.0 ($n = 12$)
	75	6.1 ± 2.0 ($n = 12$)	6.6 ± 2.1 ($n = 12$)	4.4 ± 1.4 ($n = 12$)
	100	8.1 ± 1.5 ($n = 12$)	7.9 ± 1.5 ($n = 11$)	6.4 ± 1.6 ($n = 9$)
	125	9.1 ± 1.1 ($n = 9$)	9.0 ± 0.0 ($n = 5$)	7.9 ± 1.3 ($n = 6$)
RPE-L	25	1.5 ± 1.9 ($n = 12$)	1.2 ± 0.9 ($n = 12$)	0.7 ± 0.7 ($n = 12$)
	50	3.6 ± 2.5 ($n = 12$)	2.8 ± 1.7 ($n = 12$)	2.3 ± 1.4 ($n = 12$)
	75	5.6 ± 2.3 ($n = 12$)	5.0 ± 2.5 ($n = 12$)	4.5 ± 1.8 ($n = 12$)
	100	7.9 ± 2.1 ($n = 12$)	6.7 ± 2.0 ($n = 11$)	6.8 ± 1.6 ($n = 9$)
	125	8.7 ± 1.5 ($n = 9$)	8.6 ± 0.9 ($n = 5$)	8.3 ± 1.0 ($n = 6$)
RPE-C	25	1.8 ± 1.8 ($n = 12$)	0.8 ± 0.9 ($n = 12$)	0.8 ± 0.6 ($n = 12$)
	50	3.3 ± 2.5 ($n = 12$)	2.1 ± 1.8 ($n = 12$)	2.3 ± 0.9 ($n = 12$)
	75	5.5 ± 2.0 ($n = 12$)	3.7 ± 3.0 ($n = 12$)	3.9 ± 1.2 ($n = 12$)
	100	7.8 ± 1.0 ($n = 12$)	4.4 ± 3.1 ($n = 11$)	5.9 ± 1.4 ($n = 9$)
	125	9.0 ± 0.8 ($n = 9$)	6.4 ± 2.2 ($n = 5$)	7.4 ± 1.2 ($n = 6$)
$\dot{V}O_2$ (ml min^{-1})	25	770.7 ± 184.8 ($n = 12$)	789.3 ± 115.1 ($n = 12$)	786.8 ± 156.6 ($n = 12$)
	50	1,045.8 ± 117.4 ($n = 12$)	1,076.4 ± 119.3 ($n = 12$)	1,055.5 ± 171.5 ($n = 12$)
	75	1,363.8 ± 155.7 ($n = 12$)	1,309.6 ± 155.6 ($n = 12$)	1,379.3 ± 206.0 ($n = 12$)
	100	1,624.0 ± 194.4 ($n = 12$)	1,536.6 ± 188.2 ($n = 11$)	1,619.2 ± 311.4 ($n = 9$)
	125	1,792.8 ± 201.3 ($n = 9$)	1,896.0 ± 127.6 ($n = 5$)	1,869.3 ± 164.4 ($n = 6$)
HR (beats min^{-1})	25	110.8 ± 12.5 ($n = 12$)	102.8 ± 15.0 ($n = 12$)	111.8 ± 15.9 ($n = 12$)
	50	127.5 ± 16.3 ($n = 12$)	123.3 ± 8.8 ($n = 12$)	129.0 ± 18.2 ($n = 12$)
	75	147.9 ± 17.0 ($n = 12$)	147.3 ± 14.4 ($n = 12$)	150.7 ± 20.0 ($n = 12$)
	100	166.0 ± 17.9 ($n = 12$)	163.7 ± 13.9 ($n = 11$)	162.9 ± 14.3 ($n = 9$)
	125	174.5 ± 21.3 ($n = 9$)	165.3 ± 6.8 ($n = 5$)	181.7 ± 8.0 ($n = 6$)

Values are presented as mean ± SD

(n) subjects that completed the power output stage, $\dot{V}O_2$ oxygen uptake, *HR* heart rate, *RPE-O, L, and C* rating of perceived exertion Overall, Legs, and Chest

Cohorts: *FC* female Chinese, *FM* female Malay, *FI* female Indian

test PO stages, and the mean values ranged from 1.3 ± 1.0 to 7.4 ± 1.7 for RPE-Overall, 1.1 ± 1.3 to 7.1 ± 1.9 for RPE-Leg, and 1.1 ± 1.3 to 6.1 ± 2.3 for RPE-Chest. The highest mean RPE attained for the females was at PO stage 5: 8.6 ± 1.1 for RPE-Overall, 8.5 ± 1.1 for RPE-Leg, and 7.7 ± 1.7 for RPE-Chest.

RPE responses

Linear regression analysis using data from the first four PO stages showed that RPE-Overall, RPR-Legs, and RPE-Chest within each of the six gender–race sample cohorts distributed as positive functions of both $\dot{V}O_2$ (ml min^{-1}, ml kg^{-1} min^{-1}) and HR (beats min^{-1}). Listed in Table 4 are the correlation coefficients and linear regression equations for these functions. All regression functions were statistically significant ($P < 0.01$).

Linear regression analysis using data from all PO stages were also calculated. Results showed that RPE-Overall, RPE-Legs, and RPE-Chest within each of the six gender–race cohorts distributed as positive functions ($P < 0.01$) of both $\dot{V}O_2$ (ml min^{-1}, ml kg^{-1} min^{-1}) and HR (beats min^{-1}). Listed in Table 5 are the correlation coefficients and linear regression equations for these functions.

Regression analyses for the combined sample of subjects from all the six cohorts were also calculated for the first four PO stages, as well as for all PO stages. The regression analyses demonstrated that RPE-Overall, RPE-Legs, and RPE-Chest increased positively ($P < 0.01$) when expressed as a function of corresponding responses for

Table 4 Linear regression analysis of RPE (OMNI Scale) expressed as a function of $\dot{V}O_2$ (ml min^{-1}, ml kg^{-1} min^{-1}) and HR (beats min^{-1}) for PO stages 1–4 during cycle exercise for separate cohorts of male and female, Chinese, Malay, and Indian children (12–14 years)

Variables		Cohort	Slope	Intercept	*r**	r^2	SEE
Criterion	RPE predictor						
$\dot{V}O_2$ (ml min^{-1})	Overall	MC	199.20	805.69	0.996	0.992	43.04
	Leg		190.85	849.63	0.990	0.981	63.67
	Chest		197.40	867.59	0.992	0.984	59.22
$\dot{V}O_2$ (ml min^{-1})	Overall	MM	179.77	872.76	0.963	0.928	118.51
	Leg		173.30	916.20	0.965	0.931	111.29
	Chest		170.52	897.81	0.978	0.956	85.57
$\dot{V}O_2$ (ml min^{-1})	Overall	MI	174.90	803.78	0.985	0.970	73.36
	Leg		174.55	806.48	0.984	0.968	75.03
	Chest		180.11	844.90	0.981	0.962	85.23
$\dot{V}O_2$ (ml min^{-1})	Overall	FC	126.28	741.59	0.993	0.987	46.52
	Leg		135.63	696.97	0.990	0.979	64.99
	Chest		120.69	804.88	0.992	0.984	49.87
$\dot{V}O_2$ (ml min^{-1})	Overall	FM	122.52	786.94	0.984	0.968	64.71
	Leg		113.04	811.50	0.991	0.982	44.97
	Chest		112.29	821.78	0.975	0.951	82.03
$\dot{V}O_2$ (ml min^{-1})	Overall	FI	135.62	627.19	0.991	0.983	57.52
	Leg		118.62	690.85	0.982	0.964	79.53
	Chest		134.45	708.58	0.996	0.992	39.34
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	MC	2.93	15.18	0.985	0.969	1.23
	Leg		2.75	15.68	0.979	0.959	1.35
	Chest		2.85	15.92	0.980	0.961	1.36
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	MM	4.22	14.59	0.996	0.992	0.92
	Leg		3.56	15.62	0.986	0.972	1.42
	Chest		4.10	15.19	0.996	0.992	0.88
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	MI	3.82	13.71	0.989	0.979	1.34
	Leg		3.57	14.21	0.991	0.982	1.16
	Chest		3.88	14.96	0.990	0.981	1.28
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	FC	2.50	15.06	0.971	0.944	1.96
	Leg		2.76	14.31	0.990	0.980	1.13
	Chest		2.27	16.73	0.981	0.961	1.46
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	FM	0.27	13.55	0.996	0.992	0.78
	Leg		2.37	14.86	0.993	0.986	0.89
	Chest		2.60	14.09	0.990	0.980	1.20
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	FI	2.85	13.38	0.999	0.997	0.50
	Leg		2.39	14.00	0.998	0.996	0.54
	Chest		2.65	14.51	0.997	0.993	0.69
HR (beats min^{-1})	Overall	MC	14.63	98.52	0.958	0.918	10.32
	Leg		13.12	102.75	0.960	0.921	9.09
	Chest		15.44	101.96	0.964	0.930	10.05
HR (beats min^{-1})	Overall	MM	12.49	100.16	0.991	0.981	4.10
	Leg		11.48	103.31	0.983	0.966	5.13
	Chest		11.39	104.94	0.984	0.968	4.89
HR (beats min^{-1})	Overall	MI	14.25	97.89	0.958	0.918	10.05
	Leg		12.40	103.17	0.986	0.971	5.05
	Chest		14.33	102.41	0.971	0.943	8.31

Table 4 continued

Variables		Cohort	Slope	Intercept	r*	r^2	SEE
Criterion	RPE predictor						
HR (beats min^{-1})	Overall	FC	9.46	102.98	0.995	0.990	3.11
	Leg		9.49	103.01	0.993	0.987	3.51
	Chest		9.30	109.06	0.995	0.990	3.07
HR (beats min^{-1})	Overall	FM	9.20	101.60	0.985	0.970	5.21
	Leg		8.69	103.84	0.986	0.973	4.67
	Chest		9.35	102.03	0.995	0.991	2.86
HR (beats min^{-1})	Overall	FI	9.17	97.59	0.992	0.984	3.80
	Leg		7.99	101.14	0.991	0.982	3.76
	Chest		9.25	101.35	0.989	0.978	4.48

RPE rating of perceived exertion, $\dot{V}O_2$ oxygen uptake, *HR* heart rate, *SEE* standard error of estimate, Cohorts: *MC* male Chinese ($n = 15$), *MM* male Malay ($n = 15$). *MI* male Indian ($n = 15$), *FC* female Chinese ($n = 12$), *FM* female Malay ($n = 12$), *FI* female Indian ($n = 12$)

* $P < 0.01$

Table 5 Linear regression analysis of RPE (OMNI Scale) expressed as a function of $\dot{V}O_2$ (ml min^{-1}, ml kg^{-1} min^{-1}) and HR (beats min^{-1}) for all PO stages during cycle exercise for separate cohorts of male and female, Chinese, Malay, and Indian children (12–14 years)

Variables		Cohort	Slope	Intercept	r*	r^2	SEE
Criterion	RPE predictor						
$\dot{V}O_2$ (ml min^{-1})	Overall	MC	178.68	939.51	0.986	0.973	104.02
	Leg		158.09	1,004.68	0.974	0.949	128.05
	Chest		166.42	1,045.10	0.981	0.963	114.16
$\dot{V}O_2$ (ml min^{-1})	Overall	MM	184.04	1,018.59	0.994	0.987	72.55
	Leg		169.68	1,047.32	0.973	0.947	140.77
	Chest		169.04	1,120.51	0.970	0.941	148.02
$\dot{V}O_2$ (ml min^{-1})	Overall	MI	180.86	872.34	0.984	0.969	113.13
	Leg		169.05	1,120.51	0.970	0.941	147.94
	Chest		197.73	932.69	0.988	0.976	109.42
$\dot{V}O_2$ (ml min^{-1})	Overall	FC	127.68	733.66	0.975	0.950	102.31
	Leg		131.55	722.63	0.972	0.944	111.68
	Chest		128.88	798.01	0.973	0.946	107.90
$\dot{V}O_2$ (ml min^{-1})	Overall	FM	134.50	750.55	0.986	0.972	79.44
	Leg		139.89	762.82	0.961	0.924	139.85
	Chest		141.45	745.46	0.968	0.936	129.22
$\dot{V}O_2$ (ml min^{-1})	Overall	FI	116.17	695.95	0.990	0.981	56.43
	Leg		98.91	796.73	0.971	0.943	84.99
	Chest		132.29	696.74	0.980	0.961	93.18
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	MC	3.08	16.20	0.961	0.924	1.79
	Leg		2.73	17.32	0.946	0.895	2.21
	Chest		2.87	18.02	0.946	0.894	1.97
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	MM	3.29	18.19	0.970	0.941	1.30
	Leg		3.03	18.70	0.975	0.950	2.51
	Chest		3.02	20.01	0.979	0.958	2.64
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	MI	3.35	16.21	0.974	0.949	2.10
	Leg		3.10	17.28	0.950	0.903	2.96
	Chest		3.68	17.34	0.982	0.965	2.03

Table 5 continued

Variables: Criterion	Variables: RPE predictor	Cohort	Slope	Intercept	r*	r^2	SEE
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	FC	2.57	14.79	0.981	0.962	2.06
	Leg		2.65	14.57	0.987	0.974	2.25
	Chest		2.60	16.09	0.967	0.935	2.18
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	FM	2.55	14.22	0.994	0.988	1.50
	Leg		2.65	14.45	0.972	0.946	2.65
	Chest		2.68	14.12	0.990	0.980	2.45
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	FI	2.45	14.68	0.992	0.984	1.19
	Leg		2.09	16.81	0.992	0.984	1.79
	Chest		2.79	14.70	0.997	0.994	1.97
HR (beats min^{-1})	Overall	MC	8.59	113.96	0.977	0.954	6.62
	Leg		8.21	117.14	0.980	0.960	5.85
	Chest		8.69	119.27	0.987	0.973	5.03
HR (beats min^{-1})	Overall	MM	9.21	109.48	0.981	0.962	6.37
	Leg		9.05	111.29	0.979	0.958	6.64
	Chest		8.48	115.87	0.982	0.965	5.64
HR (beats min^{-1})	Overall	MI	7.86	119.08	0.982	0.965	5.21
	Leg		7.83	117.71	0.965	0.932	7.40
	Chest		8.02	121.68	0.971	0.943	6.89
HR (beats min^{-1})	Overall	FC	8.12	106.21	0.997	0.993	2.36
	Leg		8.20	107.82	0.983	0.967	5.33
	Chest		7.79	113.22	0.983	0.966	5.08
HR (beats min^{-1})	Overall	FM	8.12	104.36	0.979	0.959	5.85
	Leg		7.12	108.94	0.975	0.951	5.63
	Chest		7.59	107.31	0.963	0.927	7.47
HR (beats min^{-1})	Overall	FI	8.20	101.58	0.990	0.979	4.16
	Leg		7.41	104.44	0.991	0.982	3.53
	Chest		8.92	101.92	0.996	0.991	2.90

RPE rating of perceived exertion, $\dot{V}O_2$ oxygen uptake, *HR* heart rate, *SEE* standard error of estimate, Cohorts: *MC* male Chinese ($n = 15$), *MM* male Malay ($n = 15$), *MI* male Indian ($n = 15$), *FC* female Chinese ($n = 12$), *FM* female Malay ($n = 12$), *FI* female Indian ($n = 12$)

* $P < 0.01$

$\dot{V}O_2$ and HR derived from the first four PO stages, as well as for all PO stages (Tables 6, 7).

Differentiated and undifferentiated RPE responses

OMNI Scale RPE-Overall, -Legs, and -Chest were statistically examined by ANOVA (gender × race × site × PO) for the separate cohorts of female and male, Chinese, Malay, and Indian children. ANOVA indicated that the main effects for gender ($F = 70.11$, $P < 0.001$), site ($F = 9.59$, $P < 0.01$), and PO ($F = 244.08$, $P < 0.001$) were significant while the main effect for race ($F = 2.89$, $P = 0.089$) was not. The three factor interaction for gender × site × PO was significant ($F = 4.24$, $P < 0.01$). A post hoc analysis with one-way ANOVA was used to examine gender differences for RPE-Overall, RPE-Leg, and RPE-Chest at each of the first four PO stages. Results showed that females had significantly higher RPE ratings for Overall, Legs, and Chest than males at all four PO stages examined.

The separate male and female cohorts were then examined by a one-way ANOVA for differences among RPE-Overall, RPE-Legs, and RPE-Chest at each PO stage. Results for the male subjects showed that no significant differences existed between undifferentiated RPE (Overall) and RPE that was differentiated to the Legs and Chest at all PO stages analyzed except PO stage 8, where RPE-Legs was found to be greater ($P < 0.05$) than both RPE-Chest and RPE-Overall. ANOVA with repeated measures applied to each of the three measurement sites over the different PO stages for the male cohort revealed that all the RPE values (Overall, Legs, and Chest) at each PO stage were significantly different ($P < 0.001$), when compared with RPE at all other PO stages. Therefore, as PO increased

Table 6 Linear regression analysis of RPE (OMNI Scale) expressed as a function of $\dot{V}O_2$ (ml min^{-1}, ml kg^{-1} min^{-1}) and HR (beats min^{-1}) for PO stages 1–4 during cycle exercise for a combined sample of male and female, Chinese, Malay, and Indian children (12–14 years)

Variables		Slope	Intercept	*r**	r^2	SEE
Criterion	RPE predictor					
$\dot{V}O_2$ (ml min^{-1})	Overall	115.09	868.37	0.970	0.940	93.14
	Leg	107.08	893.03	0.963	0.928	104.44
	Chest	113.23	909.06	0.969	0.939	93.06
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	2.56	15.62	0.982	0.965	1.57
	Leg	2.25	16.35	0.983	0.967	1.46
	Chest	2.20	17.01	0.975	0.950	1.76
HR (beats min^{-1})	Overall	8.77	106.15	0.980	0.961	5.66
	Leg	7.99	108.84	0.985	0.971	4.81
	Chest	8.85	109.17	0.988	0.975	4.50

RPE rating of perceived exertion, $\dot{V}O_2$ oxygen uptake, *HR* heart rate, *SEE* standard error of estimate
* $P < 0.01$; $n = 81$

Table 7 Linear regression analysis of RPE (OMNI Scale) expressed as a function of $\dot{V}O_2$ (ml min^{-1}, ml kg^{-1} min^{-1}) and HR (beats min^{-1}) for all PO stages during cycle exercise for a combined sample of male and female, Chinese, Malay, and Indian children (12–14 years)

Variables		Slope	Intercept	*r**	r^2	SEE
Criterion	RPE predictor					
$\dot{V}O_2$ (ml min^{-1})	Overall	143.96	924.14	0.953	0.908	160.40
	Leg	148.19	981.96	0.970	0.940	130.97
	Chest	155.56	935.22	0.972	0.944	131.99
$\dot{V}O_2$ (ml kg^{-1} min^{-1})	Overall	2.72	17.45	0.950	0.903	3.03
	Leg	2.80	18.55	0.965	0.931	2.47
	Chest	2.94	17.66	0.979	0.958	2.49
HR (beats min^{-1})	Overall	8.02	113.54	0.979	0.958	5.89
	Leg	7.62	114.32	0.983	0.966	5.01
	Chest	8.18	115.39	0.987	0.974	4.65

RPE rating of perceived exertion, $\dot{V}O_2$ oxygen uptake, *HR* heart rate, *SEE* standard error of estimate
* $P < 0.01$; $n = 81$

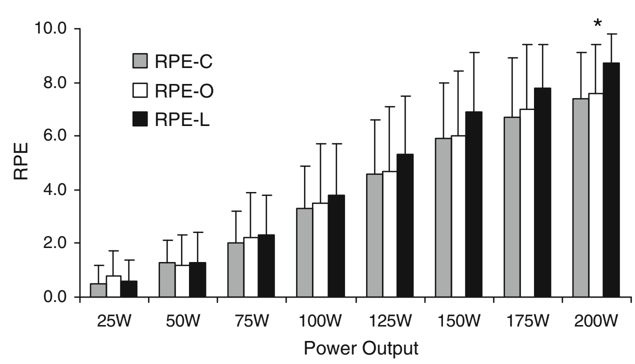

Fig. 2 Ratings of perceived exertion (OMNI Scale) for the overall body (RPE-Overall), legs (RPE-Legs), and chest (RPE-Chest) at eight power output (PO) stages during cycle exercise for the combined male cohorts. Data are mean ± SD for a repeated measures paradigm. $n = 45$ for PO stages 1–4, 42 for PO stage 5, 38 for PO stage 6, 26 for PO stage 7, and 14 for PO stage 8. *RPE-Legs was higher ($P < 0.05$) than RPE-Overall and RPE-Chest

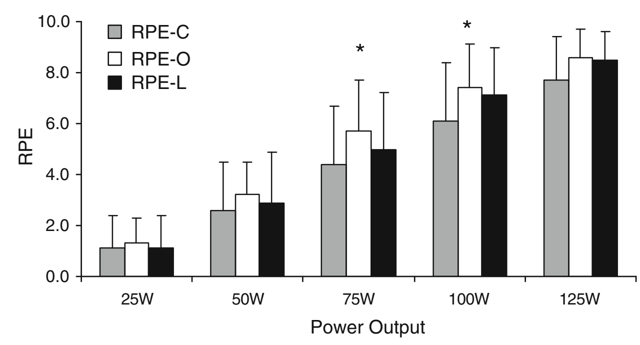

Fig. 3 Ratings of perceived exertion (OMNI Scale) for the overall body (RPE-Overall), legs (RPE-Legs), and chest (RPE-Chest) at five power output (PO) stages during cycle exercise for the combined female cohorts. Data are mean ± SD for a repeated measures paradigm. $n = 36$ for PO stages 1–3, 32 for PO stage 4, and 20 for PO stage 5. *RPE-Overall was higher ($P < 0.05$) than RPE-Chest

from 25 to 100 W the corresponding RPEs (Overall, Legs, and Chest) also increased significantly ($P < 0.001$) from stage to stage. Figure 2 presents the data as mean ± SD and summarizes the relevant RPE by PO interactions for the combined male cohort.

For the combined female cohort, at PO stages 1, 2, and 5, no significant differences were detected between undifferentiated RPE (Overall) and RPE that was differentiated to the Legs and Chest. However, at stages 3 and 4, RPE-Overall was greater ($P < 0.05$) than RPE-Chest. ANOVA also indicated that all the RPE for the measurement sites (Overall, Legs, Chest) at each PO stage were significantly different ($P < 0.001$), when compared with RPE at all other PO stages. Therefore, as PO increased from 25 to 125 W at 25 W increments, the corresponding RPEs (Overall, Legs, and Chest) also increased significantly ($P < 0.001$) from stage to stage. Figure 3 presents the data as mean ± SD and summarizes the relevant RPE by PO interactions for the combined female cohort.

Discussion

OMNI Scale RPE response

RPE responses derived from the OMNI Scale in this investigation distributed as a positive linear function of oxygen uptake ($\dot{V}O_2$ ml min^{-1} and $\dot{V}O_2$ ml kg^{-1} min^{-1}) and heart rate (HR, beats min^{-1}) for the submaximal power outputs that were utilized in the cycle ergometer exercise test. A positive correlation was evident for both the undifferentiated (RPE-Overall) and differentiated (RPE-Legs and RPE-Chest) RPE when examined separately for Chinese, Malay, and Indian, male and female children, as well as for the combined sample of all children. Validity coefficients derived from the regression analyses for separate cohorts using data from the first four PO stages ranged from $r = 0.958$ to 0.999 ($P < 0.01$). For all PO stages, the linear regression analyses yielded r values of 0.946–0.997 ($P < 0.01$). Linear regression analyses for the combined sample of all children produced r values of 0.963–0.988 ($P < 0.01$) for the first four PO stages, and 0.950–0.987 ($P < 0.01$) for all PO stages. The strong positive linear responsiveness of OMNI Scale RPE expressed as a function of selected physiological variables during load incremented cycle ergometry obtained in this present study indicates concurrent scale validity for the independent gender–race sample cohorts. Evidence of concurrent validity was taken as a positive correlation between the criterion variables ($\dot{V}O_2$ and HR) and the concurrent variables (RPE) examined over the full perceptual–physiological range (Robertson et al. 2004; Utter et al. 2004). Consistent with expectations, the ability of the children to translate into numerical values (RPE) their perceptions of physical exertion using the words and pictures of the OMNI Scale was not influenced appreciably by gender or race. Gender-specific scale validation is important when investigating the influence of neuromotor, physiological, and performance factors on RPE when responses are compared between males and females (Robertson et al. 2000a, 2001, 2004; Utter et al. 2002, 2004). Establishing OMNI Scale validity in the context of cultural differences (languages, physical activity exposure, and habituation) across racial groups is important in extending the limits of generalizability or usability of the perceived exertion construct among individuals across several racial backgrounds. These findings are consistent with previous studies that examined response validity of the OMNI Scale using both pediatric and adult samples.

In the original validation study of the Children's OMNI Scale using mixed gender and race sample cohorts, linear regression coefficients ranged from $r = 0.85$ to 0.94 for both the undifferentiated RPE (RPE-Overall) and differentiated RPE (RPE-Leg and RPE-Chest) (Robertson et al. 2000a). A study by Utter et al. (2002) that examined the validity of the OMNI Scale using a walk/run pictorial format for 6- to 13-year-old children performing a walk/run test protocol yielded significant positive correlations ($r = 0.26$–0.60). Pfeiffer et al. (2002) used a cross-modal paradigm to investigate RPE responses of adolescent girls using the cycle pictorial format of the OMNI Scale in a treadmill test protocol and reported validity coefficients from $r = 0.82$ to 0.88. Studies on RPE responses of adults performing walk/run and cycle modes and using the Adult OMNI Walk/Run and Cycle formatted scales, respectively, have also reported validity coefficients from $r = 0.67$ to 0.88 (walk/run protocol) and $r = 0.81$ to 0.95 (cycle protocol) (Robertson et al. 2004; Utter et al. 2004).

The use of positive RPE response linearity as an applied validation criterion is based on the basic principles of Borg's Model of the Three Effort Continua (Borg 1998, p. 6). The Model states that as exercise performance increases along an intensity dependent continuum, the corresponding physiological (i.e., $\dot{V}O_2$, HR) and perceptual responses (i.e., RPE) grow in a similar fashion, and these interdependent variables exhibit a positive relation. According to Robertson et al. (2000a, b), this perceptual–physiological correspondence during dynamic exercise is essential when using RPE to test exercise tolerance and prescribe exercise intensity. The positive linear relation obtained in this study between OMNI Scale RPE and selected physiological criteria satisfies the application outcomes derived from the Three Effort Continua Model. As a result, OMNI Scale RPE responses can be applied, either independently or conjunctively with physiological responses, to sport and pedagogical settings within Singapore schools having mixed cohorts of Chinese, Malay, and Indian, male and female children.

In the male cohort, 84.4% completed up to six PO stages, and in the female cohort, 88.9% completed the first four test PO stages. However, the number of subjects who reached the highest PO stage of 8 was only 31.1% of the total male cohort, and for the female cohort only 20 or 55.6% of total female cohort reached the highest PO stage of 5. The RPE responses of the male (mean RPE-Overall for PO stages 1–6 ranged from 0.8 ± 0.9 to 6.0 ± 2.4; for the highest PO stage 8, 7.6 ± 1.8) and female children (mean RPE-Overall for PO stages 1–4 ranged from 1.3 ± 1.0 to 7.4 ± 1.7; for the highest PO stage 5, 8.6 ± 1.1) differed in absolute physical work capacities in this study, but they can be fitted reasonably well within the perceptual range of the OMNI Scale, suggesting that the anchoring procedure used for the OMNI Scale in this study effectively established the cognitive effort extremes in children of varied ethnicity and cultural background (Robertson et al. 2000a).

As the OMNI Scale perceptual range can accommodate male and female children of different aerobic fitness levels, comparisons of RPE responses at relative workloads could be meaningful. Therefore, it is not unreasonable to conclude that the OMNI Scale could be a valid tool for intra- and interindividual comparisons of perceived exertions during dynamic exercise in 12- to 14-year-old male and female children of Chinese, Malay, and Indian ethnicities. A cross-modal comparison study of RPE between male and female children of similar racial mix at absolute and relative physiological criteria would verify the validity of this expectation.

Differentiated and undifferentiated RPE responses

Differentiated signals of perceived exertion arising from the legs (RPE-Legs) and the chest (RPE-Chest) are presumed to be directly linked with their respective underlying physiological responses involving the exercising muscles and the cardiopulmonary systems, whereas the undifferentiated signal of exertion (RPE-Overall) for the whole body represents an integration of the perceptually weighted differentiated signals (Pandolf et al. 1982; Robertson et al. 1982; Watt and Grove 1993). The differentiated RPE responses derived from the OMNI Scale in the present cohort of children were generally inconsistent with those reported for both children and adults. For the male cohort, no significant differences among RPE-Overall, RPE-Leg, and RPE-Chest were detected at any PO stages up to stage 7 ($n = 26$, or 57.8% of male cohort). However, at PO stage 8, RPE-Leg was found to be greater than both RPE-Overall ($P < 0.05$) and RPE-Chest ($P < 0.05$). This response indicates that RPE-Leg was the dominant signal at the highest intensity attained during the cycle ergometer exercise test for the male children, and suggests that male children were able to differentiate between RPE-Legs and RPE-Chest only at the comparatively high exercise intensities and not at low to moderate intensities. It must be noted that the number of subjects who reached stage 8 was relatively small ($n = 14$), representing only 31.1% of the total male cohort.

Results of this study indicate that male children reported a dominant perceptual signal arising from the legs only near or at maximal intensity during the cycle exercise test. This finding is similar to other studies that have demonstrated peripheral perceptual signal dominance, or feelings of strain from the exercising muscles and/or joints, at high intensity. Mahon et al. (1998) have found that at maximal exercise, children using the Borg Scale rated RPE-Legs higher than RPE-Chest. Mahon and Ray (1995) when comparing RPE at maximal exercise in children suggested that the higher RPE reported for the walking protocol, as opposed to running, was due to lower extremity fatigue caused by greater effort required to overcome high treadmill elevation. The original validation study of the OMNI Scale by Robertson et al. (2000a, b) reported dominance of the leg perceptual signal at all four PO stages tested. Similar results were attained when validating the Adult OMNI Scale for cycle ergometer exercise in men and women (Robertson et al. 2004).

It should be noted that the dominance of the legs perceptual signal at high or near maximal intensities does not always occur. Robertson et al. (2001) investigation on a normalized perceptual reference for the prescription of exercise intensity using the OMNI Scale in children aged 8–12 years reported no differences in perceptual responses between undifferentiated and differentiated RPE at peak exercise. A similar finding was reported by Mahon et al. (1998) when comparing perceptual responsiveness between adults and children at maximal exercise.

For the combined female cohort, RPE-Overall was found to be greater ($P < 0.05$) than RPE-Chest at PO stages 3 and 4. No other significant differences were detected at the other PO stages among RPE-Overall, RPE-Leg, and RPE-Chest. The observed perceptual strength of RPE-Overall across PO stages 1–4 was progressively greater than RPE-Chest, and became significant at PO stages 3 and 4, suggesting a “differentiation threshold” effect (Robertson et al., 1982), but with RPE-Overall dominating instead of RPE-Legs. This phenomenon observed in the female cohort is accounted for by 100% ($n = 36$, PO stage 3) and 88.9% ($n = 32$, PO stage 4) of female subjects. The differentiated signals of the legs and the chest in the female children in this study, thus, appear to be subordinated to the undifferentiated perceptual signal for the whole body at higher intensity levels.

Due to the inconsistent results arising out of this study regarding differentiated and undifferentiated RPE, a plausible conclusion cannot be postulated regarding the general response of 12- to 14-year-old male and female children of Chinese, Malay, and Indian origin to differentiate among RPE-Overall, RPE-Legs, and RPE-Chest at each PO stage using the Children's OMNI Scale in a cycle exercise protocol. This variability in differentiated RPE response in children (8–12 years old) have been observed before (Ueda and Kurokawa 1991), and Mahon et al. (1998) have indicated in their findings that differences exist in RPE ratings for overall, legs, and chest at ventilatory threshold between adults (mean age 24.3 years) and children (10.9 years).

Conclusion

In this investigation, evidence of OMNI perceived exertion scale validity was obtained for a mixed cohort of Chinese, Malay, and Indian, male and female children. Validation criterion stated that RPE-Overall, RPE-Legs, and RPE-Chest derived from the OMNI Scale at submaximal cycle ergometer exercise intensities would distribute as a positive linear function of heart rate (HR) and oxygen uptake ($\dot{V}O_2$). For the children aged 12–14 years in this study, RPE-Legs did not differ from RPE-Chest and as such it was not possible to identify a dominant perceptual signal.

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