Validation of the Adult OMNI Scale of Perceived Exertion for Cycle Ergometer Exercise

ROBERT J. ROBERTSON, FREDRIC L. GOSS, JOHN DUBÉ, JASON RUTKOWSKI, MANDI DUPAIN, CAROL BRENNAN, and JOSEPH ANDREACCI

Center for Exercise and Health-Fitness Research, University of Pittsburgh, Pittsburgh, PA

ABSTRACT

ROBERTSON, R. J., F. L. GOSS, J. DUBÉ, J. RUTKOWSKI, M. DUPAIN, C. BRENNAN, and J. ANDREACCI. Validation of the Adult OMNI Scale of Perceived Exertion for Cycle Ergometer Exercise. *Med. Sci. Sports Exerc.*, Vol. 36, No. 1, pp. 102–108, 2004. **Purpose:** Concurrent and construct validity of the OMNI-Cycle Scale of Perceived Exertion were examined using young adult women and men (18–32 yr). **Methods:** Concurrent validity was established by correlating OMNI-Cycle Scale ratings of perceived exertion (RPE) with oxygen consumption ($\dot{V}O_2$) and heart rate (HR) responses to a load-incremented cycle ergometer protocol. Construct validity was established by correlating RPE derived from the OMNI-Cycle Scale with RPE from the Borg (6–20) Scale. RPE, $\dot{V}O_2$, and HR were measured during each exercise stage. **Results:** The range of exercise responses across the incremental test for the female and male groups was $\dot{V}O_2$ = 0.92–2.74 $L \cdot min^{-1}$, HR = 107.2–167.2 $beats \cdot min^{-1}$, and OMNI Scale RPE-Overall, RPE-Legs, and RPE-Chest 1.0–9.1. Correlation/regression analyses indicated that RPE-Overall, RPE-Legs, and RPE-Chest distributed as a positive linear function of both $\dot{V}O_2$ and HR ($r = 0.81$ to 0.95; $P < 0.01$). Undifferentiated and differentiated RPE-OMNI Scale distributed as a positive linear function of RPE-Borg Scale ($r = 0.92$ to 0.97; $P < 0.01$). ANOVA indicated that OMNI-Cycle RPE-Legs was higher ($P < 0.01$) than RPE-Chest at each exercise stage for both genders. **Conclusion:** Concurrent and construct evidence supports use of the OMNI Scale by adult women and men to estimate RPE during cycle exercise. **Key Words:** RPE, CONCURRENT AND CONSTRUCT VALIDITY, BORG SCALE, OXYGEN CONSUMPTION, HEART RATE

This investigation validated the cycle pictorial format of the OMNI Perceived Exertion Scale for use by adult women and men. The OMNI-Cycle Scale has a category rating format that contains both pictorial and verbal descriptors positioned along a comparatively narrow numerical response range, 0–10 (Fig. 1). The "exertional meaning" of each pictorial descriptor is consonant with its corresponding verbal descriptor. OMNI is an acronym for the word omnibus, and when defined in the context of a perceived exertion metric refers to a category scale having broadly generalizable measurement properties.

The OMNI Perceived Exertion Scale was initially validated for use by female and male children (6–12 yr old) performing progressively incremented cycle ergometer and treadmill (walking/running) exercise (14,19,25). Recently, a mode-specific pictorial format of the OMNI Scale has been validated for adults performing upper- and lower-body resistance exercise (23). However, the adult format of the OMNI Perceived Exertion Scale has not been validated for use during aerobic exercise such as load-incremented cycle ergometry. This scale validation was the primary focus of the present investigation.

A substantial number of previous investigations have evaluated the possible role of the subject's gender in mediating the intensity of RPE (13,15,20). Given that gender differences can be of interest in perceived exertion research, it is important to establish that the metric employed is valid for use by both women and men performing a specified exercise protocol. The weight lifting pictorial format of the adult OMNI Scale has been validated separately for adult women and men during upper- and lower-body isotonic exercise (23). However, gender specific validation of the OMNI-Cycle Scale for adults has not been undertaken. It was expected that the cycle pictorial format of the OMNI Scale would be valid for separate samples of adult women and men performing load-incremented cycle ergometry.

During both aerobic and resistance exercise, RPE can be anatomically differentiated to the involved body regions (i.e., arms, legs, and chest) and can also be assessed as an undifferentiated signal from the overall body (18). For

Address for correspondence: Robert J. Robertson, 140 Trees Hall, University of Pittsburgh, Pittsburgh, PA 15261; E-mail: rrobert@pitt.edu.
Submitted for publication July 2003.
Accepted for publication September 2003.

0195-9131/04/3601-0102
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/01.MSS.0000106169.35222.8B

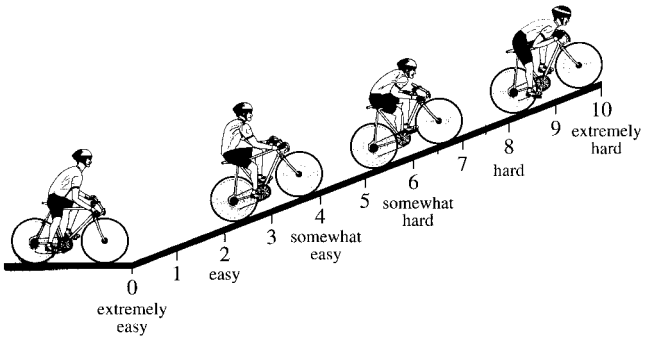

FIGURE 1—OMNI-Cycle Scale of perceived exertion for adults.

modes such as cycling and walking the intensity of the various differentiated perceptual signals usually differs from that of the undifferentiated signal at a given time point during submaximal exercise (16). To date, only one investigation has determined differentiated OMNI Scale RPE in an adult sample. Using weight lifter pictorial descriptors for the OMNI Scale, Robertson et al. (23) found that RPE for the active muscles was significantly more intense than for the overall body during upper- and lower-body resistance exercise using volume loading protocols. Differentiated RPE using the adult format of the OMNI Scale has not been examined for aerobic exercise.

The present investigation examined concurrent and construct validity of the OMNI-Cycle Scale of Perceived Exertion separately for adult women and men. Evidence of response validity was accepted according to the following hypotheses: (a) RPE derived from the OMNI-Cycle Scale would distribute as a positive linear function of submaximal $\dot{V}O_2$ and HR responses for separate groups of young adult women and men, (b) RPE derived from the OMNI-Cycle and Borg Scales during load-incremented cycle ergometer exercise would be positively correlated, and (c) the OMNI-Cycle Scale could be used by adults to differentially rate the intensity of exertional signals from the legs and chest during cycle ergometer exercise.

METHODS

Subjects. Characteristics of the women ($N = 20$) and men ($N = 20$) subjects were, respectively (mean ± standard deviation): age (yr) 21.1 ± 3.8, 24.1 ± 3.7; height (cm) 164.5 ± 9.9, 176.6 ± 9.4; body mass (kg) 61.9 ± 8.9, 79.0 ± 7.7; and peak oxygen consumption ($mL \cdot kg^{-1} \cdot min^{-1}$) 36.31 ± 8.27, 41.41 ± 7.26. Subjects did not present clinical, neuromotor, or cognitive contraindications to exercise testing. All reported regular participation in recreational health-fitness activities. Risks and benefits of the experiment were explained, and subjects gave written consent to participate. The experimental paradigm was approved by the University of Pittsburgh Institutional Review Board.

Experimental design. A cross-sectional, perceptual estimation design was used to assess exertional perceptions during a load-incremented cycle ergometer protocol that terminated at peak exercise intensity. Each subject undertook one orientation and one estimation trial. The trials were separated by a minimum of 48 h and maximum of 72 h. All subjects were tested in a 3-h postprandial state and were requested not to consume alcohol or participate in vigorous physical activity during the 24-h period preceding each trial.

Both concurrent and construct paradigms were used to establish measurement validity of the adult OMNI-Cycle Scale. A concurrent validation paradigm employs a two variable scheme: (a) criterion (i.e., stimulus) variable and (b) concurrent (i.e., response) variable. In the present investigation, both submaximal oxygen consumption ($\dot{V}O_2$) and heart rate (HR) responses to a cycle ergometer protocol served as criterion variables. The RPE for the overall body (RPE-Overall), legs (RPE-Legs), and chest (RPE-Chest) were the concurrent variables. Evidence of concurrent validity was taken as a positive correlation between criterion and concurrent variables when examined over the full perceptual-physiological range.

Construct validity was established by correlating RPE derived from the OMNI-Cycle Scale with RPE from the 1982 version of the Borg (6–20) Scale (3). In this paradigm, RPE was the construct variable. The Borg Scale was the criterion metric and the OMNI-Cycle Scale the conditional metric. A high validity coefficient demonstrates that the conditional metric measures the same perceptual construct as the criterion metric.

Orientation trial. During the orientation trial, subjects were familiarized with cycle ergometer exercise testing and the OMNI-Cycle Scale of Perceived Exertion. The cycle familiarization procedures consisted of three, 3-min incremental power output (PO) stages presented continuously. Power outputs were 50, 75, and 100 W for women and 50, 100, and 150 W for men. After completion of the third submaximal stage, PO was incremented by 25 W for women and men every minute until the subject voluntarily terminated exercise owing to fatigue. A respiratory valve/mouthpiece and HR monitor were positioned on the subject during the orientation trial. Subjects were instructed regarding use of the OMNI-Cycle Scale immediately before cycle exercise and practiced estimating their RPE-Overall, RPE-Legs, and RPE-Chest during each PO stage.

Estimation trial. Before undertaking exercise, body mass and height were determined with a Detect-Medic Scale and attached stadiometer (Detecto Scales, Inc., Brooklyn, NY). The estimation trial was performed on a Monark (model 864) cycle ergometer equipped with a plate-loading system to apply brake force. The initial PO was 50 W for women and 75 W for men. Power outputs were incremented in continuous 3-min test stages by 25 W and 50 W, respectively, for women and men. The test was terminated when: (a) the subject volitionally stopped exercise owing to fatigue or (b) the investigator determined that the subject could not maintain the designated pedal rate for 10 consecutive seconds. A pedal rate of 50 $rev \cdot min^{-1}$ signaled by an electronic metronome was used for all PO stages of the exercise test. The PO was set by an investigator at the beginning of each stage; the absolute value not known by the subject.

HR and oxygen consumption. HR (beats·min^{-1}) was measured from 45 to 60 s during each minute of the estimation trial using a Polar Monitoring System (Woodbury, NY). An open-circuit respiratory-metabolic system (TrueMax 2400, Parvo Medics, Salt Lake City, UT) was used to measure total body oxygen consumption ($\dot{V}O_2$; L·min^{-1}; STPD) from 0 to 60 s of the final minute of each power output stage.

Ratings of perceived exertion. Three separate RPE were estimated in counterbalanced order from 30 to 60 s of the second minute of each PO stage using the 1982 version of the Borg (6–20) Perceived Exertion Scale (3) and from 30 to 60 s of the third minute using the OMNI-Cycle Scale of Perceived Exertion (Fig. 1). For both scales, an undifferentiated rating was estimated for the overall body (RPE-Overall), and a differentiated rating was estimated for peripheral perceptions of exertion in the legs (RPE-Legs) and respiratory-metabolic perceptions in the chest (RPE-Chest). Standard definitions of perceived exertion and separate instructional sets for the Borg and OMNI Scales were also read to the subject immediately before the exercise test. The Borg and OMNI scales were separately viewed by the subject when their respective instructional set was read. Both scales were anchored using a combination of exercise (20) and memory (19) procedures. The initial exercise anchoring procedure was presented during the orientation trial with memory reinforcement of the anchor points presented before the estimation trial. As a respiratory valve prohibited a verbal rating response, subjects pointed to their RPE on the scale designated for that measurement period.

For both scales, perceived exertion was defined as the subjective intensity of effort, strain, discomfort, and/or fatigue that was felt during exercise (12). The instructional set for the 15-category Borg Scale has been published previously (20). The instructions for the OMNI Scale were as follows.

Instructions. We would like you to ride on a bicycle ergometer. Please use the numbers on this scale to tell us how your body feels when bicycling. Look at the person at the bottom of the hill who is just starting to ride a bicycle. If you feel like this person when you are riding, the exertion will be EXTREMELY EASY. In this case, your rating should be a number zero. Now look at the person who is barely able to ride a bicycle to the top of the hill. If you feel like this person when riding, the exertion will be EXTREMELY HARD. In this case, your rating should be a number 10. If you feel somewhere between Extremely Easy (0) and Extremely Hard (10) then give a number between 0 and 10.

We will ask you to point to a number that tells how your whole body feels, how your legs feel, and how your breathing feels. Remember, there are no right or wrong numbers. Use both the pictures and words to help you select a number. Use *any* of the numbers to tell how you feel when riding the bicycle.

Data analysis. Descriptive data for perceptual and physiological variables were calculated as means ± standard deviation (SD). Evidence for both concurrent and construct validity was determined using linear regression analysis with repeated measures over PO (SPSS 11.0 for Windows, Chicago, IL). When testing concurrent validity, the analysis separately regressed $\dot{V}O_2$ and HR against OMNI Scale RPE-Overall, RPE-Legs, and RPE-Chest using data from the final minute of each of the submaximal PO stages. Regression coefficients were calculated separately for the female and male groups. When testing construct validity, the analysis regressed OMNI Scale RPE against Borg Scale RPE using data from each of the submaximal PO stages. Separate regression coefficients were calculated for RPE-Overall, RPE-Legs, and RPE-Chest within both gender groups. Because of gender differences in the cycle test protocol and the need to examine scale validity over the widest possible perceptual-physiological range, data were analyzed at four submaximal PO for the women and three PO for the men subjects.

OMNI Scale RPE were examined with a two-factor (site × PO) ANOVA (SPSS 11.0 for Windows) with repeated measures on the PO main effect. The analysis determined differences between RPE-Legs and RPE-Chest at each PO stage for the female and male groups. Significant main and *a priori* selected interaction effects (i.e., site difference within a given PO) were decomposed with a simple effects *post hoc* analysis.

Sample size was determined for the statistical power required to demonstrate a two factor (site × PO) interaction effect within the repeated measures comparisons of RPE. This power requirement was the most stringent among any of the statistical models employed in the analysis of variance and as such required the greatest number of subjects for each contrast cell. Using a power of 0.80, an α of 0.05, and an effect size of 0.9, it was determined that a minimum of 16 women and 16 men were required to test both the main and interaction effects (24). The within subject factor in the power calculation assumed an intra-class correlation of $r = 0.70$ over the repeated measures.

RESULTS

Descriptive responses. Presented in Figures 2 and 3 are the means (± SD) of OMNI Scale and Borg Scale RPE responses during the submaximal cycle ergometer PO. Each figure presents data separately for the women and men subject groups. Listed in Table 1 are the means (± SD) of $\dot{V}O_2$ and HR responses for the gender groups at each submaximal PO. These perceptual and physiological data were used in the regression analysis to examine concurrent and construct validity of the OMNI-Cycle Scale and in the factorial analysis to examine differentiated perceptual responsiveness.

Concurrent validity: OMNI-Cycle Scale. Regression analysis indicated that for both the women and men subjects, OMNI Scale RPE-Overall, RPE-Legs, and RPE-Chest distributed as positive linear functions of both $\dot{V}O_2$ and HR. Listed in Table 2 are the correlation coefficients and linear regression analyses for these functions presented

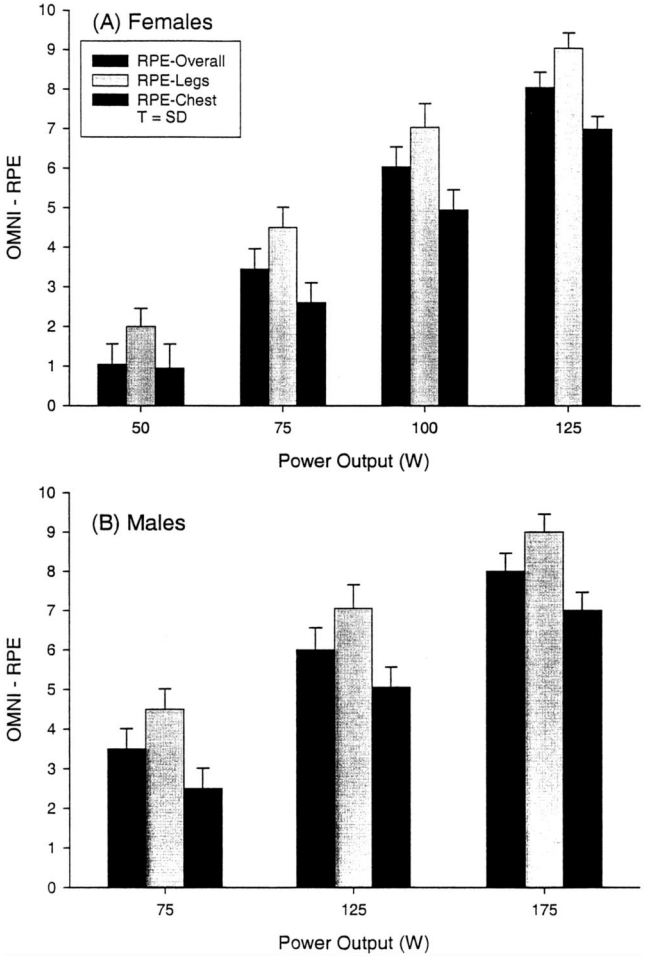

FIGURE 2—OMNI-Cycle ratings of perceived exertion for the overall body (RPE-Overall), legs, (RPE-Legs), and chest (RPE-Chest). A, females; B, males.

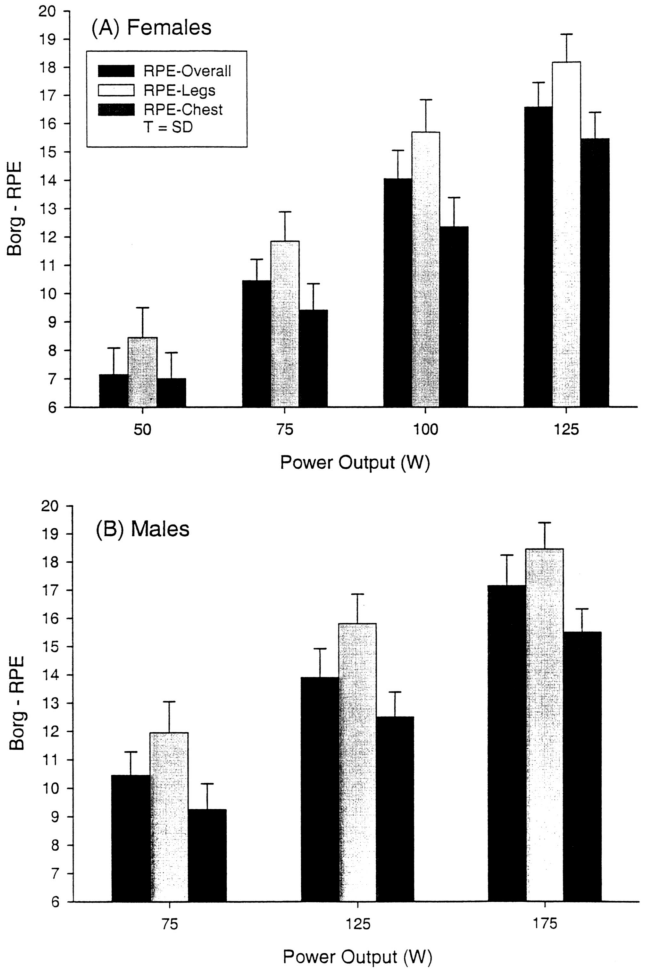

FIGURE 3—Borg (6–20) Scale ratings of perceived exertion for the overall body (RPE-Overall), legs (RPE-Legs), and chest (RPE-Chest). A, females; B, males.

by gender. All regression functions were statistically significant ($P < 0.01$).

Construct validity: OMNI-Cycle versus Borg scales. Regression analysis indicated that for both the women and men subjects, OMNI Scale RPE was positively and linearly related to Borg Scale RPE over the submaximal PO. Listed in Table 3 are the correlation coefficients and linear regression analyses for these functions. All regression analyses were statistically significant ($P < 0.01$) for RPE-Overall, RPE-Legs, and RPE-Chest.

Differentiated RPE: OMNI-Cycle Scale. The ANOVA compared RPE-Chest with RPE-Legs at each PO and was calculated separately for the women and men subjects. The ANOVA indicated significant main effects for site (*df*, 1,57; $F = 461.6$, $P < 0.01$, women; $F = 488.6$, $P < 0.01$, men) and PO (*df*, 2,57; $F = 1470.6$, $P < 0.01$, women; and $F = 730.3$, $P < 0.01$, men). The site × PO interaction effect was not significant for either the women or men subjects. Mauchly's tests of sphericity for repeated measures of RPE over PO were not significant. The factorial analysis indicated that: (a) when averaged over PO RPE-Legs was higher than RPE-Chest and (b) when averaged over measurement site, RPE increased progressively from the lowest to highest PO. These responses held for both the women and men subjects.

DISCUSSION

The cycle pictorial format of the OMNI Scale of Perceived Exertion was validated using both a concurrent and construct paradigm for separate groups of young adult women and men. Validation criteria stipulated that during load-incremented cycle ergometer exercise, (a) RPE derived from the OMNI-Cycle Scale would distribute as a positive

TABLE 1. Physiological responses during cycle exercise listed by gender and power output.

Gender	Power Output (W)	$\dot{V}O_2$ (L·min^{-1}) Mean (±SD)	HR (b·min^{-1}) Mean (±SD)
Female	50	0.92 (0.19)	115.0 (11.0)
	75	1.21 (0.16)	132.0 (13.2)
	100	1.55 (0.18)	153.3 (15.4)
	125	1.95 (0.20)	167.2 (12.8)
Male	75	1.36 (0.17)	107.2 (11.8)
	125	2.05 (0.18)	128.3 (10.6)
	175	2.74 (0.22)	156.0 (12.5)

$\dot{V}O_2$, oxygen consumption; HR, heart rate.

TABLE 2. Regression analysis of RPE (OMNI Scale-Cycle) expressed as a function of $\dot{V}O_2$ and HR during cycle exercise for adult females and males.

Gender	Variable		Slope	SEE	Intercept	SEE	r*	r^2
	Criterion	RPE Predictor						
Female	$\dot{V}O_2$	Overall	0.14	0.01	0.77	0.05	0.88	0.77
		Legs	0.14	0.10	0.64	0.05	0.87	0.76
		Chest	0.16	0.10	0.78	0.04	0.90	0.81
	HR	Overall	7.36	0.56	107.59	2.98	0.83	0.69
		Legs	7.10	0.59	101.73	3.69	0.81	0.65
		Chest	8.33	0.65	109.53	2.94	0.82	0.68
Male	$\dot{V}O_2$	Overall	0.30	0.04	0.33	80.24	0.94	0.89
		Legs	0.29	0.03	0.03	89.97	0.95	0.90
		Chest	0.31	0.04	0.62	68.82	0.95	0.90
	HR	Overall	10.83	0.69	67.33	4.25	0.90	0.81
		Legs	10.83	0.79	59.40	5.64	0.86	0.75
		Chest	10.60	0.76	79.07	3.94	0.88	0.77

RPE, rating of perceived exertion; $\dot{V}O_2$, oxygen consumption ($L \cdot min^{-1}$); HR, heart rate ($beats \cdot min^{-1}$); SEE, standard error of estimate.
* $P < 0.01$.

TABLE 3. Regression analysis of OMNI Scale RPE expressed as a function of Borg Scale RPE during cycle exercise for adult females and males.

Gender	Borg-RPE Criterion	OMNI-RPE Predictor					
		Slope	SEE	Intercept	SEE	r*	r^2
Female	Overall	1.35	0.03	5.79	0.15	0.96	0.92
	Legs	1.40	0.03	5.62	0.19	0.93	0.86
	Chest	1.38	0.03	5.70	0.14	0.94	0.88
Male	Overall	1.47	0.05	5.25	0.31	0.97	0.94
	Legs	1.45	0.05	5.50	0.34	0.94	0.88
	Chest	1.40	0.03	5.65	0.17	0.92	0.85

RPE, rating of perceived exertion; SEE, standard error of estimate.
* $P < 0.01$.

linear function of submaximal $\dot{V}O_2$ and HR responses for separate groups of young adult women and men, (b) RPE derived from the OMNI-Cycle and Borg Scales would be positively correlated, and (c) the mode specific pictorial format of the OMNI Scale could be used by adults to differentially rate the intensity of exertional signals from the legs and chest.

Concurrent validity. The first reported use of a concurrent perceptual-physiological paradigm to validate an RPE metric employed a 21 category numerical-verbal scale developed by Borg (1). Since this initial investigation, concurrent paradigms employing $\dot{V}O_2$ and HR as criterion measures have been accepted as a standard procedure when validating RPE category scales (12,19). In the present investigation, RPE derived from the OMNI-Cycle Scale distributed as a positive and linear function of $\dot{V}O_2$ and HR responses over the submaximal cycle ergometer power outputs that were studied. Response linearity held for both the undifferentiated (RPE-Overall) and differentiated (RPE-Legs and RPE-Chest) exertional responses when examined separately for the women and men subjects. Validity coefficients derived from the various regression models ranged from r = 0.81 to 0.95.

The strong positive relation between the OMNI-Cycle RPE and both $\dot{V}O_2$ and HR is consistent with previous investigations that have used concurrent paradigms to validate the Borg 6–20 Scale (1,3), Borg CR-10 Scale (11), Pittsburgh Nine Category Scale (2,17), Children's Effort Rating Table (26), Morgan's Aquatic Effort Index (9), and Fleishman's Occupational Effort Index (7). These previous experiments: (a) employed physiological ($\dot{V}O_2$, HR, lactic acid), and physical (PO, velocity, and work task) validation criteria; (b) used female and male children and adults who varied in aerobic fitness; and (c) involved weight-bearing and nonweight-bearing exercise in air and water.

The linear regression models derived in the present investigation are consistent with three previous validation paradigms that have employed the child format of the OMNI Scale. In the first of these experiments, the children's version of the OMNI-Cycle Scale was validated for use by 8- to 12-yr-old females and males performing a load-incremented cycle ergometer protocol (19). Using $\dot{V}O_2$ and HR as criterion variables, linear regression coefficients ranged from r = 0.85 to 0.94 for both the undifferentiated (RPE-Overall) and differentiated (RPE-Chest and RPE-Legs) exertional signals. Two other investigations have established concurrent validity of the OMNI Scale for use with children. Utter et al. (25) reported significant positive correlations between RPE-Overall and both $\dot{V}O_2$ and HR for 6 to 13-yr-old children performing progressive treadmill exercise. The OMNI Scale employed the walk/run pictorial format for children. Pfeiffer et al. (14) employed a unique cross-modal paradigm in which adolescent girls estimated RPE during treadmill exercise using the cycle pictorial format of the OMNI Scale. Validity coefficients between OMNI Scale RPE and percent of maximal values for $\dot{V}O_2$ and HR ranged from r = 0.82 to 0.88.

Only one previous experiment has established concurrent validity of the adult format of the OMNI Perceived Exertion Scale (23). In this investigation, the OMNI Scale was formatted with resistance exercise pictorials. Young adult women and men recreational weight lifters performed multiple sets of biceps curl and knee-extension resistance exercise. Strong positive and linear regression models were observed between total weight lifted and the RPE for both the active muscles and overall body (r = 0.79 to 0.91). In addition, OMNI Scale RPE (active muscles) was highly correlated (r = 0.87) with blood lactic acid concentration sampled during biceps curl exercise.

It was of interest in the present investigation to establish concurrent validity of the OMNI-Cycle Scale separately for the samples of women and men. Using a gender-stratified analysis, strong positive regression coefficients were found for the separate women and men subsets. These responses are consistent with previous reports of gender specific validity of the OMNI Perceived Exertion Scale for both children and adults performing cycle (19), treadmill (14,25), and resistance (23) exercise. Such gender specific validation is important given recent research interest in examining neuromotor, physiological, and performance factors that may explain similarities and/or differences in RPE between women and men (13,15,20).

Range model for category scaling. Borg's (5,6) Range Model states that category rating scales have two distinct advantages when measuring a percept in the exertional domain: (a) they provide direct intra-individual estimates of perceptual intensity relative to a fixed maximum;

and (b) they provide interindividual comparison of perceptual intensity, i.e. intersubjectivity. To satisfy these application requirements, the stimulus-response function should be reasonably linear throughout most of the measurement range. When these conditions are satisfied, RPE response linearity has direct and useful application in scaling both intra- and interindividual exertional perceptions (6). To this end, the Borg 15-Category RPE Scale was constructed to grow linearly with such criterion variables as power output, HR, and $\dot{V}O_2$ (4). The positive linear relation observed presently between RPE derived from the OMNI-Cycle Scale and selected physiological criteria is in agreement with the applications identified in Borg's Range Model of category scaling. By extension the adult OMNI-Cycle Scale is a valid perceptual metric for both intra- and interindividual comparisons of exertional responses during dynamic exercise.

Construct validity. Construct validity of the OMNI-Cycle Scale was established using the 1982 version of the Borg (6–20) Scale as the criterion metric. It was hypothesized that RPE derived from the OMNI-Cycle Scale would be positively correlated with Borg Scale RPE when perceptual estimates from both metrics were obtained during the same load-incremented cycle ergometer protocol. The findings supported this hypothesis, establishing construct validity of the OMNI-Cycle Scale. Validity coefficients between perceptual responses obtained from the two category scales ranged from $r = 0.92$ to 0.97 for RPE-Overall, RPE-Legs, and RPE-Chest.

A comparatively limited number of investigations have examined construct validity of perceived exertion category scales (2,8,10). The conditional metrics examined in these previous experiments were the Borg (6–20) Scale, Borg CR-10 Scale, Marks-Borg CR-13 Scale, and the Pittsburgh Nine-Category Scale. Criterion metrics included the Borg 21-Category Scale, Borg (6–20) Scale, a visual analog scale, and cross-modal magnitude estimation of loudness. These investigations reported modest to strong construct validity correlations ($r = 0.38–0.97$) for the various conditional RPE scales.

The construct validity coefficients observed presently for the OMNI-Cycle Scale are consistent with those described above for the various Borg Scales and the Pittsburgh Scale. The comparatively high level of construct validity observed presently indicates that the OMNI-Cycle Scale measures the same properties of an exertional percept as does the Borg (6–20) Scale when assessments are made for young adult women and men performing load-incremented cycle ergometry. Based on concurrent paradigms, the Borg (6–20) Scale is generally considered a valid metric to assess exertional perceptions over a wide range of exercise modes and metabolic rates (5). The independent and preexisting concurrent validity of the Borg (6–20) Scale strengthens the importance of the construct validity coefficients observed presently for the OMNI-Cycle Scale. It is particularly important to note that the construct validity of the OMNI-Cycle Scale held over a wide relative metabolic range during the load-incremented protocol. Validity of a category RPE scale over a wide stimulus-response range is necessary in exercise testing, prescription, and intensity self-regulation where it is expected that metabolic rate will vary from low to high levels.

One limitation to the forgoing conclusion regarding construct validity involves a potential fatigue bias in perceptual estimates, especially at higher exercise intensities. OMNI Scale RPE were measured 45–60 s after Borg Scale RPE during each exercise stage. As such, it is possible that perceptual estimates from the conditional metric could have been slightly influenced by accumulating fatigue over the final minute of the exercise stage.

Differentiated RPE. One indication of the utility of a category RPE scale is its precision in distinguishing between an anatomically regionalized perceptual signal and a total body signal when both assessments are made at approximately the same time within a defined exercise period (23). The present findings indicated that the women and men subjects were able to use the adult format of the OMNI-Cycle Scale to rate the separate intensity of exertional signals arising from the legs and chest as well as the intensity of the integrated exertional signal for the overall body. Of methodological importance is that all three ratings were estimated within a 30-s measurement period, making differentiated assessments practical during a load-incremented exercise test protocol. An RPE that is specific to the anatomical regions activated during testing can increase the precision of exercise prescription and intensity self-regulation.

Previous investigations using Borg's 6–20 and CR-10 Scales of perceived exertion consistently demonstrated that for aerobic exercise modes such as cycling and walking, the intensity of the peripheral signal arising from the involved limbs was more intense than the respiratory-metabolic signal (i.e., chest/breathing) at a given time point during submaximal exercise (16,18). The response pattern of the differentiated RPE for the legs and chest obtained presently using the OMNI-Cycle Scale was consistent with these previous reports. The RPE-Legs was higher than the RPE-Chest at each submaximal power output stage. Such responsiveness can be taken as an indication that the legs rating provided the dominant perceptual signal in shaping the total body exertional milieu during load-incremented cycle ergometry (16).

Differentiated perceptual responsiveness has been demonstrated previously for both the children and adult formats of the OMNI Perceived Exertion Scale. Using mode specific pictorials, children rated the differentiated signals arising from the legs as more intense than the differentiated chest signal (a) during progressively incremented cycle ergometer (19) and treadmill (25) exercise, (b) during cycle ergometer exercise at an intensity equivalent to the ventilatory breakpoint (21), and (c) while self-regulating intermittent cycle ergometer exercise intensities presented in ascending and descending order (22). In addition, using the resistance exercise format of the adult OMNI Scale, Robertson et al. (23) reported that women and men estimated the differentiated RPE for their active muscles to be more intense than the RPE for the overall body during both biceps curl and

knee extension exercise. When the present findings are viewed in the context of these previous reports, it can be concluded that the pictorial-verbal OMNI Scale format provides rating precision necessary to measure the intensity of differentiated exertional signals during both aerobic and resistance exercise.

CONCLUSIONS

The present findings provide both concurrent and construct evidence supporting use of the OMNI Scale by adult women and men to estimate undifferentiated and differentiated RPE during cycle exercise. This validity evidence broadens the scope of application of the OMNI perceived exertion pictorial system. When the presently validated cycle and previously validated resistance exercise formats of the Adult OMNI Scale are viewed in juxtaposition, RPE based exercise programming is possible for a wide range of aerobic and strength training protocols involving both women and men.

The strong construct validity found for the OMNI-Cycle Scale using the Borg (6–20) Scale as the criterion metric suggests that interscale RPE conversions may be possible. As an example, a general adaptation of the construct validity models for RPE-Overall indicates that OMNI-Cycle categories 0, 1, 3, 4, 6, 8 and 9 are, respectively, linked to Borg categories 6, 7, 10, 11, 14, 17, and 18. OMNI-Cycle categories 2, 5, 7, and 10 are, respectively, linked to ranges of Borg categories 8/9, 12/13, 15/16, and 19/20. It is proposed that such a RPE-Overall conversion model would allow the client and/or health-fitness practitioner to identify a target training zone using either the OMNI-Cycle or Borg (6–20) Scale and convert it to the other scale while not sacrificing prescription accuracy. Future research should explore the validity of category-by-category interscale RPE conversion between the OMNI and Borg (6–20) scales.

REFERENCES

1. BORG, G. A simple rating scale for use in physical work tests. *Kungl. Fysiografiska Sallskapets I Lund Forhandlinger*. 32:7–15, 1962.
2. BORG, G. Perceived exertion: a note on "history" and methods. *Med. Sci. Sports*. 5:90–93, 1973.
3. BORG, G. Psychological bases of perceived exertion. *Med. Sci. Sports Exerc*. 14:377–381, 1982.
4. BORG, G. Psychophysical scaling: an overview: In: Touch, temperature, and pain in health and disease: mechanisms and assessments. *Progress in Pain Research and Management*, Vol. 3. J. Boevie, P. Hansson and U. Lindblom (Eds.). Seattle, WA: IASP Press, 1994, pp. 27–39.
5. BORG, G. *Borg's Perceived Exertion and Pain Scales*. Champaign, IL: Human Kinetics, 1998, pp. 27–38.
6. BORG, G., and E. BORG. A new generation of scaling methods: level-anchored ratio scaling. *Psychologica* 28:15–45, 2001.
7. HOGAN, J. C., and E. A. FLEISHMAN. An index of the physical effort required in human task performance. *J. Appl. Psychol.* 64:197–204, 1979.
8. MARKS, L. E., G. BORG, and G. LJUNGGREN. Individual differences in perceived exertion assessed by two new methods. *Percept. Psychophys.* 34:280–288, 1983.
9. MORGAN, W. P. Utility of exertional perception with special reference to underwater exercise. *Int. J. Sport Psychol*. 32:137–161, 2001.
10. NEELY, G., G. LJUNGGREN, C. SYLVEN, and G. BORG. Comparison between the visual analogue scale (VAS) and the category ratio scale (CR-10) for the evaluation of leg exertion. *Int. J. Sports Med.* 13:133–136, 1992.
11. NOBLE, B. J., G. BORG, I. JACOBS, R. CECI, and P. KAISER. A category-ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate. *Med. Sci. Sports Exerc.* 15:6: 523–528, 1983.
12. NOBLE, B. J., and R. J. ROBERTSON. *Perceived Exertion*. Champaign, IL: Human Kinetics, 1996, pp. 4–5; 59–77.
13. O'CONNOR, P. J., M. S. POUDEVIGNE, and J. D. PASLEY. Perceived exertion to unaccustomed elbow flexor eccentric actions in women and men. *Med. Sci. Sports Exerc.* 34:862–868, 2002.
14. PFEIFFER, K. A., J. M. PIVARNIK, C. J. WOMOCK, M. J. REEVES, and R. M. MALINA. Reliability and validity of the Borg and OMNI RPE Scales in adolescent girls. *Med. Sci. Sports Exerc.* 34:2057–2061, 2002.
15. PINCIVERO, D. M., A. J. COELHO, and W. ERICKSON. Perceived exertion during isometric quadriceps contractions: a comparison between men and women. *J. Sports Med. Phys. Fitness* 40:319–326, 2000.
16. ROBERTSON, R. J., R. L. GILLESPIE, J. MCCARTHY, and K. D. ROSE. Differentiated perceptions of exertion. Part I: mode of integration of regional signals. *Percept. Mot. Skills* 49:683–689, 1979.
17. ROBERTSON, R. J., R. L. GILLESPIE, J. MCCARTHY, and K. D. ROSE. Differentiated perceptions of exertion: Part II. Relationship to local and central physiological responses. *Percept. Mot. Skills* 49:691–697, 1979.
18. ROBERTSON, R. J., and B. J. NOBLE. Perception of physical exertion: methods, mediators and applications. *Exerc. Sports Sci. Rev.* 25: 407–452, 1997.
19. ROBERTSON, R. J., F. L. GOSS, N. F. BOER, et al. Children's OMNI Scale of Perceived Exertion: mixed gender and race validation. *Med. Sci. Sports Exerc.* 32:452–458, 2000.
20. ROBERTSON, R. J., N. M. MOYNA, K. L. SWARD, N. B. MILLICH, F. L. GOSS, and P. D. THOMPSON. Gender comparison of RPE at absolute and relative physiological criteria. *Med. Sci. Sports Exerc.* 32: 2120–2129, 2000.
21. ROBERTSON, R. J., F. L. GOSS, N. F. BOER, et al. OMNI Scale perceived exertion at ventilatory breakpoint in children: response normalized. *Med. Sci. Sports Exerc.* 33:1946–1952, 2001.
22. ROBERTSON, R. J., F. L. GOSS, J. A. BELL, et al. Self-regulated cycling using the children's OMNI Scale of Perceived Exertion. *Med. Sci. Sports Exerc.* 34:1168–1175, 2002.
23. ROBERTSON, R. J., F. L. GOSS, J. RUTKOWSKI, et al. Concurrent validation of the OMNI Perceived Exertion Scale for Resistance Exercise. *Med. Sci. Sports Exerc.* 35:333–341, 2003.
24. TRAN, Z. V. Estimation sample size in repeated measures analysis of variance. In: *Measurement in Physical Education and Exercise Science (Special Issue)*, T. M. Wood (Ed.) Mahwah, NJ: Erlbaum, 1997, pp. 89–102.
25. UTTER, A. C., R. J. ROBERTSON, D. C. NIEMAN, and J. KANG. Children's Omni Scale of Perceived Exertion: walking/running evaluation. *Med. Sci. Sports Exerc.* 34:139–144, 2002.
26. WILLIAMS, J. G., R. ESTON, and B. FURLONG. Cert: a perceived exertion scale for young children. *Percept. Mot. Skills* 79:1451–1458, 1994.