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VALIDATION OF ADULT OMNI PERCEIVED EXERTION SCALES FOR ELLIPTICAL ERGOMETRY^{1,2}

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Summary

This investigation examined the validity of newly developed Adult OMNI Elliptical Ergometer Ratings of Perceived Exertion Scales. Sixty men and women performed a graded exercise test on an elliptical ergometer. Oxygen consumption (VO_2), heart rate (HR) and ratings of perceived exertion were recorded each stage from the Borg 15 Category Scale and two different OMNI scales. One scale employed an elliptical ergometer format of the OMNI Picture System of Perceived Exertion. The second scale modified verbal, numerical, and pictorial descriptors at the low end of the response range. Concurrent and construct validity were established by the positive relation between ratings of perceived exertion from each OMNI scale with VO_2 , HR and Borg Scale ratings of perceived exertion (men, $r = .94-.97$; women, $r = .93-.98$). Validity was established for both OMNI scales, indicating either metric can be used to estimate ratings of perceived exertion during partial weight bearing exercise.

Ratings of perceived exertion are defined as the subjective intensity of effort, strain, discomfort and/or fatigue that are experienced during physical exercise (Noble & Robertson, 1996). Ratings of perceived exertion can be assessed with category scales that provide a perceptual measure of exercise intensity and can aid in monitoring the progression of graded exercise tests in clinical and/or health-fitness settings. Newly developed scales must demonstrate both concurrent and construct validity to be considered a valid metric. Concurrent validity is evidenced by the concomitant increase in ratings of perceived exertion and physiological variables such as heart rate (HR) and oxygen uptake (VO_2) during load incremented exercise. Construct validity is supported by a strong positive

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correlation between ratings of perceived exertion derived from a criterion (i.e., previously validated) and conditional (i.e., new) metric.

The OMNI Picture System of Perceived Exertion was developed in the early 1990's and has been a recognized and productive part of the perceived exertion knowledge base since that time. The term OMNI is a contraction of the word *omnibus* which suggests applicability of the metric to a wide range of individuals and physical activity settings (Robertson, 2004). Therefore, a strong point of the OMNI scale is its ability to assess exertional perceptions of various population cohorts engaged in dynamic exercise modes including walking/running, stepping, cycling, and resistance exercise. Thus, a unique feature of the scale is that it employs interchanging pictorial formats that are specific to the exercise modes being performed (Robertson, Goss, Boer, Peoples, Foreman, Dabayebeh, et al., 2000; Utter, Robertson, Nieman, & Kang, 2002; Robertson, Goss, Rutkowski, Lenz, Dixon, Timmer, et al., 2003; Robertson, Goss, Dube, Rutkowski, Dupain, Brennan, et al., 2004; Utter, Robertson, Green, Suminski, McAnulty, & Nieman, 2004; Robertson, Goss, Andreacci, Dube, Rutkowski, Snee, et al., 2005; Lagally & Robertson, 2006; Nakamura, Perandini, Okuno, Borges, Bertuzzi, & Robertson, 2009). The original OMNI scale was developed for use with children of both sexes across races (Robertson, et al., 2000). The seminal investigation demonstrated that the Children's OMNI Ratings of Perceived Exertion Cycle Scale was a valid metric for assessing perceptions of exertion during cycle ergometer exercise in children. The scales verbal, numerical, and pictorial format improved upon the methodological and semantic limitations of previous ratings of perceived exertion scales (Robertson, et al., 2000).

While OMNI ratings of perceived exertion scales are considered to be valid and reliable metrics to monitor and self-regulate exercise intensity, an application limitation is evident, particularly at the lower response zone of the scale (e.g., 0–3). It is not uncommon for participants to respond with ratings of perceived exertion of “0” during low intensity exercise as the corresponding verbal descriptor is “extremely easy.” This typical response may consequently lead to a limitation when using ratings of perceived exertion as predictor variables for statistical models that estimate caloric expenditure. Weary-Smith (2007) developed a Physical Activity Index to measure the total activity load (i.e., volume of exercise $\times$ intensity of exercise) and associated caloric expenditure during varying treadmill intensities. The Physical Activity Index was calculated as the product of pedometer step count and ratings of perceived exertion estimated during treadmill walking. This index score was then used as the predictor variable in a model that estimated caloric expenditure for various walking speeds. For this prediction model to be mathematically correct, the ratings of perceived exertion response must be “1” or greater. For example, if a “0” is given as the rating response, an index score of 0 will be calculated. The index score is then used as the predictor variable in a regression model and when placed into the regression model, the “0” index score will estimate caloric expenditure at an inaccurately low level. Thus, when new verbal/pictorial formats of OMNI ratings of perceived exertion scales are developed, this inherent measurement limitation should be controlled. To address this limitation in the OMNI ratings of perceived exertion scales' format, it is suggested that minor adjustments be made to either the numerical, verbal, and/or pictorial descriptors that correspond to the lower response zones (OMNI ratings of perceived exertion = 0–3).

In recent years, the elliptical ergometer has become a popular exercise mode in health-fitness settings. The elliptical ergometer is a combination of running and cycling in its stride mechanisms. While maintaining constant contact with the pedals of the machine, participants apply force in a downward motion by alternating the exertion of each leg, leading to an elliptical motion (Green, Crews, Pritchett, Mathfield, & Hall, 2004). Usage rates of the elliptical ergometer have increased 429.5% from 1998–2007, with over 7 million

individuals employing the exercise mode for health-fitness and rehabilitation purposes (American Sports Data, Inc., 2007). Additionally, it is estimated that individuals aged 18–34 yrs comprise 42% of the total user population (American Sport Data, Inc., 2007). Previous research has indicated that elliptical ergometer exercise is associated with lower ground reaction forces compared to treadmill walking and running (Lu, Chien, & Chen, 2007). Due to the lower stress placed on the muscles and joints, the elliptical ergometer may provide a safe alternative to treadmill exercise for individuals with orthopedic limitations.

There are few studies that show evidence of cross-modal application of OMNI ratings of perceived exertion scales (Pfeiffer, Pivarnik, Womack, Reeves, & Malina, 2002; Robertson, Goss, Andreacci, Dube, Rutkowski, Snee, et al., 2005). To expand the broad-based application of the OMNI ratings of perceived exertion scale, it is important to establish a format for both adult men and women, presenting pictorial descriptors specific to the elliptical ergometer. In addition, the validity of the OMNI Picture System of Perceived Exertion following changes to the verbal descriptors and type of pictorial descriptors have not been examined. Thus, the purpose of this investigation was to establish concurrent and construct validity of Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scales using two formats, one employing an elliptical ergometer format of the OMNI Picture System of Perceived Exertion with the second employing a modified format of the Adult OMNI Elliptical Ergometer Scale of Perceived Exertion. It was hypothesized that concurrent and construct validity would be established for both Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale formats.

Method

Participants

Sixty college-aged (18–34 yrs) men ($n = 30$) and women ($n = 30$) were recruited for this investigation. Participants were mentally and physically healthy and classified as sedentary to recreationally active ($< 160 \text{ min} \cdot \text{week}^{-1}$ of activity). Participant characteristics for men and women were as follows (mean $\pm$ *SD*) age (yrs): 21.3 ± 3.3 , 22.3 ± 3.5 ; height (cm): 178.5 ± 8.0 , 166.2 ± 7.1 ; weight (kg): 73.6 ± 9.2 , 62.9 ± 7.9 ; body fat (%): 14.2 ± 3.4 , 26.3 ± 5.5 ; peak oxygen consumption ($\text{VO}_{2\text{peak}}$) ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$): 42.6 ± 6.8 , 37.4 ± 5.4 . The University of Pittsburgh Institutional Review Board approved all procedures associated with the investigation. Participants signed a written informed consent document prior to test procedures.

Procedures

All testing was conducted in the Center for Exercise and Health-Fitness Research – Human Energy Research Laboratory at the University of Pittsburgh. Participants were instructed to avoid food, tobacco, and caffeine for at least three hours prior to the testing session (American College of Sports Medicine, 2006). Participants were asked to be adequately hydrated and to not engage in exercise training, strenuous physical activity, or consume alcohol 24 hours prior to testing (American College of Sports Medicine, 2006).

Pre-test assessments—Height was recorded to the nearest .5 cm on a calibrated medical scale with attached stadiometer (D – 439, Detecto Scales, Inc., Webb City, MO). Weight was assessed to the nearest .5 kg using a bioelectrical impedance analysis scale and used the “standard” mode to assess body composition (Model TBF – 300A, Tanita Corporation of America, Inc. Skokie, IL).

Estimation trial—The investigation consisted of a single observation, cross-sectional perceptual estimation trial, employing a graded exercise test on an elliptical ergometer (EFX

546 Cross-Trainer, Precor, Inc., Woodinville, WA). The elliptical ergometer allows for manipulation of cadence, resistance, and incline of the ramp. A constant elliptical ergometer level 6 incline was maintained throughout the test. Based on pilot testing, separate protocols were designed for participants. In both sex specific protocols, cadence and/or resistance was manipulated at each two min stage. The elliptical ergometer protocols were as follows: Stage 1 – cadence (strides $\cdot$ min⁻¹): 100, 80 and resistance (level): 3, 2; Stage 2 – cadence: 120, 100 and resistance: 6, 4; Stage 3 – cadence: 140, 120 and resistance: 9, 6; Stage 4 – cadence: 140, 140 and resistance: 11, 8; Stage 5 – cadence: 140, 140 and resistance: 13, 10; Stage 6 – cadence: 140, 140 and resistance: 15, 12; Stage 7 – cadence: 140, 140 and resistance: 17, 14.

Cadence was signaled by an electronic metronome (Model XB-700, Franz Mfg. Co. Inc., New Haven, CT) and the digital display on the elliptical ergometer. The exercise test was terminated when the individual was unable to maintain cadence within 20 strides $\cdot$ min⁻¹ of the target for 10 consecutive seconds or could no longer continue due to fatigue. Holding onto the hand rails for support was not permitted unless stability was lost and participants needed to regain his or her balance. However, individuals were permitted to place their hands in a neutral position with the back of the hands against the side rails of the elliptical ergometer to maintain balance if needed.

Respiratory-metabolic and HR measurements—An open circuit respiratory-metabolic system (TrueOne 2400, ParvoMedics, Sandy, UT) measured VO_2 ($\text{l} \cdot \text{min}^{-1}$ and $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ STPD) in 15 second intervals. The last two VO_2 measurements of each stage were averaged and used in the data analyses. A standard respiratory valve (Model 2700, Hans Rudolph, Inc., Kansas City, MO) with an adult mouthpiece was used for all respiratory-metabolic measurements. The respiratory-metabolic system was calibrated before each estimation trial according to the manufacturer's specifications. A wireless monitoring system (Model FS3C, Polar Electro, Kempele, Finland) was used to measure HR (beats $\cdot$ min⁻¹) at the end of each stage of the graded exercise test.

Borg and OMNI Ratings of Perceived Exertion—Prior to the start of the estimation trial, definitions for ratings of perceived exertion, standard instructions and anchoring procedures for, a) the Borg 15 Category Perceived Exertion Scale (Borg, 1985), b) the Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale (Figure 1) and c) the Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale using a modified format (Figure 2) were read to participants. The investigator began the session by reading the following definition of ratings of perceived exertion to the individual: “The perception of physical exertion is defined as the subjective intensity of effort, strain, discomfort, and/or fatigue that you feel during exercise” (Noble & Robertson, 1996). Participants were then read standardized instructions for each of the three ratings of perceived exertion scales. Instructions for the Borg 15 Category Scale and the OMNI Elliptical Ergometer Scales used modified versions of previously published instruction sets (Borg, 1998; Robertson, et al., 2004; Utter, et al., 2004). The full instruction sets for the modified Borg scale and both OMNI scales have been described previously (Mays, 2009). Briefly, the term “elliptical ergometer” was substituted in place of other modalities throughout the instruction sets, such as “cycle ergometer” or “treadmill”. Memory anchoring was employed to establish low and high anchors (Robertson, et al., 2000). The instructions and anchoring procedures for the three scales were presented in a counterbalanced order. Ratings of perceived exertion for the overall body, legs and chest/breathing were estimated at 1:00 of each 2:00 min stage during the graded exercise test, with the three scales in full view throughout the exercise test. Participants responded by pointing to their ratings of perceived exertion on the scale displayed in front of them.

Statistical Analyses

Oxygen consumption and HR were compared separately with ratings of perceived exertion using correlation analyses accounting for clustering (stages nested within subjects) throughout the wide range of exercise intensities from the graded exercise test. Data were screened for univariate and multivariate outliers between ratings of perceived exertion and each of the physiological variables. Correlation analyses accounting for clustering were also used to determine the relation between ratings of perceived exertion determined from the Elliptical Ergometer Scales and the Borg 15 Category Scale. Data were also examined to determine the number of participants that estimated perceived exertion as “0” from the new OMNI ratings of perceived exertion scales and “6” from the Borg 15 Category scale in the first stage of the graded exercise test. Tests of marginal homogeneity were performed with McNemar’s test to determine differences between frequency data responses. Significance was set at $\alpha = .05$. Statistical analyses were performed with the Statistical Package for the Social Sciences (Version 16.0, SPSS Inc., Chicago, IL).

Results

Concurrent Validity

Listed in Table 1 are means $\pm$ *SD* for ratings of perceived exertion and selected physiological variables during submaximal elliptical ergometer exercise for men and women participants. It was determined from scatterplots between physiological variables and ratings of perceived exertion for each test stage that one woman participant was an outlier and therefore excluded from the analyses. The relation between ratings of perceived exertion for the overall body, legs and chest/breathing from both OMNI ratings of perceived exertion scales and VO_2 and HR were examined separately to establish concurrent validity. Results of correlational analyses are presented in Table 2. The analysis demonstrated a very strong relation (men, $r = .94-.95$ and women, $r = .93-.95$) between ratings of perceived exertion for the overall body, legs and chest/breathing from the Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale and VO_2 ($\text{l} \cdot \text{min}^{-1}$ and $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). Ratings of perceived exertion for the overall body, legs and chest/breathing derived from the modified format Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale also exhibited a very strong relation with VO_2 ($\text{l} \cdot \text{min}^{-1}$ and $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) (men, $r = .94-.95$ and women, $r = .93-.95$). Additionally, a very strong positive linear relation was exhibited between ratings of perceived exertion for the overall body, legs and chest/breathing from the Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale with HR (men, $r = .96-.96$ and women, $r = .96-.97$). Ratings of perceived exertion for the overall body, legs and chest/breathing from the modified format scale also demonstrated a very strong relation with HR (men, $r = .95-.95$ and women, $r = .97-.97$).

Construct Validity

The relations between differentiated and undifferentiated ratings of perceived exertion derived from the two OMNI scales and from the Borg 15 Category Scale were examined throughout the wide range of exercise intensities to establish construct validity. The pooled within-subjects correlations accounting for clustering indicated the relation of ratings of perceived exertion for the overall body, legs and chest/breathing between the Borg 15 Category Scale and the Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale were very strong (men: $r = .96, .97$ and $.97$; women: $r = .98, .98$ and $.98$, respectively). In addition, the relation between overall body, legs and chest/breathing ratings of perceived exertion derived from the Borg 15 Category Scale and the modified format Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale were very strong (men: $r = .96, .97$ and $.97$; women: $r = .97, .97$ and $.97$, respectively).

Frequency of “0” Response

Figure 3 and Figure 4 depict differentiated and undifferentiated frequency data for participants that responded with a “0” from the OMNI ratings of perceived exertion scales and a “6” from the Borg 15 Category Scale during the first stage of the graded exercise test for both men and women. There were no differences among the number of participants who responded with ratings of perceived exertion of “0” for the OMNI ratings of perceived exertion scales and “6” on the Borg Scale for ratings of perceived exertion for the overall body, legs and chest/breathing for both men and women, $ps > .05$.

Discussion

The primary purpose of this investigation was to examine concurrent and construct validity of an Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale and a modified format of the OMNI Picture System of Perceived Exertion for men and women. The validity of new and modified scales should be examined to ensure responses are concomitant with physiological variables and measure the same exertional precept as previously validated scales. Additionally, validating OMNI ratings of perceived exertion scales for use in partial weight bearing exercise has practical implications when used in health-fitness settings.

Concurrent Validity

Concurrent validation studies have been used extensively in the development of the OMNI Picture System of Perceived Exertion for children and adults (Robertson, et al., 2000; Utter, et al., 2002; Robertson, et al., 2003; Robertson, et al., 2004; Utter, et al., 2004; Robertson, Goss, Andreacci, Dube, Rutkowski, Frazee, et al., 2005; Robertson, Goss, Andreacci, Dube, Rutkowski, Snee, et al., 2005; Roemmich, Barkley, Epstein, Lobarinas, White, & Foster, 2006; Nakamura, et al., 2009). In the present investigation, ratings of perceived exertion increased concomitantly with metabolic (e.g., VO_2) and circulatory (e.g., HR) responses. The strong, positive relation between differentiated and undifferentiated ratings of perceived exertion from both elliptical ergometer scales and the physiological variables (i.e., HR, VO_2) (men, $r = .94-.96$; women, $r = .93-.97$) provided evidence that ratings of perceived exertion derived from the Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scales are valid indicators of exercise intensities from low to high levels. The findings of this investigation are in agreement with the basic concepts of Borg’s Effort Continua and Borg’s Range Models which indicate perceptual responses from the Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scales provide much of the same type of information concerning the intensity of the exercise as the physiological responses (Noble & Robertson, 1996; Borg, 1998; Robertson, 2001; Robertson, et al., 2004).

Construct Validity

Construct validity is evidenced by a strong positive correlation between a criterion and conditional metric. In the present investigation, the criterion metric was the Borg 15 Category Scale with the conditional metrics being the Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale and the Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale using a modified format. Construct validation of OMNI Ratings of Perceived Exertion scales for use in clinical and health-fitness settings has been demonstrated in previous investigations (Robertson, et al., 2004; Utter, et al., 2004; Robertson, Goss, Andreacci, Dube, Rutkowski, Snee, et al., 2005; Lagally & Robertson, 2006; Roemmich, et al., 2006; Nakamura, et al., 2009). The present findings established that differentiated and undifferentiated perceptual responses from the newly developed OMNI ratings of perceived exertion scales and the Borg 15 Category Scale were strongly correlated (men, $r = .96-.98$; women, $r = .97-.98$). Thus, the newly developed OMNI ratings of

perceived exertion scales measured the same properties of the exertional precept as the Borg 15 Category Scale.

Modifications to the OMNI Picture System of Perceived Exertion

The rationale for developing a modified version of the OMNI Picture System of Perceived Exertion was its potential use in prediction indices such as the Physical Activity Index (Weary-Smith, 2007). Additionally, the Exercise Discomfort Index was developed for children to determine the discomfort associated with progressively loaded aerobic exercise (Kane, Robertson, Fertman, McConnaha, Nagle, Rabin, et al., 2010). The Exercise Discomfort Index was calculated as the product of ratings of perceived exertion and leg muscle hurt. Similar to the Physical Activity Index, if a rating of perceived exertion of “0” is estimated by the participant, an inaccurately low Exercise Discomfort Index value will result. The modified format Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale replaced the “extremely easy” verbal descriptor with the term “rest.” It was reasoned that there could be interindividual differences when interpreting “extremely easy” levels of exertion at the lower end of the response range. For example, a healthy young adult who is resting and not performing exercise or physical activity could interpret the intensity as “extremely easy” since “rest” is not a rating option. However, when exercising at a low intensity (e.g., first stage of an exercise test, walking at a slow pace) the same individual could interpret the intensity as “extremely easy” and rate their exertion as “0.” Thus, physiological variables such as VO_2 , HR and caloric expenditure would be higher than resting values, but “0” could be the perceptual response given by the participant at rest and during exercise. When used in prediction models such as the Physical Activity Index, inaccurate predictions of caloric expenditure would occur. In the modified format Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale, the “0” was repositioned to be below the level portion of the response gradient. The verbal descriptor “rest” was placed below the “0” numerical category, with a newly developed “rest” pictorial. Additionally, the instructions for the scale were changed to specifically describe the “rest” pictorial (Mays, 2009). The strong relation between the physiological (i.e., VO_2 and HR) and perceptual variables throughout the graded exercise test (men, $r = .94-.95$ and $r = .95-.95$; women, $r = .93-.95$ and $r = .96-.97$) suggests that changes to the low perceptual response zone of the scale did not negatively affect concurrent validity. Additionally, the modified format scale demonstrated construct validity, as the relation between ratings of perceived exertion for the overall body, legs and chest/breathing with Borg ratings of perceived exertion were high (men, $r = .96-.97$; women, $r = .97$).

It should also be noted that Borg modified the original 6–20 category scale at the low response zone (Borg, 1985). The artificial “zero” or starting point, “6,” was changed to “no exertion at all.” In the older version of the scale there was no verbal expression linked to the first number category (Borg, 1971). The changes to the modified format OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale was conceptually similar to the modifications Borg made to the original 15 Category Scale (Borg, 1998), and suggests that minor changes to the OMNI Picture System of Perceived Exertion do not negatively affect concurrent or construct validity. The frequency of participants responding with a “6” and “0” for differentiated and undifferentiated perceived exertion did not significantly differ for the Borg Scale (2 men; 4 women) or the modified format OMNI ratings of perceived exertion scale (2 men; 3–4 women) when compared to the Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale (3–5 men; 5–8 women). However, these findings suggest that there may be intra- and interindividual interpretations of the “extremely easy” verbal descriptor. Because of the potential use of ratings of perceived exertion in calculating caloric expenditure indices, new strategies are needed when designing OMNI RPE scales, as several participants interpreted the first stage of the graded exercise test as “rest” and “no

exertion at all” regardless of the changes to the scale and instructional set. Novel instruction and anchoring strategies may need to be developed for educating participants prior to using OMNI ratings of perceived exertion scales with “0” as the first numerical descriptor. Future studies should also examine the validity of different scale formats across the entire perceptual response range, particularly adjusting the low end of the response zone (e.g., placement and number of verbal, numerical and pictorial descriptors). The validity of an exercise only, 10 numerical category format, such as a 1–10 response range without “rest” verbal and pictorial descriptors may improve the metric properties of the OMNI Picture System of Perceived Exertion.

This study highlights several additional areas of research that could be explored in the field of perceived exertion. Because there are limited data on the cross-modal application of OMNI ratings of perceived exertion scales (Robertson, 2001; Pfeiffer, et al., 2002; Robertson, Goss, Andreacci, Dube, Rutkowski, Snee, et al., 2005), future research should examine applications of OMNI ratings of perceived exertion scales across different modalities such as weight bearing, non-weight bearing, and partial weight bearing exercise. Additionally, the current investigation used an elliptical ergometer designed for movement of the legs only. There are a number of commercially available elliptical ergometers in health-fitness settings which may use both arms and legs as well as different gait cycles and striding mechanisms. Thus, future investigations should examine ratings of perceived exertion from the newly developed OMNI scales using different elliptical ergometer models, as the scales are currently applicable only to elliptical ergometers that allow for leg movement only.

In conclusion, the conceptual basis for the current study was to develop valid OMNI ratings of perceived exertion scales for use during elliptical ergometer exercise. Participants in this investigation estimated differentiated and undifferentiated perceptions of exertion that correlated strongly with physiological measures. Thus, there is practical application of the newly developed Adult OMNI Elliptical Ergometer Scales of Perceived Exertion in health-fitness settings for individualized prescription of optimal exercise intensity. The findings from the present investigation are important for improving upon the methodological and semantic components of ratings of perceived exertion scales.

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References

- American College of Sports Medicine. ACSM’s Guidelines for Exercise Testing and Prescription. 7. Baltimore, MD: Lippincott Williams and Wilkins; 2006.
- American Sports Data. SuperStudy® of Sports Participation. Vol. 1. American Sports Data, Inc; New York: 2007.
- Borg, G. The perception of physical performance. In: Shepard, RJ., editor. *Frontiers of fitness*. Springfield, IL: Charles C. Thomas; 1971.
- Borg, G. An introduction to Borg’s RPE-scale. Ithaca, NY: Movement; 1985.
- Borg, G. Borg’s perceived exertion and pain scales. Champaign, IL: Human Kinetics; 1998.
- Green JM, Crews TR, Pritchett RC, Mathfield C, Hall L. Heart rate and ratings of perceived exertion during treadmill and elliptical exercise training. *Perceptual and Motor Skills*. 2004; 98:340–348. [PubMed: 15058894]
- Kane I, Robertson RJ, Fertman CI, McConnaha WR, Nagle EF, Rabin BS, Rubinstein EN. Predicted and actual exercise discomfort in middle school children. *Medicine and Science in Sports and Exercise*. 2010; 42:1013–1021. [PubMed: 19996994]

- Lagally KM, Robertson RJ. Construct validity of the OMNI resistance exercise scale. *Journal of Strength and Conditioning Research*. 2006; 20:252–256. [PubMed: 16686549]
- Lu TW, Chien HL, Chen HL. Joint loading in the lower extremities during elliptical exercise. *Medicine and Science in Sports and Exercise*. 2007; 39:1651–1658. [PubMed: 17805099]
- Mays, RJ. Published doctoral dissertation. University of Pittsburgh; PA: 2009. Validation of Adult OMNI Perceived Exertion Scales for Elliptical Ergometry.
- Nakamura FY, Perandini LA, Okuno NM, Borges TO, Bertuzzi RC, Robertson RJ. Construct and concurrent validation of OMNI-Kayak rating of perceived exertion scale. *Perceptual and Motor Skills*. 2009; 108:744–758. [PubMed: 19725310]
- Noble, BJ.; Robertson, RJ. Perceived Exertion. Champaign, IL: Human Kinetics; 1996.
- Pfeiffer KA, Pivarnik JM, Womack CJ, Reeves MJ, Malina RM. Reliability and validity of the Borg and OMNI rating of perceived exertion scales in adolescent girls. *Medicine and Science in Sports and Exercise*. 2002; 34:2057–2061. [PubMed: 12471316]
- Robertson RJ. Exercise testing and prescription using RPE as a criterion variable. *International Journal of Sport Psychology*. 2001; 32:177–188.
- Robertson, RJ. The OMNI Picture System of Perceived Exertion. In: Bahrke, MS., editor. *Perceived Exertion for Practitioners: Rating Effort with the OMNI Picture System*. Champaign, IL: Human Kinetics; 2004.
- Robertson RJ, Goss FL, Andreacci JL, Dube JJ, Rutkowski JJ, Frazee KM, Aaron DJ, Metz KF, Kowallis RA, Snee BM. Validation of the Children's OMNI-Resistance Exercise Scale of perceived exertion. *Medicine and Science in Sports and Exercise*. 2005; 37:819–826. [PubMed: 15870636]
- Robertson RJ, Goss FL, Andreacci JL, Dube JJ, Rutkowski JJ, Snee BM, Kowallis RA, Crawford K, Aaron DJ, Metz KF. Validation of the children's OMNI RPE scale for stepping exercise. *Medicine and Science in Sports and Exercise*. 2005; 37:290–298. [PubMed: 15692326]
- Robertson RJ, Goss FL, Boer NF, Peoples JA, Foreman AJ, Dabayebeh IM, Millich NB, Balasekaran G, Riechman SE, Gallagher JD, Thompkins T. Children's OMNI scale of perceived exertion: mixed gender and race validation. *Medicine and Science in Sports and Exercise*. 2000; 32:452–458. [PubMed: 10694131]
- Robertson RJ, Goss FL, Dube J, Rutkowski J, Dupain M, Brennan C, Andreacci J. Validation of the adult OMNI scale of perceived exertion for cycle ergometer exercise. *Medicine and Science in Sports and Exercise*. 2004; 36:102–108. [PubMed: 14707775]
- Robertson RJ, Goss FL, Rutkowski J, Lenz B, Dixon C, Timmer J, Frazee K, Dube J, Andreacci J. Concurrent validation of the OMNI perceived exertion scale for resistance exercise. *Medicine and Science in Sports and Exercise*. 2003; 35:333–341. [PubMed: 12569225]
- Roemmich JN, Barkley JE, Epstein LH, Lobarinas CL, White TM, Foster JH. Validity of PCERT and OMNI walk/run ratings of perceived exertion. *Medicine and Science in Sports and Exercise*. 2006; 38:1014–1019. [PubMed: 16672857]
- Utter AC, Robertson RJ, Green JM, Suminski RR, McAnulty SR, Nieman DC. Validation of the Adult OMNI Scale of perceived exertion for walking/running exercise. *Medicine and Science in Sports and Exercise*. 2004; 36:1776–1780. [PubMed: 15595300]
- Utter AC, Robertson RJ, Nieman DC, Kang J. Children's OMNI Scale of Perceived Exertion: walking/running evaluation. *Medicine and Science in Sports and Exercise*. 2002; 34:139–144. [PubMed: 11782659]
- Weary-Smith, KA. Published doctoral dissertation. University of Pittsburgh; PA: 2007. Validation of the Physical Activity Index (PAI) as a measure of total activity load and total kilocalorie expenditure during submaximal treadmill walking.

Figure 1.
Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale

Figure 2.
Adult OMNI Ratings of Perceived Exertion Elliptical Ergometer Scale using a modified
format of the OMNI Picture System of Perceived Exertion

Figure 3.

Frequency distribution of low perceptual responses – Men; RPE = ratings of perceived exertion; EE = Elliptical Ergometer

Figure 4.

Frequency distribution of low perceptual responses – Women; RPE = ratings of perceived exertion; EE = Elliptical Ergometer

Table 1

Descriptive responses for ratings of perceived exertion and selected physiological variables during submaximal elliptical ergometer exercise (mean $\pm$ SD)

Variable	Stage 1 * (n=30; 29)	Stage 2 (n=30; 29)	Stage 3 (n=30; 29)	Stage 4 (n=27; 28)	Stage 5 (n=17; 25)	Stage 6 (n=4; 14)	Stage 7 (n=1; 2)
Adult OMNI RPE EE Scale							
Men							
O	(1.5) (1.0)	3.1 (1.1)	5.2 (1.3)	7.0 (1.6)	8.0 (1.3)	8.8 (1.0)	10.0
L	2.2 (1.5)	3.8 (1.5)	6.1 (1.6)	7.7 (1.4)	8.5 (1.1)	9.0 (.8)	10.0
C	1.5 (1.0)	3.0 (1.2)	5.2 (1.4)	7.0 (1.3)	8.2 (1.0)	9.3 (1.0)	10.0
Women							
O	1.1 (1.0)	2.4 (1.2)	3.9 (1.4)	5.6 (1.3)	7.4 $\pm$ 1.3	8.9 (.7)	10.0 (.0)
L	1.5 (1.3)	2.9 (1.5)	4.6 (1.4)	6.1 (1.5)	7.5 $\pm$ 1.3	8.8 (.9)	10.0 (.0)
C	1.2 (1.0)	2.4 (1.2)	4.1 (1.4)	5.7 (1.2)	7.5 $\pm$ 1.1	9.0 (.7)	10.0 (.0)
Modified Format OMNI RPE Scale							
Men							
O	1.8 (.9)	3.3 (1.3)	5.3 (1.2)	7.1 (1.5)	8.0 (1.3)	9.0 (.8)	10.0
L	2.3 (1.5)	4.0 (1.5)	6.1 (1.4)	7.7 (1.5)	8.6 (1.1)	9.0 (.8)	10.0
C	1.7 (.8)	3.1 (1.2)	5.3 (1.2)	7.0 (1.5)	8.0 (1.2)	8.8 (1.0)	10.0
Women							
O	1.2 (.9)	2.6 (1.1)	3.8 (1.4)	5.8 (1.3)	7.4 (1.3)	9.1 (.6)	10.0 (.0)
L	1.6 (1.2)	2.9 (1.3)	4.5 (1.6)	6.1 (1.5)	7.6 (1.4)	8.8 (.9)	10.0 (.0)
C	1.4 (1.0)	2.6 (1.2)	4.0 (1.5)	5.7 (1.2)	7.5 (1.1)	9.0 (.7)	10.0 (.0)
Borg RPE							
Men							
O	8.2 (1.4)	10.2 (1.9)	12.9 (1.5)	15.6 (2.3)	16.7 (1.9)	17.8 (1.0)	19.0
L	8.6 (1.7)	11.0 (2.2)	13.9 (1.8)	16.1 (2.2)	17.2 (1.7)	18.0 (1.2)	19.0
C	8.1 (1.5)	10.1 (1.6)	12.8 (1.4)	15.6 (2.1)	16.6 (1.7)	17.8 (1.0)	19.0
Women							
O	7.2 (.9)	9.1 (1.8)	10.8 (2.0)	12.8 (1.6)	15.4 (1.8)	17.8 (1.2)	20.0 (.0)
L	7.6 (1.5)	9.4 (2.0)	11.5 (2.3)	13.3 (2.0)	15.3 (2.1)	17.8 (1.6)	20.0 (.0)
C	7.3 (1.0)	9.0 (1.7)	10.8 (1.9)	12.7 (1.7)	15.5 (2.0)	17.9 (1.2)	20.0 (.0)

Variable	Stage 1 [*] (n=30; 29)	Stage 2 (n=30; 29)	Stage 3 (n=30; 29)	Stage 4 (n=27; 28)	Stage 5 (n=17; 25)	Stage 6 (n=4; 14)	Stage 7 (n=1; 2)
VO_2 (l · min ⁻¹)							
Men	1.3 (.1)	1.5 (.2)	2.2 (.2)	2.7 (.2)	3.2 (.2)	3.7 (.3)	4.1
Women	.9 (.1)	1.0 (.1)	1.2 (.1)	1.6 (.1)	2.1 (.1)	2.5 (.2)	3.1 (.1)
VO_2 (ml · kg ⁻¹ · min ⁻¹)							
Men	18.4 (2.1)	21.2 (1.9)	29.8 (2.6)	35.8 (2.9)	42.6 (4.1)	47.7 (2.2)	53.0
Women	14.8 (2.0)	16.2 (2.0)	19.3 (2.2)	26.1 (2.8)	32.6 (3.5)	38.6 (4.0)	45.2 (1.0)
% $\text{VO}_{2\text{peak}}$							
Men	44.1 (8.2)	50.9 (10.2)	71.5 (12.7)	83.8 (11.6)	92.0 (7.9)	95.5 (4.0)	96.2
Women	40.2 (8.2)	43.8 (8.9)	52.6 (10.0)	70.4 (10.5)	85.4 (9.0)	95.5 (4.9)	95.8 (3.0)
HR (beats · min ⁻¹)							
Men	120 (13.8)	137 (16.7)	162 (15.1)	179 (13.0)	189 (12.2)	193 (13.6)	183
Women	115 (14.7)	126 (16.6)	143 (18.0)	165 (14.5)	179 (12.1)	190 (9.5)	192 (.0)

* sample size for men and women each test stage;

RPE = ratings of perceived exertion; EE = elliptical ergometer; O = overall body; L = legs; C = chest/breathing; VO_2 = oxygen consumption; HR = heart rate; $\text{VO}_{2\text{peak}}$ = peak oxygen consumption

Table 2

Concurrent validation – Relation between physiological variables and OMNI RPE

Sex	Criterion	RPE	Adult OMNI RPE EE Scale	Modified Format OMNI RPE Scale
			r^*	r^*
Men	VO ₂ (l · min ⁻¹)	O	.95	.94
		L	.95	.95
		C	.95	.94
	VO ₂ (ml · kg ⁻¹ · min ⁻¹)	O	.95	.94
		L	.95	.95
		C	.95	.94
	HR (beats · min ⁻¹)	O	.96	.95
		L	.96	.95
		C	.96	.95
Women	VO ₂ (l · min ⁻¹)	O	.95	.95
		L	.93	.93
		C	.94	.94
	VO ₂ (ml · kg ⁻¹ · min ⁻¹)	O	.94	.94
		L	.93	.93
		C	.94	.94
	HR (beats · min ⁻¹)	O	.97	.97
		L	.97	.97
		C	.96	.96

*
 $ps < .001$;VO₂ = oxygen consumption; HR = heart rate; RPE = ratings of perceived exertion; EE = Elliptical Ergometer; O = overall body; L = legs; C = chest/breathing