Concurrent Validation of the OMNI Perceived Exertion Scale for Resistance Exercise

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ABSTRACT

ROBERTSON, R. J., F. L. GOSS, J. RUTKOWSKI, B. LENZ, C. DIXON, J. TIMMER, K. FRAZEE, J. DUBE, and J. ANDREACCI. Concurrent Validation of the OMNI Perceived Exertion Scale for Resistance Exercise. *Med. Sci. Sports Exerc.*, Vol. 35, No. 2, pp. 333–341, 2003. **Purpose:** Concurrent validity of the newly developed OMNI-Resistance Exercise Scale (OMNI-RES) of perceived exertion was examined for 18- to 30-yr-old women ($N = 20$) and men ($N = 20$) performing biceps curl (BC) and knee extension (KE) exercise. **Methods:** The criterion variables were total weight lifted (Wt_{tot}) determined separately for women and men during BC and KE, and blood lactic acid concentration ([Hla]) determined for a combined female ($N = 10$) and male ($N = 10$) subset during BC. Subjects performed three separate sets of 4, 8, and 12 repetitions for BC and KE at 65% one-repetition maximum. Rating of perceived exertion for the active muscles (RPE-AM) was measured during the mid and final repetition and RPE for the overall body (RPE-O) during the final repetition. **Results**: For both female and male groups across the three sets: (a) RPE-AM ranged from 3.6 to 8.2 for BC and 5.1 to 9.6 for KE and (b) RPE-O ranged from 2.4 to 6.7 for BC and 4.2 to 7.6 for KE. Positive linear regressions ranged from $r = 0.79$ to 0.91 ($P < 0.01$) between Wt_{tot} and RPE-AM (mid), RPE-AM (final), and RPE-O for both BC and KE in both sex groupings. A positive ($P < 0.01$) linear regression was found between [Hla] and RPE-AM (final) ($r = 0.87$) during BC. RPE did not differ between women and men at any measurement point within each set for BC and KE. RPE-AM (final) was greater ($P < 0.01$) than RPE-O in the three sets of BC and KE. **Conclusion:** Findings provided concurrent validation of the OMNI-RES to measure RPE for the active muscle and overall body in young recreationally trained female and male weight lifters performing upper- and lower-body resistance exercise. **Key Words:** DIFFERENTIATED RPE, SEX EFFECT, BLOOD LACTIC ACID, TOTAL WEIGHT LIFTED

Ratings of perceived exertion (RPE) have been assessed for female and male subjects performing concentric and eccentric resistance exercise paradigms that varied the total volume of weight lifted (i.e., volume loading), percent of one repetition maximum muscular action (% 1-RM; i.e., intensity loading), and rest periods between separate sets and exercises (1,6–8,14,17–19,26,27). These resistance exercise paradigms: (a) established force-effort psychophysical functions using torque, electromyography (EMG), and magnetic resonance imaging (MRI) as criterion measures (5,10,19,21); (b) examined blood lactic acid concentration ([Hla]), HR, EMG, epinephrine, norepinephrine, cortisol, beta-endorphins, and pain as possible physiological mediators of the effort sense (1,4,7,8,11,13,17–19,27,28); and (c) used RPE to prescribe muscular strength, endurance and hypertrophic training programs, and to track conditioning progress (1–3,9). In these foregoing investigations, RPE was assessed using the original and modified versions of Borg's 15-category scale and Borg's Category-Ratio (CR-10) scale.

The present investigation examined concurrent validity of the newly developed OMNI-Resistance Exercise Scale (OMNI-RES) to measure RPE in young adult female and male subjects performing separate upper- and lower-body exercise (Fig. 1). The term OMNI is a contemporary contraction of the word *omnibus.* Used in the context of perceived exertion metrics, OMNI means a RPE scale having broadly generalizable properties. The scale has both verbal and mode specific pictorial descriptors distributed along a comparatively narrow numerical response range, 0–10. The pictorial descriptors depicting a "weight lifter" are positioned along the response range consonant with corresponding verbal descriptors. The scale is presented in a visually discernible exertional format, i.e., an intensity gradient.

During aerobic exercise, RPE is often anatomically differentiated to the involved body regions (i.e., arms, legs, or chest) and is also assessed as an undifferentiated signal from the overall body (15; pp. 99–100). For modes such as cycling and walking, the intensity of the various differenti-

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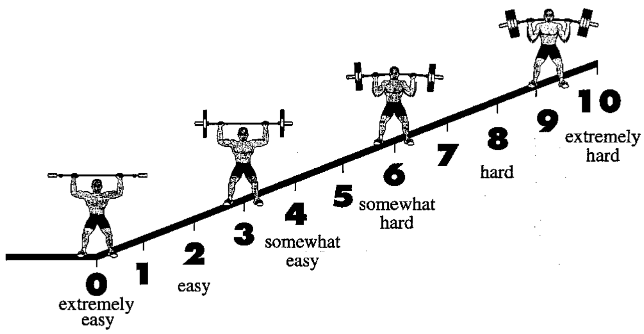

FIGURE 1—OMNI-Resistance Exercise Scale (OMNI-RES) of perceived exertion.

ated perceptual signals usually differs from that of the undifferentiated signal at a given time point during submaximal exercise (23). Some investigations involving resistance exercise have measured only the overall RPE (1,7,8,10,17,27,29) with perceptual estimates primarily recorded during the postexercise recovery period (2,29). However, a number of other investigations have differentiated RPE to active muscles during resistance exercise (2–5,11,12,18,20–22), providing anatomic specificity to the perceptual response. Using this rationale, the present experiment examined the sensitivity of the OMNI-RES to differentially measure RPE arising from active muscle groups as well as the overall body where the total weight lifted (Wt_{tot}) increased over separate sets of upper- and lower-body isotonic resistance exercise.

The majority of previous investigations that examined RPE responses to resistance exercise employed single-sex subject samples. Of these investigations, most involved male subjects whose resistance exercise experience ranged from novice/recreational (1,4,6,17,18,25–27) to well-trained (7,13) weight lifters. A few investigations employed mixed-sex samples to establish force-effort psychophysical functions and/or identify neurophysiological pathways for the effort-sense often equating female and male subjects on the basis of age and resistance exercise training status (4,12,14,22,29). Some of these experimental paradigms also evaluated the possible role of the subject's sex in mediating the intensity of RPE (4,20,22). Given that a sex main effect can be of interest in perceived exertion research, it is important to establish that the metric employed in such experimentation is valid for use by both female and male subjects performing a specified resistance exercise dosage. As such, the present investigation employed young adult female and male recreationally active weight lifters as experimental subjects. It was anticipated that the OMNI-RES would be valid for the separate female and male samples. Such findings would demonstrate the utility of the OMNI-RES for use in resistance exercise research and programming that involves a mix of female and male participants.

The purpose of this investigation was to examine concurrent validity of the newly developed OMNI-RES for use by female and male adults during upper- and lower-body isotonic resistance exercise. It was hypothesized that for both the women and men, RPE for the active muscles (RPE-AM) and RPE for the overall body (RPE-O) would demonstrate a positive correlation with Wt_{tot} and blood [Hla], establishing concurrent validity of the OMNI-RES. Additionally, it was hypothesized that RPE-AM would be more intense than RPE-O during each set of upper- and lower-body resistance exercise for both sex groupings.

METHODS

Subjects

Forty (20 female and 20 male) clinically normal subjects participated in the investigation. The characteristics (mean ± SD) of the female and male subjects were respectively: age (yr) 21.35 ± 3.67, 21.55 ± 2.06; height (cm) 162.16 ± 4.62, 178.44 ± 6.86; weight (kg) 58.17 ± 6.78, 82.76 ± 9.68; fat (%) 22.59 ± 4.51, 13.01 ± 2.86; 1-RM (kg) biceps curl 18.72 ± 4.88, 46.69 ± 9.64; and 1-RM (kg) knee extension 43.01 ± 11.70, 96.25 ± 21.91. Subjects were classified as recreational weight trainers who had participated in resistance exercise training and/or classes at least twice per week over the previous 6 months. The subjects were volunteers who did not have clinical, neuromotor, or cognitive limitations to exercise testing. They were instructed to: (a) not undertake resistance and/or aerobic exercise 48 h before each exercise trial; (b) not eat for 4 h before exercise testing; and (c) not use alcohol, caffeine, or nicotine for at least 24 h before testing. During testing, each subject wore a short-sleeve shirt, shorts, and exercise shoes. Exercise trials were performed at the same time of the day and were separated by 48–72 h. Risks and benefits of the investigation were explained, and subjects gave their written consent to participate. The experimental protocol was approved by the University of Pittsburgh Institutional Review Board.

Sample size was determined for the statistical power required to demonstrate a three factor (site × set × sex) 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 female and 16 male subjects were required to test both the main and interaction effects (30). The within subject factor in the power calculation assumed an intraclass correlation of r = 0.70 over the repeated measures.

Experimental Design

The investigation used a cross-sectional, perceptual estimation design consisting of one orientation and three experimental trials. All subjects undertook the orientation trial first followed by the three experimental trials. One set of biceps curl exercise and one set of knee extension exercise was performed during each of the three experimental trials. Therefore, two sets were performed during a trial with one trial administered for a given laboratory session. Using a counterbalanced assignment, one half of the female group and one half of the male group performed the biceps curl followed by the knee extension exercise. The remaining half of each group performed the opposite order within a given trial, i.e., knee extension then biceps curl. Three sets consisting separately of 4, 8, and 12 repetitions were performed for both the biceps curl and knee extension exercises. The three sets (i.e., 4, 8, and 12 repetitions) for the biceps curl and the three sets for the knee extension exercise were presented in counterbalanced order over the three experimental trials. This was done by establishing an inclusive counterbalanced schedule for the three repetitions/sets within a given exercise (i.e., biceps curl and knee extension) and then assigning a separate subject to each sequence.

Correlations between RPE and Wt_{tot} during biceps curl and knee extension exercise and between RPE and blood [Hla] during biceps curl exercise were determined to establish concurrent scale validity by using a volume loading resistance protocol. In this protocol, relative exercise intensity (i.e., 65% 1-RM) was the same for three separate exercise sets while exercise repetitions increased over sets. As such, Wt_{tot} increased with accumulating repetitions within each set and also varied across the three successive sets for a given exercise. A volume loading protocol at 65% 1-RM intensity was used because it has been shown to produce: (a) a wide range of Wt_{tot} within and between exercise sets for both upper- and lower-body resistance exercises (2,13,17,27), and (b) large increases in blood [Hla] above resting levels during isotonic resistance exercise (1,7,8,13,17,27). Large response ranges for both Wt_{tot} and [Hla] were requisite for correlational analyses of the type used to establish concurrent scale validity.

Orientation Trial

During the orientation trial, the purpose of the experiment was explained to the subjects, descriptive characteristics were determined, and resistance exercise training status was documented. Body height (cm) and weight (kg) were determined with a Detecto-Medic Scale and attached stadiometer (Detecto Scales, Inc., Brooklyn, NY) and body fat (%) estimated by bioelectrical impedance analysis (Tanita Body Composition Analysis, Arlington Heights, IL). Instructions and anchoring procedures for the OMNI-RES were then presented to the subject. The exercise techniques and equipment for the biceps curl and knee extension exercise were explained, and a 1-RM was determined for both exercises using the procedures described by Gearhart et al. (2). Finally, a supervised practice session to standardize “lifting technique” was undertaken. During this practice session, the weights equivalent to 65% of the separately determined 1-RM for the biceps curl and knee extension exercise were calculated and recorded for each subject. The appropriate seat adjustment on the knee extension exercise machine was also determined and recorded.

Experimental Trials

Biceps curl. The weight for the biceps curl exercise was 65% 1-RM for that exercise. One half of the weight was attached to each end of an Olympic curl bar (Power Systems, Knoxville, TN). Magnetic Plate Mates (Bodytrend, Carpenteria, CA) were used to adjust the weight to the nearest 0.57 kg. The arms position was standardized by a Biceps Blaster chest plate (Home-gym, Oxnard, CA) suspended from an adjustable neck strap. The chest plate extended laterally beyond the right and left anterior axillary lines, providing a fixed support for the posterior lower third of the upper arms. The upper arms were in contact with the lateral supports at all times during the concentric and eccentric phases of the exercise. The hands were positioned shoulder distance apart by using a supinated grip. The biceps curl was performed with the subject in a standing position, the feet shoulder distance apart and the heel of each foot 15.24 cm from a vertical wall. The subject’s back was positioned as flat as possible against the wall. The concentric action started with the elbows in 180° extension and the weight bar at the closest point to the floor. At the end of the concentric phase, the elbows were in the maximum flexion allowed while maintaining contact with the lateral supports of the chest plate. During the eccentric phase, the weight bar was lowered until the elbows were again in 180° extension, marking completion of one full repetition. The concentric phase was completed in 2 s and the eccentric phase in 1 s with this sequence signaled by an electronic metronome. A set was finished when the required number of repetitions for that exercise was completed.

Knee extension. The weight for the knee extension exercise was 65% 1-RM for that exercise. One half of the total weight was attached to each end of the transverse bar on a Hammer Strength Plate Loaded Machine (Life Fitness, Franklin Park, IL). Magnetic Plate Mates were used to adjust the weight to the nearest 0.57 kg. The back was positioned flat against the back support, and the hips were stabilized with an adjustable strap. The hands gripped stabilizing points on the seat. The seat position and back support were adjusted for each subject so that the knees were in 90° flexion and the feet at the closest position to the floor at the start of the concentric phase of the contraction. At the end of the concentric phase, the knees were in 180° extension with the legs parallel to the floor. During the eccentric phase, the weight bar was lowered until the knees were again in 90° flexion, marking completion of one full repetition. The concentric phase was completed in 2 s and the eccentric phase in 1 s with the sequence signaled by an electronic metronome. A set was finished when the required number of repetitions for that exercise was completed.

Exercise was observed by an investigator to ensure that the concentric and eccentric phases were complete for each repetition. Subjects were instructed to exhale during the concentric phase and inhale during the eccentric phase. The two exercises were separated by a 5-min seated recovery period.

RPE

Three separate RPE were estimated during each exercise set using the OMNI-RES. A differentiated rating for the active muscles (RPE-AM) was estimated at the end of the concentric phase of the middle and final repetition of each set. An undifferentiated rating for the overall body (RPE-O) was estimated immediately after the RPE-AM during the final repetition. Subjects were reminded during the repetition before each designated estimation time point to "think about your feelings of exertion." The OMNI-RES was in clear view of the subject during the entire exercise set. A standardized definition of perceived exertion and a set of instructions pertaining to the OMNI-RES were read to the subject immediately before each trial. These perceived exertion scaling procedures were adapted from those previously published for the original OMNI Scale (24). The definition of perceived exertion and scaling instructions were as follows:

Definition: The perception of physical exertion is defined as the subjective intensity of effort, strain, discomfort, and/or fatigue that you feel during exercise. Instructions: We would like you to use these pictures to describe how your body feels during weightlifting exercise (show subject the OMNI-RES). You are going to perform resistance exercises using your upper and lower body. Please look at the person at the bottom of the scale who is performing a repetition using a light weight. If you feel like this person when you are lifting weights the exertion will be EXTREMELY EASY. In this case, you would respond with the number zero. Now look at the person at the top of the scale who is barely able to perform a repetition using a very heavy weight. If you feel like this person when you are lifting weights the exertion will be EXTREMELY HARD. In this case, you would respond with the number 10. If you feel somewhere in between Extremely Easy (0) and Extremely Hard (10), then give a number between 0 and 10. We will ask you to give a number that describes how your active muscles feel and then a number that describes how your whole body feels. Remember, there are no right or wrong numbers. Your number can change as you lift weights. Use both the pictures and the words to help select the numbers. Use any of the numbers to describe how you feel when lifting weights.

The low and high perceptual anchors for the OMNI-RES were established using a visual-cognitive procedure (24). This procedure instructs the subject to cognitively establish a perceived intensity of exertion that is consonant with that depicted visually by the weight lifter at the bottom (i.e., low anchor, rating 0) and top (i.e., high anchor, rating 10) of the incline as presented in the OMNI-RES. Subjects were instructed to use their memory of the least and greatest effort that they had experienced while lifting weights to help in establishing the visual-cognitive link. The OMNI-RES was in full view of the subject at all times during the experimental protocol.

Blood Lactic Acid

Blood samples for the determination of [Hla] were obtained from an antecubital vein with the subject in a seated position. The sampling procedure was intended to anatomically link the antecubital venipuncture site with the muscles activated during the upper-body resistance exercise. Phlebotomy was only performed for those subjects who undertook the experimental trials where the biceps curl preceded the leg extension exercise. This avoided residual sample contamination that could have occurred in the experimental trials where the leg extension preceded biceps curl exercise. As such, blood was sampled from a subset comprised of 50% of the female ($N = 10$) and male ($N = 10$) groups. The exercise sample was obtained immediately upon completion of the biceps curl exercise. Blood was collected in a 3-mL Vacutainer containing potassium oxalate and sodium fluoride. Samples were immediately assayed for [Hla] with a YSI 2700 Select Biochemistry analyzer (YSI Inc., Yellow Springs, OH).

Data Analysis

Descriptive data for perceptual and physiological variables were calculated as mean ± SD. Evidence for concurrent validity was determined using linear regression analysis with repeated measures over exercise sets (SAS Version 8; Cary, NC). 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 the Wt_{tot} during a single set of resistance exercise and the immediate postexercise blood [Hla] served as the criterion variables. The RPE-AM and RPE-O were the concurrent variables. The regression analysis separately correlated Wt_{tot} with RPE-AM (mid), RPE-AM (final), and RPE-O, using data from the three exercise sets performed during the biceps curl and leg extension exercise. Separate regression coefficients were calculated for the female and male groups. For each exercise, the Wt_{tot} was calculated as the absolute weight equivalent to 65% 1-RM multiplied by the number of repetitions for a given set. Blood [Hla] was regressed against RPE-AM (final) using the data obtained for the combined female and male sample subset described previously.

Ratings of perceived exertion were examined with a three effect (site × set × sex) analysis of variance (ANOVA; SPSS 10.0 for Windows, Chicago, IL) with repeated measures on the within effect of set. The analyses determined differences between REP-AM (final) and RPE-O for each set of the biceps curl and knee extension exercise for both the female and male groups. The analyses also examined differences in RPE-AM (final) and RPE-O between female and male subjects for each set. Separate ANOVA were calculated for the biceps curl and knee extension exercises. The Mauchly's test of sphericity was not significant for either the biceps curl or knee extension analyses. Significant main and interaction effects were examined with a simple effects *post hoc* analysis.

RESULTS

Descriptive responses: RPE, Wt_{tot}, [Hla]. Presented in Figures 2–4 are means (±SD) of RPE measured

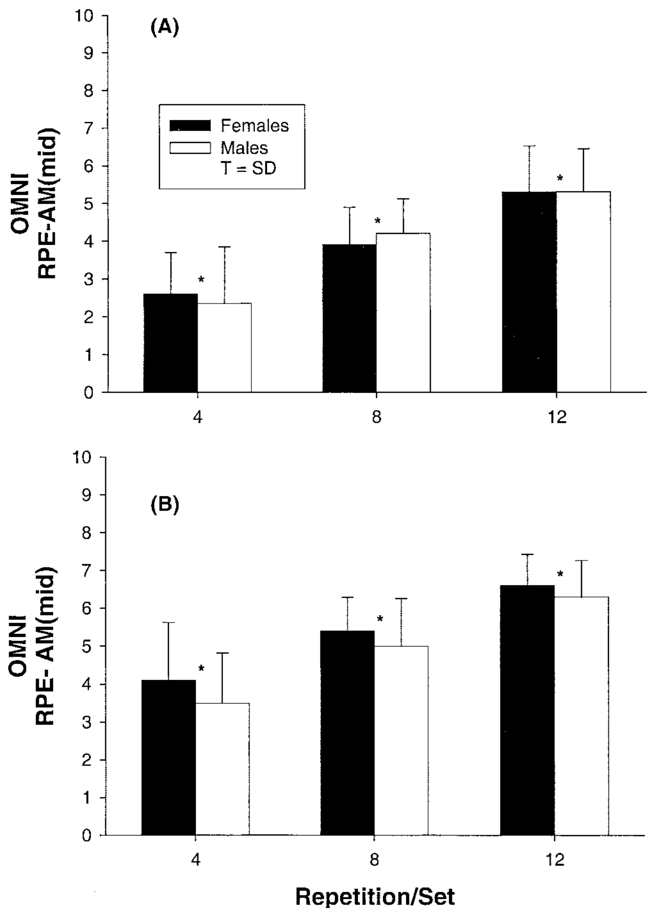

FIGURE 2—Ratings of perceived exertion (OMNI Scale) for the active muscles during the mid-repetition (RPE-AM (mid)) for female ($N = 20$) and male subjects ($N = 20$) performing three sets of biceps curl (A) and knee extension (B) resistance exercise at 65% 1-RM. *Indicates that RPE increased ($P < 0.01$) from the 4- to 8- and 8- to 12-repetition set in both the female and male groups.

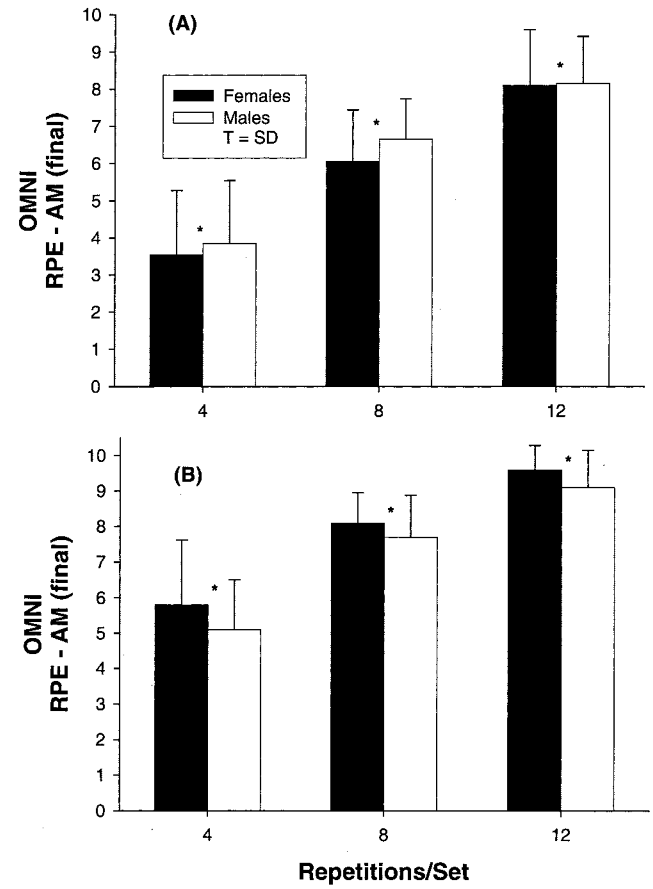

FIGURE 3—Ratings of perceived exertion (OMNI Scale) for the active muscles during the final repetition (RPE-AM (final)) for female ($N = 20$) and male subjects ($N = 20$) performing three sets of biceps curl (A) and knee extension (B) resistance exercise at 65% 1-RM. *Indicates that RPE increased ($P < 0.01$) from the 4- to 8- and 8- to 12-repetition set in both the female and male groups.

during the three sets of biceps curl and knee extension resistance exercise. Each figure presents data separately for the female and male subject groups. Table 1 lists the means (±SD) of Wt_{tot} determined for the female and male groups during the three sets of biceps curl and knee extension exercise. Table 2 lists the means (± SD) of the RPE-AM (final) and the pre- and post-exercise blood [Hla] for the combined female and male subset performing the biceps curl. These data were used in the regression analysis to examine concurrent validity of the OMNI-RES and in the factorial analysis to examine sex influences and differentiated perceptual responsiveness. The results of these analyses are described below.

Concurrent validity. Table 3 lists the results of the linear regression analyses that expressed RPE as a function of increasing Wt_{tot} for both the biceps curl (BC) and knee extension (KE) exercises. For the female subjects, positive linear regression coefficients ($P < 0.01$) were found between Wt_{tot} and RPE-AM (mid) (BC: r = 0.87; KE: r = 0.81), RPE-AM (final) (BC: r = 0.89; KE: r = 0.79), and RPE-O (BC: r = 0.87; KE: r = 0.86). Similarly, for the male subjects, positive linear coefficients ($P < 0.01$) were found between Wt_{tot} and RPE-AM (mid) (BC: r = 0.88; KE: 0.85), RPE-AM (final) (BC: r = 0.91; KE: 0.87), and RPE-O (BC: r = 0.89; KE: r = 0.87).

Table 3 also lists the linear regression analysis for RPE-AM expressed as a function of [Hla] measured immediately after the three biceps curl exercise sets. A positive linear coefficient was found between blood [Hla] and RPE-AM (final) (r = 0.87; $P < 0.01$).

Effect of sex and measurement site. The ANOVA of the biceps curl and knee extension responses indicated that the main effect for site and set were significant ($P < 0.01$), whereas the main effect for sex was not significant. Neither the two-factor nor three-factor interaction effects were significant. The nonsignificant sex main effect for both the biceps curl and knee extension data indicated that RPE-AM (final) and RPE-O did not differ between female and male subjects within each of the three exercise sets. Selected *post hoc* analyses indicated that: (a) when averaged over the sets and sex main effects, RPE-AM (final) was higher ($P < 0.01$) than RPE-O during both the biceps curl and knee extension exercises (Fig. 5); and (b) when averaged over the site and sex main effects, RPE increased ($P < 0.01$) from the 4- to 8-repetition set and the 8- to-12 repetition set for both the biceps curl and knee extension exercises (Figs. 2–4).

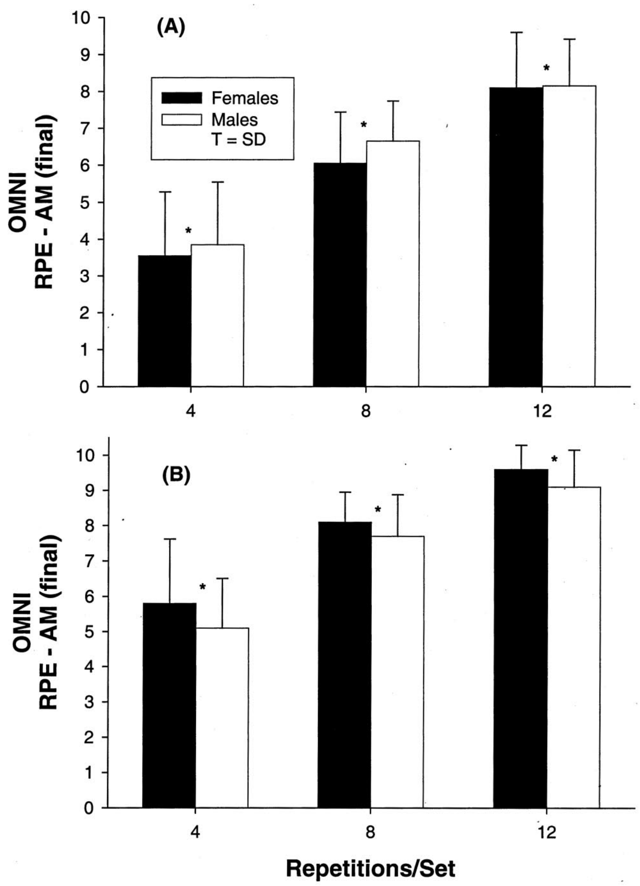

FIGURE 4—Ratings of perceived exertion (OMNI Scale) for the overall body during the final repetition (RPE-Overall) for female ($N = 20$) and male subjects ($N = 20$) performing three sets of biceps curl (A) and knee extension (B) resistance exercise at 65% 1-RM. *Indicates that RPE increased ($P < 0.01$) from the 4- to 8- and 8- to 12-repetition set in both the female and male groups.

DISCUSSION

This investigation examined concurrent validity of the newly developed OMNI-RES for rating exertional perceptions. Scale validity was established for young female and male adults performing isotonic biceps curl and knee extension resistance exercise. Validation criteria stipulated that: (a) RPE-AM and RPE-O would distribute as a positive linear function of Wt_{tot} for the separate female and male groups, (b) RPE-AM would distribute as a positive linear function of blood [Hla] for a combined female and male subset, and (c) the OMNI-RES could be used to separately rate the intensity of the differentiated perceptual signal arising from the active muscles and the undifferentiated signal for the overall body during both upper- and lower-body resistance exercise. The findings of the investigation supported each of the expected outcomes.

Concurrent validity: Wt_{tot}. Previous investigations employing Borg scales demonstrated that RPE increased as a function of increasing $Wt_{tot,}$ (1,3,7,8,13,17,18,20,22,27,29), relative intensity (% 1-RM) (17,20,22,27), and isometric contraction time (4,5,14,19,21,26,28). The present findings are generally in agreement with those previous experiments that examined perceived exertion responses using a volume loading (i.e., Wt_{tot}) resistance exercise paradigm. Validity coefficients derived from linear regression analyses ranged from r = 0.79 to 0.91 and were significant for both female and male subject groups. However, it is recognized that interpretive comparison between the present and previous reports is equivocal owing to interprotocol differences in the types of muscle actions (isotonic, isometric, and isokinetic) and protocol dosages (volume vs intensity loading) that were employed. In addition, previous investigations of RPE responsiveness during resistance exercise have employed the original and modified versions of both the Borg 15- (6–20) category and Borg CR-10 scales. As the present investigation used the newly developed OMNI-RES, direct cross-scale comparison of RPE responsiveness is not appropriate.

Concurrent validity: [Hla]. In the present investigation, blood [Hla] was considered a metabolic analog of Wt_{tot} for each set of biceps curl exercise. Therefore, blood [Hla] served as a co-criterion variable with Wt_{tot} in assessing concurrent RPE (i.e., OMNI-RES) responsiveness during the three biceps curl exercise sets. Peak blood [Hla] ranged from 3.1 $mM \cdot L^{-1}$ in the 4-repetition set to 6.8 $mM \cdot L^{-1}$ in the 12-repetition set for the biceps curl exercise, providing sufficient response variability for correlational analysis. Blood [Hla] measured immediately upon conclusion of each set of the biceps curl exercise evidenced a positive and linear correlation with RPE-AM (final). This finding is generally consistent with previous reports (1,7,8,11,13,17,27) that demonstrated a concurrent increase in RPE as a function of blood [Hla] determined during single and multiple sets of isotonic resistance exercise. In particular, Kraemer et al. (7) reported a high correlation (r = 0.84) between RPE and blood [Hla] responses to 10 consecutively presented resistance exercises.

TABLE 1. Total weight lifted (kg) by the mid and final repetition of three sets of biceps curl (BC) and knee extension (KE) resistance exercise at 65% 1-RM.

				Repetitions/Set					
				4		8		12	
Sex	N	Exercise		Mid(2)	Final(4)	Mid(4)	Final(8)	Mid(6)	Final(12)
Female	20	BC	Mean	24.70	49.55	49.45	98.85	74.05	146.05
			± SD	5.75	11.64	11.73	23.33	17.54	35.56
		KE	Mean	54.65	109.40	110.50	220.90	165.75	331.50
			± SD	15.74	31.22	30.62	61.31	46.03	91.96
Male	20	BC	Mean	59.85	119.85	115.75	231.65	179.80	359.70
			± SD	12.00	24.23	23.29	46.74	36.31	72.73
		KE	Mean	124.60	249.50	249.50	498.85	374.15	748.65
			± SD	28.90	57.90	57.90	115.80	86.86	173.73

1-RM, one-repetition maximum. Number in parentheses after mid and final indicates the completed repetitions at that time point within a given set.

TABLE 2. Ratings of perceived exertion for active muscle (RPE-AM; OMNI Scale) and venous blood lactic acid concentration [Hla] (mM·L^{-1}) in a subset of female ($N = 10$) and male subjects ($N = 10$) performing biceps curl exercise.

	Repetitions/Set					
	4		8		12	
	RPE-AM	[Hla]	RPE-AM	[Hla]	RPE-AM	[Hla]
Mean	3.9	3.11	6.2	5.13	8.2	6.82
± SD	1.5	1.18	1.2	1.67	1.3	2.07

RPE response linearity. Linear and positive RPE responsiveness has been accepted as one form of concurrent validation of perceived exertion category scales for both adult (15; pp. 60–77) and pediatric (24) female and male samples performing aerobic exercise. The present investigation is the first to examine the concurrent validity of a pictorial-verbal category scale of perceived exertion for use by female and male adults during upper- and lower-body resistance exercise. Consistent with expectations, the findings demonstrated that young female and male adults were able to use the verbal-pictorial format of the OMNI-RES to translate into numbers (i.e., RPE) their perceptions of physical exertion during both upper- and lower-body isotonic exercise. The strong positive and linear relation observed between RPE and both Wt_{tot} and blood [Hla] provides concurrent validity evidence for use of the OMNI-RES by both female and male subjects during dynamic resistance exercise.

Linearity between RPE and both Wt_{tot} and blood [Hla] has practical application for prescription and self-regulation of resistance exercise programs. Such application is facilitated if perceptual responses distribute as positive linear functions of both physical (i.e., Wt_{tot}) and physiological (i.e., [Hla]) responses, and in doing so satisfy the basic tenants of Borg's Effort Continua Model (24). The model predicts concurrent perceptual and physical/physiological responsiveness as a function of incremental changes in exercise performance. It follows that RPE responses derived from the OMNI-RES might be applied either independently or conjunctively with physical and physiological responses in clinical, sport, research, and physical education settings that employ resistance exercise programs for female and male participants.

Sex-specific validation. Concurrent validity of the OMNI-RES using Wt_{tot} as a criterion variable was examined separately for female and male subjects performing upper- and lower-body resistance exercise. Regression coefficients between RPE (AM and O) and Wt_{tot} across the three exercise sets ranged from $r = 0.79$ to 0.89 for female subjects and $r = 0.85$ to 0.91 for male subjects. A number of previous reports have assessed RPE during resistance exercise by using mixed sex samples (3,12,14,20,22,29). In particular, the designs employed by Pincivero et al. (20,22) examined whether RPE grew as a linear or exponential function of resistance exercise dosage with data analyzed separately for female and male subjects. They reported linear responses between RPE and relative torque output (i.e., % MVC) for separate groups of female and male subjects by using a modified version of Borg's CR-10 scale. In a conceptually similar manner, the linear perceptual responses found presently for both sex groups indicated that the OMNI-RES pictorial-verbal format was equally valid for use by young female and male adults during upper- and lower-body resistance exercise.

Neither the differentiated nor the undifferentiated RPE differed between female and male subjects during the upper- and lower-body exercises. Sex comparisons of RPE were made separately for each of the three exercise sets. It is noteworthy that although Wt_{tot} was greater for the male than female subjects at each set, the relative intensity (i.e., 65% 1-RM) was the same for the female and male groups. As such, the present response is consistent with previous reports by Pincivero et al. (20,22) and Gerdle et al. (4), who found that RPE (CR-10) did not differ between untrained adult female and male subjects when performing isotonic and isometric muscle actions at the same relative exercise

TABLE 3. Linear regression analysis of RPE expressed as a function of total weight and lactic acid concentration during upper- and lower-body resistance exercise.

Exercise	Sex	N	Variable: Criterion (x)	Variable: Concurrent (y)	Intercept	SE	Slope	SE	r*	r^2
BC	F	20	Wt_{tot}	RPE-AM(mid)	1.141	0.219	0.055	0.004	0.87	0.76
				RPE-AM(final)	1.425	0.335	0.045	0.003	0.89	0.79
				RPE-O	0.419	0.345	0.042	0.003	0.87	0.76
BC	M	20	Wt_{tot}	RPE-AM(mid)	0.760	0.253	0.027	0.002	0.88	0.77
				RPE-AM(final)	1.883	0.297	0.018	0.001	0.91	0.83
				RPE-O	0.651	0.312	0.018	0.001	0.89	0.79
KE	F	20	Wt_{tot}	RPE-AM(mid)	2.963	0.251	0.022	0.002	0.81	0.66
				RPE-AM(final)	4.764	0.350	0.014	0.001	0.79	0.62
				RPE-O	2.444	0.283	0.015	0.001	0.86	0.74
KE	M	20	Wt_{tot}	RPE-AM(mid)	2.037	0.261	0.012	0.001	0.85	0.72
				RPE-AM(final)	3.580	0.308	0.007	0.001	0.87	0.76
				RPE-O	2.306	0.300	0.007	0.001	0.87	0.76
BC	M&F	20	[Hla]	RPE-AM(final)	1.794	0.352	0.851	0.064	0.87	0.76

RPE, rating of perceived exertion (OMNI-RES) for the active muscle (RPE-AM) and overall body (RPE-O); BC, biceps curl; KE, knee extension; Wt_{tot}, total weight; [Hla], lactic acid concentration; F, female; M, male.
* $P < 0.01$.

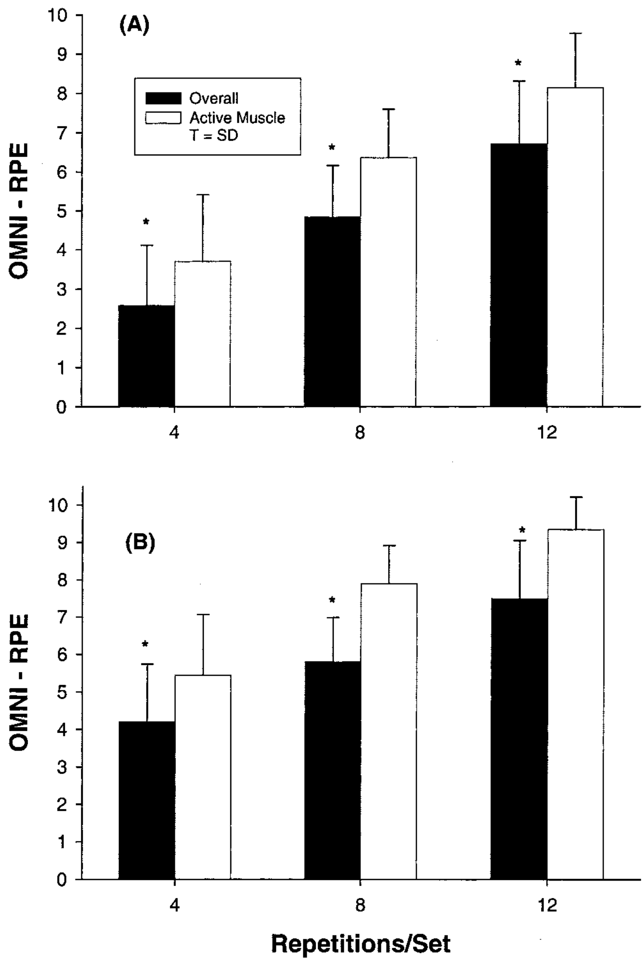

FIGURE 5—Comparison between OMNI Scale ratings of perceived exertion for the overall body (RPE-Overall) and active muscle (RPE-AM) determined during the final repetition of three sets of biceps curl (A) and knee extension (B) resistance exercise at 65% 1-RM. For each set, data are averaged over the female and male groups. * Indicates that RPE-AM > RPE-Overall for each set ($P < 0.01$).

intensity. However, the present data contrast with a previous report by O'Connor et al. (16) of sex differences in RPE during eccentric elbow flexor exercise when comparisons were made at a given relative intensity. Therefore, the role of the relative exercise intensity (i.e., % 1 RM) in explaining sex specific exertional perceptions during resistance exercise remains inconclusive.

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 within a comparatively narrow time frame (25). Using the OMNI-RES, the present investigation measured both the RPE-AM (final) and RPE-O during the last repetition for each of the three resistance exercise sets. The RPE-AM (final) was higher than the RPE-O for both the female and male subject groups performing biceps curl and knee extension exercise. A number of previous investigations using the Borg 15-category scale have also demonstrated that RPE for activated muscle and the overall body can be measured concurrently either during or immediately following a single isotonic repetition of upper- and lower-body resistance exercise (2,11,12). In these previous reports, the intensity of the perceptual signal that was differentiated to the predominantly active muscle groups was always greater than that for the overall body. In a similar manner, the present findings indicate that the OMNI-RES can be used to assess differences in the intensity of differentiated and undifferentiated perceptual signals during upper- and lower-body resistance exercise.

Of applied importance is that the female and male subjects were able to use the OMNI-RES to separately rate the differentiated and undifferentiated RPE when assessments occurred within a 3-s period. Comparatively rapid assessment of both the differentiated and undifferentiated RPE is then possible during multiple set protocols that activate different muscle groups according to the body regions involved. An RPE that is anatomically regionalized to the primary muscle actions required for performance may increase the precision of perceptually based intensity self-regulation during resistance exercise training (25).

CONCLUSION

Ratings of perceived exertion (i.e., OMNI-RES) for the active muscles and overall body distributed as positive linear functions of Wt_{tot}. The findings were consistent for both the female and male subject groups when performing biceps curl and knee extension exercise at a 65% 1-RM intensity. Linear responsiveness was also noted between RPE-AM and blood [Hla] during biceps curl exercise, using a combined subset of the female and male subjects. Sex differences in perceived exertion responses were not observed. Taken as an aggregate, the findings provide concurrent validation of the OMNI-RES for use by young recreationally trained female and male weight lifters performing upper- and lower-body resistance exercise.

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