Reliability and validity of the Borg and OMNI rating of perceived exertion scales in adolescent girls

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ABSTRACT

PFEIFFER, K. A., J. M. PIVARNIK, C. J. WOMACK, M. J. REEVES, and R. M. MALINA. Reliability and validity of the Borg and OMNI rating of perceived exertion scales in adolescent girls. *Med. Sci. Sports Exerc.*, Vol. 34, No. 12, pp. 2057–2061, 2002. **Purpose:** To examine the reliability and validity of the Borg and OMNI rating of perceived exertion (RPE) scales in adolescent girls during treadmill exercise. **Methods:** Adolescent girls (N = 57, age = 15.3 ± 1.5 yr) were randomly assigned to use an RPE scale (Borg or OMNI) during one of three treadmill submaximal exercise conditions (walking, walking uphill, or jogging). After RPE assessment, exercise intensity was increased until participants achieved volitional exhaustion ($\dot{V}O_{2max}$). Expired respiratory gases and heart rate (HR) were measured continuously during exercise. Reliability of the RPE scales was assessed using ANOVA (intraclass) and Spearman-Brown prophecy formula (single trial) measures. Validity estimates were calculated using Pearson Product Moment correlations, with % HR_{max} and % $\dot{V}O_{2max}$ as criterion measures. **Results:** Intraclass and single-trial reliability estimates were higher for the OMNI (r_{xx} = 0.95 and r_{kk} = 0.91, respectively) compared with the Borg (r_{xx} = 0.78 and r_{kk} = 0.64, respectively) RPE scale. Validity estimates were also higher for the OMNI scale compared with the Borg scale. Validity coefficients (r_{xy}) for %HR_{max} and %$\dot{V}O_{2max}$ comparisons were 0.86 and 0.89, respectively, for the OMNI, compared with 0.66 and 0.70, respectively, for the Borg. **Conclusion:** The OMNI cycle pictorial scale was found to be reliable and valid for use with adolescent girls. It also appears to be more reliable and valid than the Borg scale for use in this population during treadmill exercise. **Key Words:** CHILDREN, PERCEIVED EXERTION, TREADMILL EXERCISE

Perceived exertion is the ability to detect and respond to sensations that arise as a result of physiological adaptations to exercise (16). The cognitive awareness of these sensations is considered a form of biofeedback in which central, peripheral, and metabolic changes during exercise are assimilated. Borg (4) designed the first rating of perceived exertion (RPE) scale, which is widely believed to be one of the best indicators of degree of physical strain. In addition, several RPE scales, including the original Borg scale (6–20) and Borg CR-10, Pittsburgh 9, and Fleishman Occupational Effort Scale, have demonstrated validity for use with adults (18).

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It is possible that perceived exertion is a factor that affects physical activity behavior in children and adolescents. Before examining any potential relation between RPE and physical activity, one should consider whether reliable and valid measurement scales for RPE in children and adolescents exist. Applicability of RPE in the pediatric population has not been studied as extensively as it has in adults (12), and research thus far has not provided a clear answer as to which scale works best for children and/or adolescents. In terms of reliability of the original Borg 6–20 scale, Mahon and Marsh (14) found an intraclass correlation coefficient of r_{xx} = 0.78 in 8- to 12-yr-old children exercising at ventilatory threshold. The participants reported a wide range of RPE for a given treadmill intensity. Others have also found the Borg scale to be reliable in children and adolescents (3,10,11,21). Many of the RPE studies were conducted using cycle ergometer exercise.

The original Borg 6–20 scale has most often been validated in children and adolescents using heart rate (HR) as the criterion measure during cycle ergometer exercise (18). Validity coefficients obtained have ranged from r_{xy} = 0.20–0.28 in prepubertal children (15) to r_{xy} = 0.86–0.92 in participants ages 9–15 yr (3,10,21). Robertson and Noble

(18) suggested a potential age threshold associated with accurate use of the Borg scale, although researchers do not agree what that threshold might be.

Some researchers have noted that they believe that limitations with use of the Borg scale in children/adolescents are related to cognitive abilities and testing methods used (18,22). Williams et al. (22) noted that children younger than 11 yr have difficulty assigning words or phrases to describe exercise intensity. Thus, they designed the Children's Effort Rating Table (CERT) scale for use with children ages 6–9 yr. The CERT includes categories from 1 to 10, with verbal descriptors that were derived from pilot research with children. The verbal descriptors range from "very, very easy" to "so hard I am going to stop." Although one study seemed to indicate that the CERT may be slightly more reliable than the original Borg 6–20 scale (10), validation studies of the CERT showed that relation between RPE and HR deteriorates at higher intensity exercise (13).

The Children's OMNI Scale of Perceived Exertion was developed for use with children of mixed ethnicity and gender (17). The scale uses numerical ratings that range from 0 to 10 with a series of pictures showing a child riding a bicycle. The pictorial format was used so that "the exertional meaning of each pictorial descriptor is consonant with its verbal descriptor." The scale can be used to determine overall RPE or differentiated RPE (e.g., legs, chest). Previous data indicate acceptable validity of the OMNI scale over a range of cycle ergometer exercise intensities in 8- to 12-yr-old boys and girls (17). The authors noted that the scale may not be generalizable to other exercise modes or children/adolescents of different ages.

As a follow-up to the original OMNI scale, a walking/running version of the OMNI was developed for use with treadmill exercise (20). Utter et al. (20) tested this scale with children ages 6–13 yr and found it to be valid for use with this age group. Although both versions of the OMNI scale seem to have promise for use with children and adolescents, additional work on reliability and validity is necessary, particularly in the adolescent population (generally considered to be ages 13–18 yr). It is also noted that the effects of cross-modal/pictorial format is not known, i.e., can the OMNI cycle scale be used for treadmill exercise (17,20)?

The purpose of this study was to compare the reliability and validity of the Borg (6–20) and OMNI cycle RPE scales during submaximal treadmill exercise in a sample of adolescent girls. We hypothesized that the Borg and OMNI scales would have similar reliability and validity and that both would be appropriate for use in adolescent girls.

METHODS

Participants

Study participants were a convenience sample of 57 adolescent girls, ages 13–18 yr (15.3 ± 1.5 yr). All but three girls engaged in some type of organized sport activity (e.g., basketball, gymnastics, soccer, swimming). The sample included mostly white girls (approximately 93%), and participants were above average in cardiorespiratory fitness ($\dot{V}O_{2max}$ = 46.9 ± 5.3 mL·kg^{-1}·min^{-1} (9). Written assent to participate and parental consent were obtained for each participant. This research was approved by the University Committee on Research Involving Human Subjects at Michigan State University.

Instruments

Two RPE scales, the Borg scale and the OMNI cycle pictorial scale, were used in the testing protocol. Before performing the exercise tests, participants were familiarized with one of the scales. This included defining perceived exertion, anchoring the perceptual range, explaining the use of the scale, and answering questions, as indicated in the guidelines outlined by Bar-Or (2) and Noble and Robertson (16).

Borg 6–20 RPE (category) scale. The Borg category scale (4) is designed to describe perceptions of physical exertion during a wide range of exercise modes. The scale consists of numbered categories, 6–20, and verbal cues, from "very, very light" to "very, very hard." During the last minute of the assigned phase of the testing protocol, participants were asked how hard they felt they were exercising.

Children's OMNI scale of perceived exertion. The OMNI scale was developed specifically for use with boys and girls of mixed ethnicity (17). It consists of 11 numbered categories, 0–10, and verbal cues, from "not tired at all" to "very, very tired." The scale also has a set of four pictures of a child riding a bicycle. The first picture is placed at the level zero and depicts the child riding on flat ground. The other three pictures show the child riding uphill and appearing more tired as the scale progresses. Participants were asked how they felt according to this scale (i.e., overall RPE) during the last minute of the assigned exercise stage during the treadmill test.

Testing Protocols

Data collection consisted of two treadmill testing protocols performed approximately 1 wk apart. During both treadmill bouts, expired gases were collected continuously via indirect calorimetry (SensorMedics 2900; Yorba Linda, CA). HR was measured via telemetry (Polar; Seattle, WA) and recorded during each minute of exercise. The basic treadmill protocol for both days was performance of three exercise stages: walking at 3.2 km·h^{-1}and 0% grade, followed by walking uphill at 4.8 km·h^{-1} and 5.0% grade, followed by jogging at 7.2 km·h^{-1} and 0% grade. Time spent in each treadmill exercise stage varied by testing day.

Treadmill test 1. Before data collection, participants were randomly assigned to use either the Borg or the OMNI RPE scale for one of three submaximal exercise stages. Random assignment involved creating a repetitive list of the six possible combinations of RPE scale and treadmill stage and using a random number table to choose each participant's combination. During this first treadmill test, each girl spent 6 min in the randomly assigned stage and 2–5 min in each of the other two stages. Also, participants were given a definition of RPE and high and low anchors (provided by

Robertson et al. (17)) before the treadmill exercise. In the last minute of the randomly assigned stage, participants were asked to rate their perceived exertion according to the appropriate RPE scale. Therefore, each participant reported one RPE on one scale during one stage of the treadmill test (e.g., one girl might be assigned to Borg stage 2, whereas the next might be assigned to OMNI stage 1).

Treadmill test 2. Participants were again given the definition of RPE and high and low anchors before the test. The three exercise stages corresponded to the same intensities as were performed during treadmill test 1, and the duration of each stage was 6 min. RPE was obtained during the last 30 s of the same, randomly assigned stage as treadmill test 1. After completing the third stage, participants continued jogging at the same speed while the elevation was raised 2.5% each minute until they volitionally terminated the test because of exhaustion. Criteria for reaching $\dot{V}O_{2max}$ included two of the following: 1) respiratory exchange ratio >1.0, 2) maximum HR >95% of age-predicted maximum, and 3) plateau or decrease of $\dot{V}O_2$ (<2 mL·kg^{-1}·min^{-1}) during the final minute of the stage.

Statistical Analysis

Power analysis revealed that for a moderate correlation (r = 0.60) with a power of 0.80, 23 participants were needed for an alpha of $P < 0.05$. Reliability (r_{xx}) for each scale was determined using intraclass correlations obtained from ANOVA. Single-test reliability (r_{kk}) was determined using the Spearman-Brown prophecy formula: $r_{kk} = K \cdot (r_1)/[1 + (K - 1) \cdot r_1]$, where K is the number of trials performed and r_1 is the reliability coefficient established for K trials. SEM were calculated using the formula $SEM = SD \cdot \sqrt{(1 - r_{xx})}$, where SD is the standard deviation of the RPE categories and r_{xx} is the intraclass correlation coefficient. Validity was determined using Pearson correlations (r_{xy}), with both percentage of HR maximum (%HR_{max}) and percentage of maximal aerobic power (%$\dot{V}O_{2max}$) as the criterion measures.

RESULTS

All participants included in the analysis reached $\dot{V}O_{2max}$ according to our criteria. Average $\dot{V}O_{2max}$ was 46.9 ± 5.3 mL·kg^{-1}·min^{-1}. HR_{max} was 202 ± 9.3 beats·min^{-1}. R_{max} was 1.1 ± 0.06. Descriptive statistics for RPE categories during treadmill tests 1 and 2 and physiological responses during treadmill test 2 are summarized in Table 1; reliability estimates are summarized in Table 2. Borg RPE differed by approximately one category between the two test bouts. OMNI RPE did not differ by more than one half a category between the two test bouts, but it is also noted that the span of the scale is more condensed than the span of the Borg scale. The OMNI scale showed better reliability ($r_{xx} = 0.95$) than the Borg scale ($r_{xx} = 0.78$). Single-day reliability estimates were slightly lower than intraclass estimates, and the OMNI scale ($r_{kk} = 0.91$) was more reliable than the Borg scale ($r_{kk} = 0.64$).

Validity estimates (r_{xy}) were higher for the OMNI scale compared with the BORG scale (Table 2). Validity coefficients were $r_{xy} = 0.86$ and $r_{xy} = 0.89$ for the OMNI scale and $r_{xy} = 0.66$ and $r_{xy} = 0.70$ for the Borg scale, for %HR_{max} and %$\dot{V}O_{2max}$ comparisons, respectively. Pearson correlations for physiological variables are also summarized in Table 2. Correlations were comparatively high for the relation between RPE and $\dot{V}O_2$, %$\dot{V}O_{2max}$, HR, minutes of ventilation ($\dot{V}E$), and respiratory rate (RR). Correlation between RPE and $\dot{V}E/\dot{V}O_2$ was relatively low.

DISCUSSION

The reliability estimate for the Borg scale in this study ($r_{xx} = 0.78$) is similar to those found in other studies with youths. The low SEM associated with the Borg scale indicates that test-to-test variability was low. Mahon and Marsh (14) reported the same reliability estimate for the Borg scale in 8- to 12-yr-old children who were tested at ventilatory threshold. In adolescent, obese children, Bar-Or and Ward (3) reported an average RPE reliability of $r_{xx} = 0.92$ across different exercise intensities. They also reported coefficients of $r_{xx} = 0.59$ at 20% of maximal aerobic power and r_{xx} =

TABLE 1. Perceptual responses to exercise during tests 1 and 2 and physiological responses during test 2.

	Test 1 RPE*	Test 2 RPE*	%HR_{max}	%$\dot{V}O_{2max}$	HR	$\dot{V}O_2$·kg^{-1}	$\dot{V}O_2$	R	$\dot{V}E$	RR	$\dot{V}E/\dot{V}O_2$
Borg stage 1	8.2 (2.2)	8.0 (1.7)	53.3	24.2 (2.5)	107	11.8	663	0.82	18.7	29 (5)	28.4
(*n* = 9)	7.0	8.0	(2.8)		(10)	(1.0)	(55)	(0.04)	(1.2)		(3.5)
Borg stage 2	11.1 (1.8)	12.0 (1.7)	70.8	47.5 (5.8)	145	21.1	1164	0.86	30.5	31 (5)	26.2
(*n* = 9)	11.0	12.0	(7.1)		(17)	(1.4)	(59)	(0.06)	(2.4)		(2.7)
Borg stage 3	11.5 (2.3)	12.7 (2.1)	82.6	65.8 (4.7)	164	31.5	1703	0.91	46.2	42 (7)	27.1
(*n* = 10)	12.0	13.0	(5.0)		(14)	(1.4)	(169)	(0.03)	(6.4)		(2.3)
OMNI stage 1	0.3 (0.5)	0.7 (0.8)	51.2	23.1 (2.3)	103	11.0	603	0.78	17.0	28 (7)	28.3
(*n* = 10)	0.0	0.5	(4.9)		(12)	(0.7)	(37)	(0.04)	(1.6)		(2.5)
OMNI stage 2	2.3 (1.3)	2.4 (1.0)	64.0	44.0 (4.9)	127	21.0	1149	0.88	30.0	28 (6)	26.0
(*n* = 10)	2.0	2.0	(6.7)		(12)	(0.9)	(129)	(0.03)	(5.5)		(2.9)
OMNI stage 3	4.8 (1.6)	5.2 (1.6)	87.9	73.4	181	33.9	1798	0.93	53.4	45 (6)	29.7
(*n* = 9)	5.0	5.0	(6.8)	(12.8)	(14)	(2.8)	(329)	(0.04)	(11.2)		(3.1)

Values are mean (SD).
* Median value is in italics.
HR, heart rate in beats·min^{-1}; $\dot{V}O_2$·kg^{-1}, weight-relative $\dot{V}O_2$ in mL·kg^{-1}·min^{-1}; $\dot{V}O_2$, absolute $\dot{V}O_2$ in mL·min^{-1}; R, respiratory quotient; VE, minute ventilation in L·min^{-1}; RR, respiratory rate in breaths·min^{-1}; $VE/\dot{V}O_2$, ventilatory equivalent for oxygen.

TABLE 2. Reliability and validity of the Borg and OMNI RPE scales and Pearson correlations for physiological data.

	Borg	OMNI
Reliability		
Reliability across two trials (r_{xx})	0.78	0.95
Single-day reliability (r_{kk})	0.64	0.91
SEM (%)	1.24	0.49
Validity		
Validity (%HR_{max}; r_{xy})	0.66*	0.86*
Validity (%$\dot{V}O_{2max}$; r_{xy})	0.70*	0.89*
Pearson correlations		
HR	0.64*	0.82*
$\dot{V}O_2 \cdot kg^{-1}$	0.67*	0.88*
$\dot{V}O_2$	0.63*	0.88*
R	0.49	0.76*
$\dot{V}E$	0.64*	0.89*
RR	0.44	0.73*
$\dot{V}E/\dot{V}O_2$	−0.01	0.33

HR, heart rate; $\dot{V}O_2 \cdot kg^{-1}$, weight-relative $\dot{V}O_2$; absolute $\dot{V}O_2$; R, respiratory quotient; $\dot{V}E$, minute ventilation; RR, respiratory rate; $\dot{V}E/\dot{V}O_2$, ventilatory equivalent for oxygen.
* $P < 0.05$.

0.89 at 80% of maximal aerobic power in another group of obese adolescents (21). Lamb (10) reported an intraclass correlation $r_{xx} = 0.90$ for the Borg scale in fourth graders. Furthermore, when examining the reliability of regulating exercise intensity to a particular RPE category in 9- to 10-yr-olds, Lamb (11) found intraclass correlation coefficients ranging from $r_{xx} = 0.48–0.85$ for HR and $r_{xx} = 0.08–0.76$ for power output at various RPE categories.

The reliability estimate for the OMNI scale in this study was high. To our knowledge, no previous studies have evaluated the reliability of the OMNI scale in adolescents. The difference between both days of OMNI RPE for all three treadmill stages was <0.5 category. The low SEM associated with the OMNI scale indicates that test-to-test variability was low. Proportionally, the SEM for OMNI (~4%) was approximately half the SEM for the Borg scale (~8%).

Traditionally, HR at a given power output has been used to validate RPE scales in children (1,6,8). Using HR as the criterion measure can be a limitation because HR tends to be highly variable in children. Dishman (5) has stated that RPE and relative $\dot{V}O_2$ ($mL \cdot kg^{-1} \cdot min^{-1}$) correspond at all exercise intensities independent of exercise mode in adults, indicating that $\dot{V}O_2$ may be a better criterion measure than HR when determining the validity of RPE. However, using $\dot{V}O_2$ can be a limitation because it represents absolute effort, not relative effort. In contrast, we used relative intensities, both $\%HR_{max}$ and $\%\dot{V}O_{2max}$, as criterion measures. We considered these to be sound criteria because maximal values were known and differed among the subjects. We believe that it is easier to make comparisons about perception of effort when the criterion measure is relative to intensity of effort. Furthermore, Utter et al. (20) used $\%\dot{V}O_{2max}$ in their validation study of the walking/running OMNI scale.

In studies in which HR was used as a criterion measure for RPE, Borg scale validity coefficients have been good to excellent. Lamb (10) found validity coefficients between HR and RPE of $r_{xy} = 0.90$ and $r_{xy} = 0.95$ across two trials in 9- to 10-yr-old children when using means of individual correlations. However, when simultaneous analysis of the entire group was performed, coefficients were $r_{xy} = 0.50$ and $r_{xy} = 0.64$. Similarly, in another study, Lamb (11) found coefficients of $r_{xy} = 0.54$ and $r_{xy} = 0.61$ when data were analyzed simultaneously for the group. Gillach et al. (8) found validity coefficients between Borg scale RPE and HR of $r_{xy} = 0.92$ and $r_{xy} = 0.94$ in 11- to 14-yr-old participants on two different occasions when they examined the data based on the mean of individual correlations. When they used simultaneous analysis of the entire group, their correlations were lower, $r_{xy} = 0.64$ on occasion one and $r_{xy} = 0.65$ on occasion two. Similarly, Eston et al. (7) found a validity coefficient between Borg scale RPE and HR ($r_{xy} = 0.74$) in adolescent boys when the data were analyzed on a group basis. It should also be noted that all of these studies were performed using a cycle ergometer.

The validity coefficient for the Borg scale in this study ($r_{xy} = 0.66$) was found using simultaneous analysis of the group and is similar to previous studies. It is important to note that we used $\%HR_{max}$ rather than absolute HR, however. Bar-Or (1) seems to be the only other investigator who has examined RPE related to $\%HR_{max}$. Correlations between Borg scale RPE and HR varied between 0.70 and 0.88 for individuals 7–20 yr old as summarized by Bar-Or (1). However, the data were plotted and the correlation was not calculated, which makes comparison with the present study difficult. It is important to note that participants in the present study have higher $\dot{V}O_{2max}$ values compared with average girls of the same age (19), and it is possible that their RPE could be lower than those reported by less fit individuals when compared at a given submaximal intensity. The fitness level of the participants in Bar-Or's study (1) was not reported. In addition, all of Bar-Or's participants were boys, which raises the issue of potential gender effect on RPE.

When the OMNI cycle pictorial scale was originally validated, Robertson et al. (17) used both HR and $\dot{V}O_2$ as criterion measures. The authors used regression analysis to determine whether there was a linear relation between OMNI RPE and both HR and $\dot{V}O_2$. The model for HR had $r_{xy} = 0.93$, and the model for $\dot{V}O_2$ had an $r_{xy} = 0.94$, indicating high correlation between the OMNI RPE scores and both HR and $\dot{V}O_2$. The scale was developed for and validated on children 8–12 yr during cycle ergometer exercise. The present investigation is the first to examine the validity of the cycle pictorial format of the OMNI scale for use with adolescents during treadmill exercise. The results showed higher validity estimates than the Borg scale scores, regardless of whether $\%HR_{max}$ ($r_{xy} = 0.86$) or $\%\dot{V}O_{2max}$ ($r_{xy} = 0.89$) was the criterion measure. These values are similar to those found in the original validation study of the OMNI scale.

When the OMNI walking/running scale was validated, Utter et al. (20) found the strongest correlations between RPE and $\%\dot{V}O_{2max}$ ($r_{xy} = 0.41–0.60$) and RPE and HR ($r_{xy} = 0.26–0.52$). The correlations between RPE and relative $\dot{V}O_2$ ($r_{xy} = 0.88$ vs 0.32), $\%\dot{V}O_{2max}$ ($r_{xy} = 0.89$ vs 0.42), HR ($r_{xy} = 0.82$ vs 0.40), $\dot{V}E$ ($r_{xy} = 0.89$ vs 0.33), and RR ($r_{xy} = 0.73$ vs 0.35) were higher in the current study than in the Utter et al. study. The correlation between RPE and $\dot{V}E/\dot{V}O_2$ for the present study was lower than the Utter et al. study ($r_{xy} = 0.33$ vs 0.43). However, these correlations were

based on several exercise stages in the Utter et al. study and only one exercise stage (representing three different exercise intensities) in the present study.

Each participant used one RPE scale during the same, randomly selected stage of both treadmill tests. It is unknown how the reliability and validity coefficients may have been affected by this protocol. Most other studies that have examined reliability and validity of RPE scales have included assessment of perceived exertion at several exercise stages. However, this study design allowed us to evaluate RPE without having the scores affected by previous ratings in previous stages.

A potential limitation of this study was the method by which reliability was determined. The conditions for assessing RPE were not exactly the same during the first and second tests. All first-day assessments of RPE were measured during a 6-min treadmill stage that was one of the three treadmill stages completed on the second day. Despite that the participants did perform the other two stages on the first day, the stages were not performed for the full 6-min time period as they were on the second day, in an effort to minimize participant burden. However, our goal was to assess RPE for one given stage so that any RPE measurement would not be affected by previous measurements. It is noted that this possibly made it easier for girls to report the same RPE on both days, but it is also possible that performing two slightly different testing protocols made it difficult to report the same RPE on the second day. Furthermore, the sample consisted of athletic girls, so the generalizability of our results to less fit girls is not known.

Overall, the results indicate that the OMNI cycle pictorial scale is a reliable and valid instrument to use with adolescent girls while performing treadmill exercise. To our knowledge, this is the first study to include OMNI reliability data on an adolescent population during treadmill exercise. Although the OMNI cycle pictorial scale was originally developed for use with 8- to 12-yr-olds performing cycle ergometer exercise, it was more reliable and valid than the Borg scale for treadmill exercise in adolescent girls. The OMNI cycle pictorial scale also showed better validity in adolescent girls while performing treadmill exercise than the OMNI walking/running scale showed in younger participants (ages 6–13 yr). Exactly which characteristics of the OMNI cycle pictorial scale made it reliable and valid in adolescent girls is not known, despite that some may argue that the Borg scale is more universal in application because of its absence of pictures. It is possible that the OMNI walking/running scale would show even better reliability and validity in this population because it shows pictures of the same exercise mode.

Recommendations for additional research include comparing the use of both OMNI scales in the adolescent population (both genders) during treadmill exercise at multiple exercise intensity levels. It is also recommended to test both OMNI scales with younger age participants (<8 yr old) and participants of different ethnicity and gender, and to examine the scales' reliability and validity using other exercise modalities in a sample with a wider range of fitness levels.

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