HHS Public Access
Author manuscript
*Med Sci Sports Exerc*. Author manuscript; available in PMC 2017 August 01.

Published in final edited form as:
*Med Sci Sports Exerc*. 2016 August ; 48(8): 1590–1594. doi:10.1249/MSS.0000000000000918.

# Age-Related Differences in OMNI-RPE Scale Validity in Youth: A Longitudinal Analysis

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## Abstract

Rating of perceived exertion (RPE) scales are used in exercise science research to assess perceptions of physical effort. RPE scale validity has been evaluated by assessing correlations between RPE and physiological indicators. Cross-sectional studies indicate that RPE scale validity improves with age; however, this has not been studied longitudinally.

**PURPOSE—**To examine age-related trends in OMNI-RPE scale validity, using a longitudinal study design, and heart rate (HR) and oxygen uptake ($VO_2$) as criterion measures.

**METHODS—**Participants performed 11, five-minute activity trials at baseline, 12-, 24-, and 36-months follow-up ($VO_2$ data: N=160; HR data: N=138). HR and $VO_2$ between minutes 2.5–4.5 of each activity were recorded. At the end of each activity, participants reported RPE. Children were stratified into age groups: 6–8, 9–10, 11–12 and ≥13 years. Within-subject correlations between OMNI-RPE and HR/$VO_2$ were calculated at each time point. Differences between correlations for consecutive time points were evaluated using 95% confidence intervals.

**RESULTS—**Among children aged 6–8 years at baseline, correlations progressed from 0.67 to 0.78 ($VO_2$) and 0.70 to 0.79 (HR) over 36 months. Among children aged 9–10 years at baseline, the mean within-subject correlation was 0.78 at baseline and 0.81 at 36–months follow up. Among children aged 11–12 and ≥13 years at baseline, OMNI-RPE ratings demonstrated strong validity (r≥0.82) at each time point.

**CONCLUSION—**Over the 36-months follow-up, OMNI-RPE scale validity improved among children aged 6–8 years at baseline, and remained strong among children aged 9–10, 11–12, and ≥13 years at baseline. Moderate correlations for the youngest participants suggest that caution should be used when interpreting OMNI-RPE reports from children younger than 8 years.

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**Conflict of Interest**
The results of the present study do not constitute endorsement by ACSM. All authors declare that they have no professional relationship with companies or manufacturers who will benefit from the results of present study.

### Keywords

Perceived Exertion; Heart Rate; Children; Adolescents

## Introduction

Rating of perceived exertion (RPE) scales provide a means of assessing perceptions of physical effort during exercise. The scales present a range of numbers, from which an individual selects the value reflective of the perceived intensity of exertion. Many RPE scales are based on an assumed linear relationship between reported values and physical activity intensity, whereby higher numbers will be reported during more intense physical effort (15). RPE scales are used regularly during exercise testing as a means of assessing the subjective wellbeing of participants (2). They are also used to describe the intensity of health-enhancing physical activity as part of exercise prescriptions. The extent to which individuals perceive and report a higher RPE during more intense exercise has implications for their ability to enact an RPE-based description of health-enhancing physical activity (7,11). Understanding how people interpret and report physical cues is important for establishing the utility of RPE scales in exercise and public health domains.

The concurrent validity of RPE scales is typically assessed by examining correlations between RPE and physiological indicators (such as heart rate [HR], oxygen uptake [$VO_2$], and respiratory rate). The Children's OMNI-RPE scale for walking and running is a widely used, pediatric RPE scale. Perceived exertion response options range from 0 to 10, and the scale includes illustrations and descriptive terms, which correspond to levels of physical effort. Initial validation was performed on 8–12 year-old children with correlation coefficients of 0.85–0.94 between RPE and HR and $VO_2$ (14). A number of studies have since evaluated the validity of the OMNI-RPE scale in age diverse samples of youth; correlations of 0.32–0.40 between OMNI-RPE and physiological indicators have been reported for 6–13 year-olds (19), while equivalent correlations of 0.94–0.99 have been reported for 12–15 year olds (1). Collectively, findings from these cross-sectional studies suggest stronger validity among older children, however, the very large or very narrow age ranges of participants and variation in the exercise protocols prevent conclusions about the influence of age on RPE scale validity being made.

A previous study by our research team systematically evaluated age-related differences in OMNI-RPE scale validity across four age groups of youth (6–8, 9–10, 11–12, and ≥13 years old; [10]). Participants performed a standardized protocol of 11 activity trials, permitting direct comparison of correlation coefficients across age groups. This study supported the notion of age-dependent validity, as progressive increases in correlation coefficients were observed with age. OMNI-RPE scale validity among 6–8 year olds (HR: 0.65 and $VO_2$: 0.67) was significantly weaker than the validity among 11–12 (HR and $VO_2$: 0.84), and ≥13 year old youth (HR: 0.86 and $VO_2$: 0.87). Similar to other existing RPE research in youth, our previous study employed a cross-sectional study design, and the next logical step in the research process was to examine how within-person correlations change over time, using a longitudinal study design. Thus, the purpose of this study was to examine age-related trends in the validity of the OMNI-RPE scale using a longitudinal study design. It was hypothesized that the mean within-subject correlations between RPE and physiological indicators (HR and $VO_2$) would increase over time, indicating stronger validity of the OMNI-RPE scale with age.

## Methods

### Participants

A total of 209 children and adolescents (48% male) enrolled in the study. Half were recruited by Michigan State University, and half were recruited by Oregon State University. In an attempt to recruit a sample balanced by age and sex, each site aimed to recruit 100 participants between the ages of 6–15 years (five boys and five girls of each age). The Institutional Review Boards of both universities approved the study protocol. Parental consent and child assent were obtained for all participants at each time point (baseline, 12-months, 24-months, 36-months). At baseline, participants ranged from 5.7–16.1 years-old; at 36 months follow up, participants ranged from 8.4–18.9 years-old.

### Protocol

Participants completed 11 standardized activity trials that were 5-minutes in duration, while wearing a portable metabolic analyzer and heart rate monitor; the protocol has been described in detail in an earlier publication (10,18). Eleven activity trials were completed over two laboratory visits scheduled within a 2-week period and repeated on an annual basis over a 3-year period. The activities completed during visit 1 were handwriting, a laundry task, throw and catch, an over-ground walk at a comfortable pace, and dance aerobics. A treadmill familiarization trial was provided at the end of visit 1. The activities completed during visit 2 were a computer game, sweeping up confetti, an over-ground walk at a brisk pace, basketball, running/jogging, and a brisk-paced walk on a treadmill. The activity trials ranged from sedentary to vigorous-intensity, and within each visit were completed in order of increasing intensity. This arrangement ensured that physiological measures recorded during each trial were not influenced by a previous, more intense activity trial. An exception was the brisk-paced walk on the treadmill (a moderate-intensity activity), which was completed after the running/jogging trial (a vigorous-intensity activity) during visit 2 (due to a logistical arrangement). In between trials, sufficient rest (5–10 minutes) was provided for HR and $VO_2$ to return to resting levels.

### Anthropometrics

Height was measured to the nearest 0.1cm using a wall-mounted stadiometer (Seca 222 or Harpenden). Two measurements were taken, and if not within 1.0 cm, a third was taken. Body mass was measured to the nearest 0.1kg using a Seca portable electronic scale (Seca 770). Two measurements were taken, and if not within 0.5kg, a third was taken. All participants removed shoes for measurements. Body mass index (BMI) was calculated from body mass and height ($kg/m^2$). BMI percentiles were calculated using SAS code from the Centers for Disease Control and Prevention (3).

### Physiological Data

$VO_2$ and HR during each activity were measured using the Oxycon Mobile (CareFusion, Hoechberg, Germany), a lightweight (950g) portable indirect calorimetry system, and a HR telemetry belt (Polar WearLink). A flexible facemask (Hans Rudolph, Kansas City, MO) held in place by a head harness covered the participant's nose and mouth. The mask was attached to a bidirectional rotary flow and measurement sensor (Triple V) to measure the volume of inspired and expired air, which was collected breath by breath. A sample tube running from the Triple V to the analyzer unit delivered expired air for the determination of $O_2$ and $CO_2$ content. Before each test, the Oxycon unit was calibrated according to manufacturer's guidelines. Flow control and gas calibration were performed using Oxycon's automated calibration system, with the $CO_2$ and $O_2$ analyzers calibrated against room air as well as to a reference gas of known composition (4% $CO_2$ and 16% $O_2$). The Oxycon Mobile has been shown to provide valid measures of oxygen uptake over a range of exercise intensities (16,17). To ensure the collection of steady state physiological data, HR and $VO_2$ data collected between minutes 2.5 and 4.5 of each activity trial were averaged by minute and used for data analysis. Attainment of a physiological steady state was confirmed in the first year of the study (Rice et al., 2015). RPE: Perceived exertion was assessed using the Children's OMNI-RPE scale for walking/running (14). Prior to the activity trials, the RPE scale was explained to the participants using the following instructions: "*Perceived exertion is how tired your body feels during exercise. Please use the numbers on the picture to tell us how your body feels when you are doing the activity. Look at the person at the bottom of the hill. If you feel like this person you will be "not tired at all", so you should point to the 0 (zero). Now look at the person who is at the top of the hill. If you feel like this person you will be "very, very tired", so you should point to number 10. If you fall somewhere in between, point to a number between 0 and 10. We want you to tell us how your whole body feels, and remember there are no right or wrong answers. Use both the pictures and the words to help you choose."* A verbal anchoring procedure is typical for explaining the use of RPE scales. To maximize the child's attention to, and understanding of the RPE scale instructions, the script was read to the child in a quiet space with few distractions. The child was also shown the RPE scale and given the opportunity to ask questions. RPE was reported immediately after completion of each five-minute activity trial.

## Statistical Analysis

Children were stratified into four age groups based on age at study enrollment: 6.0–8.99, 9.0–10.99, 11.0–12.99, and ≥13.0 years. Only participants with complete data for all four time points were included in the analyses. Validity was assessed by calculating within-subject correlations between OMNI-RPE and HR, and OMNI-RPE and $VO_2$ using data from the 11 activity trials. Participants missing data on more than three activity trials were excluded from the analyses. For each age group, within-subject correlations were averaged using the fisher-z transformation, and 95% confidence intervals were calculated using methods outlined by Zou (20). Correlation coefficients were interpreted using the following criteria: r=0.00–0.19: poor, r=0.20–0.49: weak, r=0.50–0.79: moderate, r=0.80–1.0: strong (6).

Changes in correlation coefficients between consecutive time points (12 months follow up – baseline, 24 months follow up – 12 months follow up, and 36 months follow up – 24 months follow up) and baseline and 36 months follow up, were evaluated for statistical significance using methods accounting for the dependent, non-overlapping nature of the correlation coefficients (20). In short, the difference between two correlation coefficients was calculated and confidence intervals were constructed around the difference. The confidence interval was examined for the inclusion of zero, indicative of a non-statistical change in correlation coefficient between time points.

## Results

Descriptive characteristics of the four age groups at baseline are shown in Table 1. Of the 209 enrolled participants, 138 provided sufficient HR and RPE data for all four years, and 160 provided sufficient $VO_2$ data for all four years. Loss of data was due to: (1) participant drop out over the 36-months follow-up (N=31), (2) participants missing one year of data or starting the study after baseline measurements (and therefore not providing 4 years of data; N=14), (3) equipment issues such an ill-fitting telemetry belt during data collection (N=4 for $VO_2$, N=26 for HR). The BMI percentiles indicate that on average, participants were a healthy weight for their heights.

The average within-subject correlation coefficients for RPE and HR, and RPE and $VO_2$ are shown in Table 2. Over the 36-months follow-up, the mean within-subject correlations for 6–8 year-olds at baseline were of moderate strength, and increased from r=0.70 to r=0.79 for HR and from r=0.67 to r=0.78 for $VO_2$. Among children aged 9–10 years at baseline, mean within-subject correlations demonstrated minimal change over the 36-months follow-up (progressed from r=≥0.78 to r=≤0.81). Among children aged 11–12 and ≥13 years at baseline, OMNI-RPE ratings demonstrated strong evidence of validity over time (r≥0.82). Statistical comparison of correlation coefficients for consecutive time points, and between baseline and 36 months revealed non-significant changes for all age groups.

## Discussion

This is the first study to examine age-related changes of RPE scale validity using a longitudinal study design. The purpose was to examine the notion of age-related validity of the OMNI-RPE scale across time using HR and $VO_2$ as criterion measures. It was hypothesized that the mean within-subject correlations between RPE and physiological indicators (HR and $VO_2$) would increase over time, indicating stronger validity of the OMNI-RPE scale with age. In support of this hypothesis, the average within-subject correlation between OMNI-RPE ratings and the physiological indices among 6–8 year-olds improved over the 36-months follow-up; however, this change was not statistically significant. Among children aged 9–10, 11–12 and 13 years or older at baseline, the correlation between OMNI-RPE ratings and the physiological indices remained strong across time points.

The study design provided a unique opportunity to compare the longitudinal findings to the cross-sectional age-group related differences at baseline. After 36-months follow-up, the average within-subject correlation for the 6–8 year old cohort approximated the average within-subject correlation among 9–10 year olds at baseline. Similarly, after 36 months of follow-up, the average within subject correlation for the 9–10 and 11–12 year old cohorts approximated the average within-subject correlations for 11–12, and ≥13 year olds at baseline. Hence, the longitudinal data are consistent with the cross-sectional age group findings. The trend for age-dependent validity may be due to more advanced cognitive maturation at older ages, which permits better understanding and interpretation of RPE scales and physical cues (5,9). Evidence also suggests that as children age there is a shift in the dominant sensory signal for RPE from the legs to cardiorespiratory factors (5,12,13). As the criterion measures in this study were indicators of cardiorespiratory effort, this may explain the stronger correlations between RPE and HR/$VO_2$ at later time points. The decline in validity coefficients observed among children aged ≥13 was unexpected, although the decrease was relatively small (-0.04) and indicated that validity remained at a high level. By the fourth time performing the study protocol, the oldest participants' interest level may have decreased and influenced how carefully they were willing to think about the RPE scale.

Previous studies have pooled data for all study participants and reported average between-subject correlations for the association between RPE and physiological indicators. While the use of within-subject correlations in the current study means it is difficult to compare to previous correlations, the coefficients for the 9–10, 11–12, and ≥13 year-olds are consistent with those reported by earlier cross-sectional studies (4,8). The correlations for 6–8 year-olds are higher (0.67–0.78) than those reported by previous cross sectional studies. For example, correlations of 0.26–0.60 between RPE and physiological indicators were reported for 6–13 year-olds during treadmill activities (19). The stronger correlations observed in the current study may be due to the variety of activity modes performed. It is likely that younger children have limited experience of treadmill-based exercise, and lower correlations in previous studies may reflect children's comfort with, or excitement for using the treadmill. The range of activities and calculation of within-subject correlations in the current study controlled for some of these individual differences and thus, the results are less subject to variation in skill level and fitness across participants.

A strength of this study is the longitudinal research design. This is the first study to examine age-related changes of RPE scale validity across time, and thus makes a unique contribution to the literature. An additional strength is the range of activities performed. The majority of studies examining RPE involve participants performing ergometer-based activities (walking/running and cycling), and this study extends the examination of RPE scale validity to a variety of activity modes. Limitations of this study include the loss of HR data due to ill-fitting equipment and that peak $VO_2$ and maximum HR data were not available to examine relationships between RPE and relative exercise intensity. Using relative measures can account for variation in physiological parameters such as maximum HR and $VO_2$ peak. By calculating and comparing within-subject correlations, however, we effectively controlled for any between-person or between-group differences in the relative intensity of the physical activity trials. Future studies should consider collecting peak $VO_2$ and HR data to permit the assessment of RPE scale validity using indicators of relative exercise intensity. In addition, while a standardized instructional RPE protocol was used, no further measures were taken to ensure participants' comprehension of the RPE concept.

In summary, overall results showed age-related trends in the validity of the OMNI-RPE scale across time. Findings provided support for previous results of cross-sectional studies indicating stronger RPE scale validity among older children. Given that the OMNI-RPE scale was designed for children ≥8 years-old, the results indicate that caution should be used when interpreting the OMNI-RPE reports of younger children. Research examining a measure of relative exercise intensity, in addition to testing of an effort production model, will further understanding of the influence of age on RPE scale validity.

## Acknowledgments

This study was supported by funding from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD R01 55400). The results of the present study do not constitute endorsement by ACSM. All authors declare that they have no professional relationship with companies or manufacturers who will benefit from the results of present study.

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**Table 1**

Descriptive characteristics of the sample at baseline

| | Sample with valid data for HR Analyses | | | | | Sample with valid data for $VO_2$ analyses | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Group (years)** | **N** | **Age (years)** | **Height (cm)** | **Weight (kg)** | **BMI percentile** | **N** | **Age (years)** | **Height (cm)** | **Weight (kg)** | **BMI percentile** |
| **6.0–8.99** | 39 | 7.6 (0.9) | 128.0 (7.1) | 28.9 (9.0) | 66.9 (19.9) | 44 | 7.6 (0.9) | 127.9 (7.1) | 28.6 (8.7) | 62.9 (23.3) |
| **9.0–10.99** | 36 | 10.0 (0.6) | 140.6 (6.8) | 36.7 (8.4) | 53.2 (25.0) | 40 | 10.0 (0.6) | 140.1 (6.7) | 36.3 (8.1) | 56.5 (24.4) |
| **11.0–12.99** | 28 | 12.0 (0.7) | 152.2 (7.1) | 46.1 (11.5) | 58.9 (29.0) | 36 | 12.0 (0.7) | 152.6 (8.1) | 46.7 (12.3) | 59.7 (31.1) |
| **≥13.0** | 35 | 14.1 (0.8) | 165.4 (8.5) | 59.5 (15.1) | 53.3 (29.4) | 40 | 14.1 (0.8) | 165.6 (8.4) | 58.8 (14.6) | 53.0 (28.2) |

Results reported as: mean (standard deviation)

## Table 2

Within-subject correlations between OMNI-RPE ratings and physiological indices ($VO_2$ and HR)

| | HR and OMNI-RPE | | | | $VO_2$ and OMNI-RPE | | | |
|---|---|---|---|---|---|---|---|---|
| **Group (years)** | **Baseline** | **12 months** | **24 months** | **36 months** | **Baseline** | **12 months** | **24 months** | **36 months** |
| **6.0–8.99** | 0.70 (.05–.93) | 0.70 (−.06–.95) | 0.77 (.25–.94) | 0.79 (.36–.95) | 0.67 (.02–.92) | 0.68 (−.02–.93) | 0.78 (.25–.95) | 0.78 (.35–.94) |
| **9.0–10.99** | 0.79 (.05–.97) | 0.80 (.19–.97) | 0.82 (.30–.96) | 0.80 (.23–.96) | 0.78 (.21–.96) | 0.77 (.01–.96) | 0.82 (.34–.96) | 0.81 (.25–.97) |
| **11.0–12.99** | 0.83 (.30–.97) | 0.85 (.43–.97) | 0.87 (.57–.97) | 0.87 (.57–.96) | 0.82 (.18–.97) | 0.84 (.46–.96) | 0.89 (.52–.98) | 0.88 (.47–.98) |
| **≥13.0** | 0.88 (.34–.98) | 0.90 (.53–.98) | 0.89 (.59–.97) | 0.85 (.23–.98) | 0.89 (.16–.99) | 0.91 (.47–.99) | 0.88 (.50–.98) | 0.86 (.36–.98) |

Results reported as: mean (confidence interval)