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Validation of the OMNI Rate of Perceived Exertion Color-Face Scale With Prescription Congruence and Intensity Discrimination in Laboratory and Field

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Abstract

Purpose

To develop and validate the OMNI RPE Color-Face Scale (CFS) on adults.

Methods

A total of 28 healthy participants were recruited for the study which involved scale development and validation. Scale development – participants matched facial illustrations, verbal descriptors and color blocks to a corresponding rate of perceived exertion (RPE) value on a vertical 0–10 scale, and semantic differential analysis (SDA) was carried out. In the validation segment, participants were randomly assigned to experimental group (EG) or control group (CG). During the estimation trial (ET), participants ran a discontinuous graded submaximal treadmill test with 4-minute work-rest cycle at 1% gradient until volitional exhaustion. In production trial (PT), participants ran three counterbalanced trials (RPE 2, 5 and 7) for 8-minute each, In the 3rd session, participants played a 30-minute modified soccer game. RPE and HR were recorded after each segment.

Results

SDA revealed verbal descriptors, colors and illustrations corresponded with increasing intensity of the OMNI CFS. Construct validity from ET indicated positive linear regression of OMNI CFS against control scale ($r = 0.88$, $p = 0.00$). Concurrent validity from PT was obtained with strong positive correlation with control scale for VO_2 ($r = 0.80$, $p = 0.00$) and HR ($r = 0.69$, $p = 0.00$). Prescription congruence was attained with no significant difference between ET and PT in HR ($p = 0.49$) and VO_2 ($p = 0.97$). Intensity discrimination indicated significant difference in VO_2 ($p = 0.65$) and HR ($p = 0.86$) between each increasing RPE. Significant differences were identified between warm-up and cool-down with game time in HR (warm-up: $p = 0.00$, cool-down: p = 0.00) and RPE (warm-up: $p = 0.00$, cool-down: p = 0.00).

Conclusion

OMNI CFS was well established, meeting the validation criteria for self-regulation in both indoor and outdoor settings.

Introduction

The perceived exertion scale has since been reinvented and modified in various ways by different individuals to serve the same purpose of estimating exercise intensity. The more widely used scales are Borg's 15-grade scale and Robertson's OMNI Rating of Perceived Exertion (RPE) Scale. Borg's 15-grade

scale was developed for the general public to measure physical strain. It contains numerals from 6–20, which represent the minimum and maximum heart rate (HR) of an individual when multiplied by 10, and includes seven verbal descriptors alternating on the number ratings (1). Contrastingly, Robertson's OMNI RPE scale was developed with the consideration of adults' and children's cognitive abilities (2, 3), and is also specific to exercise modality (e.g. running, cycling, resistance training etc.). The fundamental elements that make up an OMNI exercise scale are – four lateral full-body pictorial and six verbal descriptors positioned strategically on a diagonal 0–10 scale. Both the pictorial system and verbal descriptors are age-group-appropriate. Despite the earlier introduction of Borg's 15-grade scale, the results for assessing exercise intensity were less effective than the OMNI RPE scale, especially for different demographics (4, 5, 6, 7, 8, 9).

As Robertson justified, many younger children have difficulty interpreting verbal cues that are not part of their present vocabulary (3). Hence, the influence of age on spoken language ability played a major role in selecting different sets of verbal descriptors for both adult and children scales. Similarly, the grey scale pictorials on the OMNI RPE scale, illustrating the lateral side of individuals exerting different exercise intensities were also drawn according to the age group of the scale users. The reason for omitting colors from the scale was to "maximize generalization over normal variations in human skin tones" (3). Despite the lack of color, the simple yet effective tool has withstood the test of time for both exercise prescription and exercise intensity regulation.

Studies have presented results on the influence of colors on emotions and behavior during exercise, however, the addition of color to a perceived exertion scale has been minimally studied. In a study on visual color perception on perceived exertion conducted by Akers et al. (2012), the author identified green and red with lower and higher ratings of perceived exertion respectively (10). Serafim et al., (2014) imposed 11 colors on Borg's RPE scale which showed strong correlation with HR and VO_2 for the younger age group, but moderate to high correlation coefficients in HR for the older age group (11). Toh and Balasekaran's (2015) study of a four-color gradient bar on a 10-point RPE scale was validated by the adult population and results indicated a high correlation coefficient between HR and VO_2 with exercise intensity (12).

The inclusion of illustrations on the OMNI RPE scale was to aid children in the understanding of the scale as opposed to solely words and numbers (3). Pictorial scales are also used in clinical settings and are observed to have more advantages over verbal scales (13). It is more effective in engaging non-English speakers in reflecting their perceived effort during exercise (14, 15). A pictorial scale developed by Huang and Chiou (2013) revealed promising results of observers successfully mapping facial illustrations to individuals exercising at various intensities (16). With recent studies modifying the perceived exertion scale for greater ease of use, the OMNI RPE scale can be further modified for greater usability.

To date, no validated perceived exertion scale encompasses the use of color, verbal descriptors, and facial pictorials that are suitable for usage across exercises, different age groups, and health statuses.

The study aims to 1) develop a scale modified from Robertson's OMNI RPE by incorporating colors, replace full-bodied pictures with facial features expressing various exercise intensity levels and the use of simple vocabulary verbal descriptors; 2) validate the scale with construct and concurrent validation; and 3) validate the scale in an outdoor setting.

Methods

Participants

This study involved the recruitment of healthy adults to participate in the development and validation of the OMNI RPE Color Face Scale (CFS). Inclusion criteria of the study are: above 21 years of age; no present or history of musculoskeletal injury (i.e. sprain, strains or fracture); illness or disease for past 6 months; non-smoker; without color-blindness of any type (red-green, blue-yellow or total color blindness); participates in moderate physical activity at least three times a week and at least 1.5 hours per session (≥ 150 minutes of total moderate physical activity time per week); and ability to play a 30-minutes five-a-side soccer game. A total of 28 participants (Males: N = 14, Age: 29.36 ± 4.95 yrs, height: 1.74 ± 0.03m, weight, 71.11 ± 9.64kg, %BF: 19.66 ± 7.20; Females: N = 14, age: 25.21 ± 3.51yrs, height: 1.59 ± 0.06m, weight: 54.60 ± 8.26kg, %BF: 23.04 ± 5.21%) were recruited for the study with 14 participants per experimental group (EG) and control group (CG) (Table 1). The sample size was derived for the statistical power of 0.8, beta of 0.05 and effect size of 1.2. It was determined that a minimum of 12 participants were needed per group. The Institutional Review Board (IRB) of Nanyang Technological University had approved the investigation before the administration of the study (IRB-2020-05-037). This study does not meet the definition of a clinical trial and was not conducted in a clinical setting. All methods were performed in accordance with the relevant guidelines, regulations and Declaration of Helsinki.

Procedure

Pre-test Administration

Prior to the commencement of the intervention, the purpose, objectives, intervention protocols, commitment period, participant rights and reimbursement were communicated to the participant. All clarifications were addressed before participants read and signed on the informed consent to indicate their agreement to participate voluntarily in the research study. All participants were also required to complete a PAR-Q + to confirm their eligibility of health status.

Experimental Design

The experimental design of this study was divided into two segments - scale development and scale validation – where all participants were involved.

In the development stage, all 28 participants placed the elements of the CFS on a vertical 0–10 scale, and qualitative results were tabulated. For validation, construct and concurrent tests were conducted using an estimation and production trial respectively. Both validation sessions were laboratory-based and were carried out at least 48–72 hours apart. An outdoor session was conducted a few days after the laboratory sessions to validate the usability of OMNI RPE CFS in outdoor setting.

Participants were randomly assigned to either EG or CG where the groups used the OMNI RPE CFS and OMNI RPE scale respectively during both laboratory sessions. All participants were advised against vigorous physical activity, and no ingestion of caffeine 24-hour before any sessions. Adequate rest and hydration were encouraged before sessions.

Anthropometric and Body Composition Assessment

Participants' height was measured with a height machine (ID1 Plus, Mettler-Toledo, Albstadt, Germany). Measurement of weight and percentage body fat (%BF) were obtained using the Inbody 720 bioelectrical impedance analysis (InBody 720, Biospace Co, Seoul, Korea).

Scale Development – Semantic Differential Analysis (SDA)

The development of the OMNI RPE CFS required participants to match six verbal descriptors (not tired at all; a little tired; getting more tired; tired; really tired; very, very tired), four color blocks (red, orange, green and blue) and four facial expressions onto a 0–10 vertical scale. Each color block, verbal descriptors and facial illustrations were presented as cut-outs for the participants to place along the scale for the matching process. All cut-outs were placed randomly in front of the participants. The placement of each item was recorded. The mean and standard deviation and chi square of each element were tabulated to construct the OMNI RPE CFS.

Construct Validation using Estimation Trial

Participants ran a discontinuous graded exercise test (GXT) on a treadmill (Woodway ELG 70.200 Sport, Steinackerstr, Denmark). First, participants were anchored on the use of the OMNI RPE CFS or OMNI RPE scale depending on their assigned group. The memory anchoring method required the participant to think of a time when his/ her effort was exactly as depicted on the scale. The definition of perceived exertion and instructions to use the OMNI perceived exertion scale were read out to all participants, using those from Robertson's OMNI RPE Adult-Walk/run scale (17, 18). Participants warmed up for 5-minute on the treadmill at their preferred speed and stretched thereafter.

The GXT protocol is a progressive speed increment protocol with a 1:1 work-rest ratio at 4-minute per work and rest stage. The treadmill speed increased by $0.5 km \cdot h^{-1}$ per work stage and treadmill gradient was kept at 1% throughout. All gas exchanges were determined using an open-circuit respiratory-metabolic cart (ParvoMedics TrueOne 2400, ParvoMedics, Sandy, Utah, USA).

Both RPE and HR were manually recorded during the last 15-second of each work stage. The perceived exertion scale was in full view of the participants throughout the test, and they gestured their perceived exertion to the researcher when prompted. During each rest stage, blood lactate was taken via the finger prick method and analysed immediately using the YSI biochemistry analyzer (2500 Glucose/Lactate Anlyzer, YSI Xylem, Yellow Springs, OH, United States). The test terminated when two of the standard criteria were obtained: 1) a peak or plateau in oxygen consumption (changes of less than 2 $mL \cdot kg^{-1} \cdot min^{-1}$), 2) a Respiratory Exchange Ratio of ≥ 1.1, and 3) achieving an age-estimated maximum HR (220 $beats \cdot min^{-1}$ – age).

Concurrent Validation using Production Trial

Participants were read the instructions for the OMNI perceived exertion scale and the protocol for the session, followed by a 5-minute warm-up on the treadmill at their preferred speed, and some stretches afterward.

Participants ran three bouts of 8-minute with 90-second of active rest between each bout. Each 8-minute run required participants to produce three different exercise intensity – RPE 2, 5 and 7, at self-selected speed while using the respective RPE scale to assist them in identifying the exertion level. Participants were randomly assigned to reproduce in an ascending (RPE 2, 5 then 7) or descending (RPE 7, 5 then 2) order. The order of production was counterbalanced across participants within groups. The treadmill speed was maintained at $1 km \cdot h^{-1}$ during rest stage, and treadmill gradient was maintained at 1% throughout.

For each bout of 8-minute, participants were given 3-minute to adjust their self-selected speed (adjustment phase) and maintain the self-selected speed for the next 5-minute (maintenance phase). At the last minute of the adjustment phase, participants were informed and a countdown of 10-second was given to signal the start of the maintenance phase. The perceived exertion scale was in full view of the participant throughout the test. Both HR and RPE were recorded at the last 15-second of each minute during each trial. Participants were unaware of the speed throughout the session.

Outdoor Session

During the outdoor session, all participants were anchored on the use of the OMNI RPE CFS. During the 30-minute session, participants were instructed to self-regulate their exercise intensity within the assigned range. For warm-up and cool-down, the RPE range was 1–4 and game time at RPE 5–7. The warm-up and cool-down segments were 5-minute each and 20-minute for the game time. All participants wore an HR transmitter across their chest and a Polar HR watch on their wrist. Participants were notified the last 10-second before the end of each segment for them to record their RPE and HR on the record sheet provided.

Data Analysis

All analysis were performed using an SPSS for Windows statistical package (SPSS, Inc., Chicago, IL.) A $p < 0.05$ was used for all significant differences. The sample size was derived for the statistical power of 0.8, beta of 0.05 and effect size of 1.2. It was determined that minimal 12 participants were needed per EG and CG.

Descriptive Characteristics

All descriptive characteristics such as age, height, weight, %BF were calculated as means ± standard deviation (SD). Characteristics were compared between EG and CG using independent t-test.

Semantic Differential Analysis

Frequency count and chi-square test of independence were used to identify the association between every item of each element with the corresponding RPE.

Construct and Concurrent Validation

For construct validation, linear regression was carried out with RPE from both OMNI RPE and OMNI RPE CFS. For concurrent validation, two separate regression analysis was carried out for VO_2 and HR against RPE.

Prescription Congruence Analysis

A three-factor (2 X 2 X 2) ANOVA on exercise trials (estimation and production trial), and RPE (RPE 2, 5 and 7) and gender (male and female) was used to examine prescriptive congruence on HR and VO_2.

Intensity Discrimination Analysis

A three-factor (2 X 2 X 2) ANOVA with repeated measures RPE (RPE 2, 5 and 7), order (ascending and descending) and gender (male and female) was used to determine intensity discrimination from the production trial. Analysis for HR and VO_2 were conducted separately. In the event of where RPE 2, 5 and/ or 7 was/ were not present from the estimation trial, a separate regression line of RPE against HR and VO_2 was plotted to derive the estimated HR and VO_2 of the RPE (19, 20).

Outdoor Self-regulation Analysis

Both HR and RPE recorded at different segments (warm-up, game, and cool-down) were compared using ANOVA with repeated measures.

Results

No significant differences were observed between the same genders from different groups in all characteristics ($p > 0.05$) (Table 1).

Table 1
Descriptive Characteristics of Participants by Trial Group and Gender

Variables	Experimental (n = 14)		Control (n = 14)	
	Males	Females	Males	Females
N	7	7	7	7
Age (years)	30.29 ± 4.86	24.71 ± 4.07	28.43 ± 5.62	25.71 ± 3.40
Height (m)	1.76 ± 0.03	1.56 ± 0.07	1.73 ± 0.03	1.62 ± 0.05
Weight (kg)	71.21 ± 7.06	53.24 ± 8.30	71.01 ± 12.93	55.96 ± 9.28
BMI ($kg{\cdot}m^{-2}$)	22.94 ± 1.98	21.69 ± 2.51	23.84 ± 4.22	21.26 ± 2.42
%BF (%)	20.93 ± 7.54	22.51 ± 5.95	18.39 ± 7.78	23.56 ± 5.22
VO_{2max} ($L{\cdot}min^{-1}$)	3.06 ± 0.46	2.15 ± 0.28	3.07 ± 0.53	2.32 ± 0.49
VO_{2max} ($ml{\cdot}kg^{-1}{\cdot}min^{-1}$)	42.90 ± 4.48	40.64 ± 3.33	44.03 ± 4.08	41.25 ± 4.22

m: meters, kg: kilograms, $kg.m^{-2}$: weight per height square, %: percentage, $L{\cdot}min^{-1}$: liters per minute, $ml{\cdot}kg{\cdot}min^{-1}$: millilitres per kilograms per minute, BMI: body mass index, %BF: percentage body fat, VO_{2max}: maximal oxygen uptake

^Indicates significant difference between males of EG and CG at $p < 0.05$

&Indicates significant difference between females of EG and CG at $p < 0.05$

Semantic differential analysis. Face 1 has the lowest variety of RPE ratings (RPE 7, 8, 9 and 10), followed by face 4 with four different RPE ratings (RPE 0, 1, 2 and 3). Faces 2 and 3 both have six (RPE 1, 2, 3, 4, 5 and 6) and five (RPE 6, 7, 8 and 9) different RPE ratings respectively. The RPE with the highest percentage for faces 1, 2, 3 and 4 are RPE 0 (53.6%), RPE 4 (42.9%), RPE 7 (46.4%) and RPE 10 (46.4%). All the highest frequency count are close to 50% of the total.

Chi-square test of independence indicated a significant association between facial expression and RPE indicated ($x(30) = 253.47$, $p = 0.00$). Chi-square test of independence indicated significant association between color and RPE indicated ($x(30) = 212.952$, $p = 0.00$). Chi-square test of independence indicated significant association between verbal descriptors and RPE indicated ($x(50) = 491.692$, $p = 0.00$).

Results from the above derived the following OMNI RPE CFS (Fig. 1).

Construct validation. A linear function plot with ratings from OMNI RPE CFS against ratings from OMNI RPE were used from the estimation trial. Significant similarity was observed in cohort ($p = 0.00$) with high correlational coefficient ($r = 0.88$) (Table 2).

Table 2
Regression analysis of OMNI RPE CFS expressed as a function of OMNI RPE Adult-Walk/run scale

OMNI RPE Adult-Walk/run scale criterion	OMNI RPE Color-Face Scale Predictor					
	Slope	SEE	Intercept	*r*	r^2	Sig
Overall	0.86	1.27	1.11	0.88	0.78	0.00
RPE: Rating of Perceived Exertion, SEE: Standard error of estimate						

Concurrent validation was obtained with separate linear function plot of VO_2 and HR against ratings from OMNI RPE obtained from estimation trial (Table 3). Results showed significant positive linear regression for cohort for both VO_2 and HR ($p = 0.00$). High coefficients were obtained from VO_2 ($r = 0.80$) and HR (r = 0.69).

Table 3
Regression analysis of oxygen uptake and heart rate express as a function of OMNI RPE CFS

Variable							
Criterion	RPE Predictor	Slope	SEE	Intercept	*r*	r^2	Sig
VO_2	Overall	0.16	0.33	1.10	0.80	0.65	0.00*
HR	Overall	6.28	18.06	118.42	0.69	0.47	0.00*
VO_2: oxygen uptake, HR: heart rate, RPE: Rating of Perceived Exertion; SEE: standard error of estimate							
*Indicates significance of regression at $p < 0.05$							

Prescription Congruence. No significant differences were observed between estimation and production trial in VO_2 and HR for each assigned RPE (Figs. 2 and 3) ($p < 0.05$). No significant differences were observed for HR and VO_2 between estimation and production when compared at RPE 2, 5 and 7 based on the ANOVA (intensity * session) analysis ($p < 0.05$). Analysis by session (estimation and production trial), RPE (RPE 2, 5, 7) and gender (male and female). The analysis of intensity main effect was significant for HR ($F = 31.84$, $p = 0.00$) and VO_2 ($F = 53.90$, $p = 0.00$). The main effect of session was not significant for HR ($F = 0.05$, $p = 0.82$) and VO_2 ($F = 0.79$, $p = 0.38$) which indicated no influence of assigned session for HR and VO_2 produced. The main effect for gender was significant for HR ($F = 24.35$, $p = 0.00$) and VO_2 ($F = 44.34$, $p = 0.00$) which indicated gender influence in HR and VO_2 produced.

No significant difference was observed in the interaction of intensity * session [HR ($F = 0.40$, $p = 0.68$), VO_2 ($F = 0.03$, $p = 0.97$)], intensity * gender [HR ($F = 1.01$, $p = 0.37$), and session * gender [HR ($F = 0.54$, $p = 0.46$), VO_2 ($F = 1.20$, $p = 0.23$). Significant difference was observed in VO_2 (F = 4.23, $p = 0.02$) in the intensity * gender interaction. No significant difference was observed in the three-way interaction of

intensity * session * gender in HR ($F = 0.73$, $p = 0.49$) and VO_2 ($F = 0.03$, $p = 0.97$). Significance difference was observed in Mauchly's Test of Sphericity of repeated measures with sphericity assumed for both HR ($p = 0.00$) and VO_2 ($p = 0.00$).

Both VO_2 and HR did not differ significantly between the ET and PT sessions based on the ANOVA session * RPE * gender ($p < 0.05$).

Intensity discrimination. Analysis by RPE (RPE 2, 5 and 7) and order (ascending and descending) and gender (male and female). The main effect for intensity showed significant difference in HR ($F = 12.77$, $p = 0.00$) and VO_2 ($F = 21.00$, $p = 0.00$) which indicated significant difference in HR and VO_2 between each increasing RPE assigned. The main effect for order showed no significant difference in HR ($F = 1.67$, $p = 0.21$) and VO_2 ($F = 3.91$, $p = 0.06$) which indicates no influence of assigned order for RPE produced. The main effect for gender showed significant difference in HR ($F = 9.48$, $p = 0.00$) and VO_2 ($F = 17.51$, $p = 0.00$).

No significant difference was observed in the interaction of intensity * order [HR ($F = 1.29$, $p = 0.29$), VO_2 ($F = 0.10$, $p = 0.91$)]; intensity * gender [HR ($F = 0.23$, $p = 0.80$), VO_2 ($F = 1.48$, $p = 0.24$)], order * gender [HR ($F = 1.34$, $p = 0.26$), VO_2 ($F = 0.01$, $p = 0.91$)]. The three-way interaction between intensity * order * gender had no significant difference in HR ($F = 0.16$, $p = 0.86$) and VO_2 ($F = 0.44$, $p = 0.65$). Significance was observed in Mauchly's Test of Sphericity of repeated measures with sphericity assumed for both HR ($p = 0.03$) and VO_2 ($p = 0.00$).

Both HR and VO_2 did not differ significantly between the ascending or descending mode in the RPE * order* gender ANOVA analysis ($p < 0.05$).

Significant differences were observed between each increasing RPE ($p < 0.05$) in both HR and VO_2. An increment of 19.43beats·min^{-1} and 0.46 L·min^{-1} between RPE 2 and 5 for HR and VO_2 was observed. An increment of 10.75 beats·min^{-1} and 0.30 L·min^{-1} between RPE 5 and 7 for HR and VO_2 was observed (Fig. 4).

Outdoor self-regulation. ANOVA repeated measures identified significant difference between warm up, activity and cool down in both RPE ($F = 1.87$, $p = 0.00$) and HR ($F = 1.89$, $p = 0.00$) Pairwise comparison showed no significant difference between warm-up and cool-down in RPE (warm-up: 1.45 ± 0.87, cool-down: 1.85 ± 1.01, $p = 0.05$) and HR (warm-up: 150.55 ± 14.46. cool-down: 114.35 ± 12.73 $p = 0.17$).

Discussion

Scale Development – Semantic Differential Analysis

Results obtained showed that participants gave similar ratings for each color, image and verbal descriptor. Although the verbal descriptors used were those from the Children's OMNI Perceived Exertion

Scale identified by Robertson, the adults were able to distinguish intensity from the terms. This suggests that the cognitive ability of the adults was sufficient to understand the meaning behind the matched phrases. Contrastingly, in the reverse situation, children may not be able to distinguish the varying differences of the adults' set of verbal descriptors due to their exposure to the language and learning development phase (21, 3).

Participants were also able to identify and match the facial illustrations depicting increasing exercise intensity to a corresponding RPE. The possibility is supported by the study conducted by Huang & Chiou (2013) and Robertson et al. (2000) whereby observers were able to determine the exercise intensity of participants through observation (16, 17). Huang & Chiou's study required participants to rate exercisers' perceived exertion using a scale of facial illustrations, whereas Robertson's study had participants rate exercisers' perceived exertion using the OMNI RPE scale. In Robertson's study, the high correlation between participant and observer-rated RPE was attributed to the observer's extensive experience in perceived exertion scaling. However, the observers of Huang & Chiou's study, did not fit the profile description of Robertson's. This shows that inexperienced observers can identify and discriminate exercise intensity through the changes in the features of a person performing the exercise at various intensities.

The RPE colors are generally clustered within a small range. The highest frequency for blue, green, yellow and red are RPE 0 (42.9%), RPE 3 (35.7%), RPE 7 (39.3%) and RPE 10 (42.9%) respectively. This is supported by research indicating the influence of color on emotions as well as learning (10, 22). The color bar was set to gradient mode to reflect the transitioning of intensity between each increasing RPE.

Scale Validation

Both construct and concurrent validation results were obtained from the estimation and production trial respectively.

Construct validity was established using OMNI RPE Adult-Walk/run scale as the criterion metric. It was hypothesized that the RPE derived from the OMNI RPE CFS would be positively correlated with the criterion measure (i.e., ratings from OMNI RPE Adult-Walk/run scale) when obtained from the same GXT protocol. Results from this study supported the hypothesis, hence establishing construct validity for the OMNI RPE CFS. The validity coefficient obtained ranged between $r = 0.74–0.99$. In comparison with the other construct validation studies conducted on OMNI RPE scales, results from this study showed similarity across different exercise types and age groups (23).

Concurrent validity which is a form of measure for the new assessment against one that is respectable and well-established. In this study, HR and VO_2 were used as criterion measures. given its long acceptance as a standard procedure for validating perceived exertion scales (2, 3, 24). The importance of concurrent validity indicates the agreement between two assessments by using a respectable and established assessment (i.e., HR and VO_2) to validate the other (i.e., OMNI RPE CFS). Therefore, the

similarity between the two assessments indicates the degree of concurrent validation (25). With a cohort measure of $r = 0.80$ and $r = 0.69$ for VO_2 and HR for this study, concurrent validity is established.

Prescription Congruence and Intensity Discrimination

Prescription congruence is achieved when the assessed physiological responses (i.e., HR and VO_2) did not differ between the estimation and production trial (26). Suggested by Haile, Gallagher & Robertson (2015), an established prescription congruence is also an indicator of self-regulation ability (27). Results from the study established both prescription congruence with no significant difference observed in both HR and VO_2 between estimation and production trial across cohort ($p < 0.05$). The result also indicated that the sequence assigned (i.e., ascending or descending) did not influence the results. A few studies have validated the use of OMNI RPE scales to observe for ability to self-regulate. Dunbar's study which used treadmill and cycling showed prescription congruence at 50% VO_{2max} (28). Other studies conducted on PC showed accuracy in high and moderate $\%VO_{2max}$ (21, 29). Results of PC supports the hypothesis that males and females can reproduce the dependent variables (HR and VO_2) during production trial and there is no significant difference in HR and VO_2 when compared at low and moderate RPE. This also reflects self-regulation ability regardless of gender.

Intensity discrimination is the analysis of HR and VO_2 of the user on three RPEs (RPE 2, 5 and 7). It is hypothesized that HR and VO_2 will be higher at each increasing RPE which corresponds with exercise intensity. Results from this study established intensity discrimination with significant differences observed between each increasing RPE, which was not influenced by order of reproduction (i.e., ascending or descending) or gender. However, in Schafer's study on reproducibility at 50% and 70% of VO_{2max} at randomized order, his participants were unable to reproduce in the descending mode (30). He attributed it to participants using the lower of the two targets $\%VO_{2max}$ as warm-up which was absent for those in assigned descending order. Robertson's cycling study with analysis of the interaction between reproduction sequence, intensity, and gender also showed boys' and girls' ability to self-regulated regardless of the sequence of reproduction (19). As such, intensity discrimination across gender, exercise intensity, and mode of production is established with the OMNI RPE CFS.

Self-Regulation of Exercise Intensity in Outdoor Setting

The last hypothesis of the study read that all participants can self-regulate their perceived exertion according to the assigned zones during the outdoor activity. Results from this study support the hypothesis with participants regulating their warm-up and cool-down between RPE 1–4 and at RPE 5–7 when engaging in the activity. Both HR and RPE showed significant differences between warm-up and cool-down with the activity (warm-up: 1.45 ± 0.87, cool-down: 1.85 ± 1.01, $p = 0.05$) and HR (warm-up: 150.55 ± 14.46. cool-down: 114.35 ± 12.73 $p = 0.17$). Other outdoor studies using the Robertson OMNI Adult-Walk/run scale also showed similar trends of ability to self-regulate within prescribed RPE zones. In a study involving female soccer university students, their HR and RPE were similar in two outdoor games. Significant difference was observed between their cool-down and warm-up with their 30-minute

game (31). Other field studies involving adolescents also agree with the results of the study (18, 31, 33). Hence, this further substantiates the fact that users understood how to use the OMNI RPE CFS scale to assist them in regulating their perceived exertion in an outdoor environment where HR and perceived exertion are influenced by many external factors (e.g., heat, play area, peer's fitness level, etc.).

Conclusion

The validity of the OMNI RPE CFS has been covered extensively on many levels in this study. From the stage of scale development, the items generated ensured suitability for users of different cognitive abilities which explains the combination of colors, picture system and child-friendly verbal descriptors on a 0–10 scale. Next, potential users were involved in by matching each color, facial illustration and verbal descriptor to a corresponding RPE value to construct the OMNI RPE CFS.

In a controlled laboratory setting to prove validity, the OMNI RPE CFS was randomly assigned to participants to establish construct and concurrent validity through the estimation and production trial respectively. The OMNI RPE CFS had been scientifically proven to be suitable and safe for self-regulatory and prescription use. The established prescription congruence and intensity discriminations reflected users' ability to distinguish and hence reproduce the assigned exercise intensities while using the OMNI RPE CFS. Results from the ANOVA with repeated measures also indicated that results from the production trial were not influenced by gender or order of assigned RPE. Furthermore, the scale allowed participants to effectively regulate their perceived exertion within the assigned range as observed in the outdoor activity. The ecological validity of the use of OMNI RPE CFS from laboratory settings to outdoor settings is extended.

In summary, it is valid for OMNI RPE CFS to be used for self-regulation and by practitioners to monitor exercise intensity in mass setting. Potential users can use the four elements (color, pictorial system, numbers and verbal descriptors) individually or in combination to assist them in estimating their perceived exertion for any intended activity. Physical education teachers, sports practitioners and coaches may utilize the OMNI RPE CFS during physical activities, workouts and training sessions to monitor their students and/or athletes exercise intensity. Exercising or training within the optimal zone of RPE 5–7 may reap cardiovascular benefits while reducing the risk of sustaining injuries.

Declarations

Conflict of interest

The authors declare that they have no conflict of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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Author Contribution

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Data Availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Figures

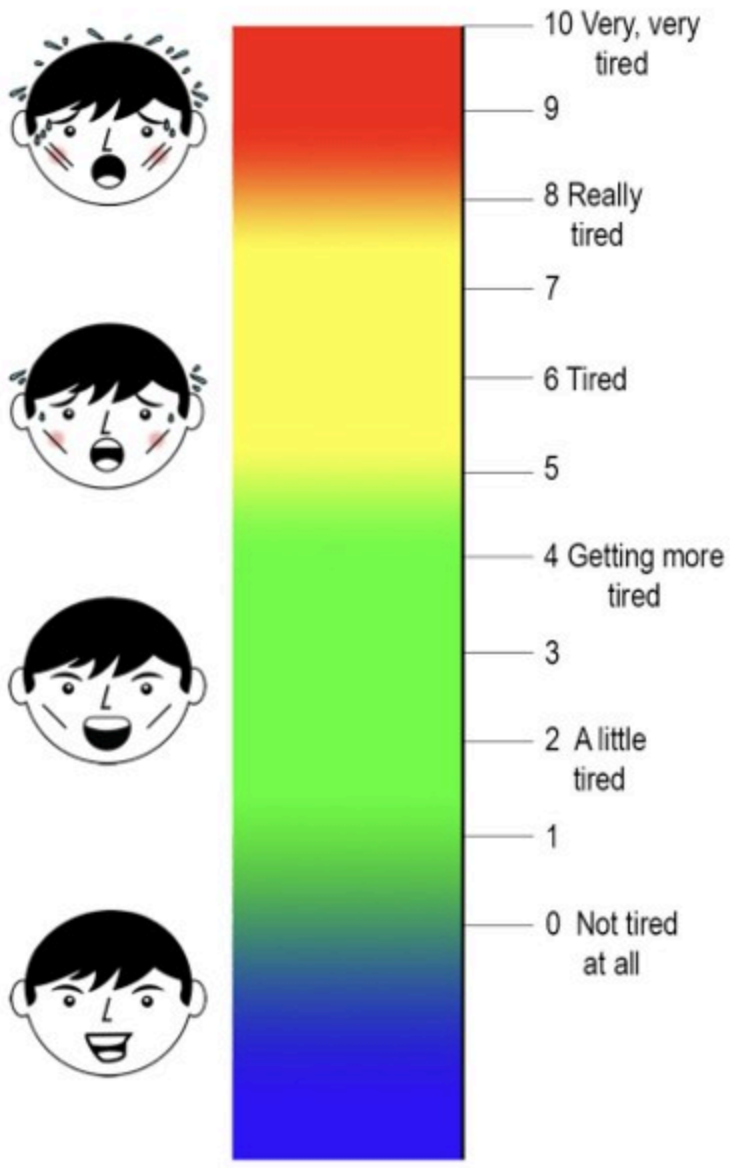

Figure 1

OMNI Rate of Perceived Exertion Color Face Scale

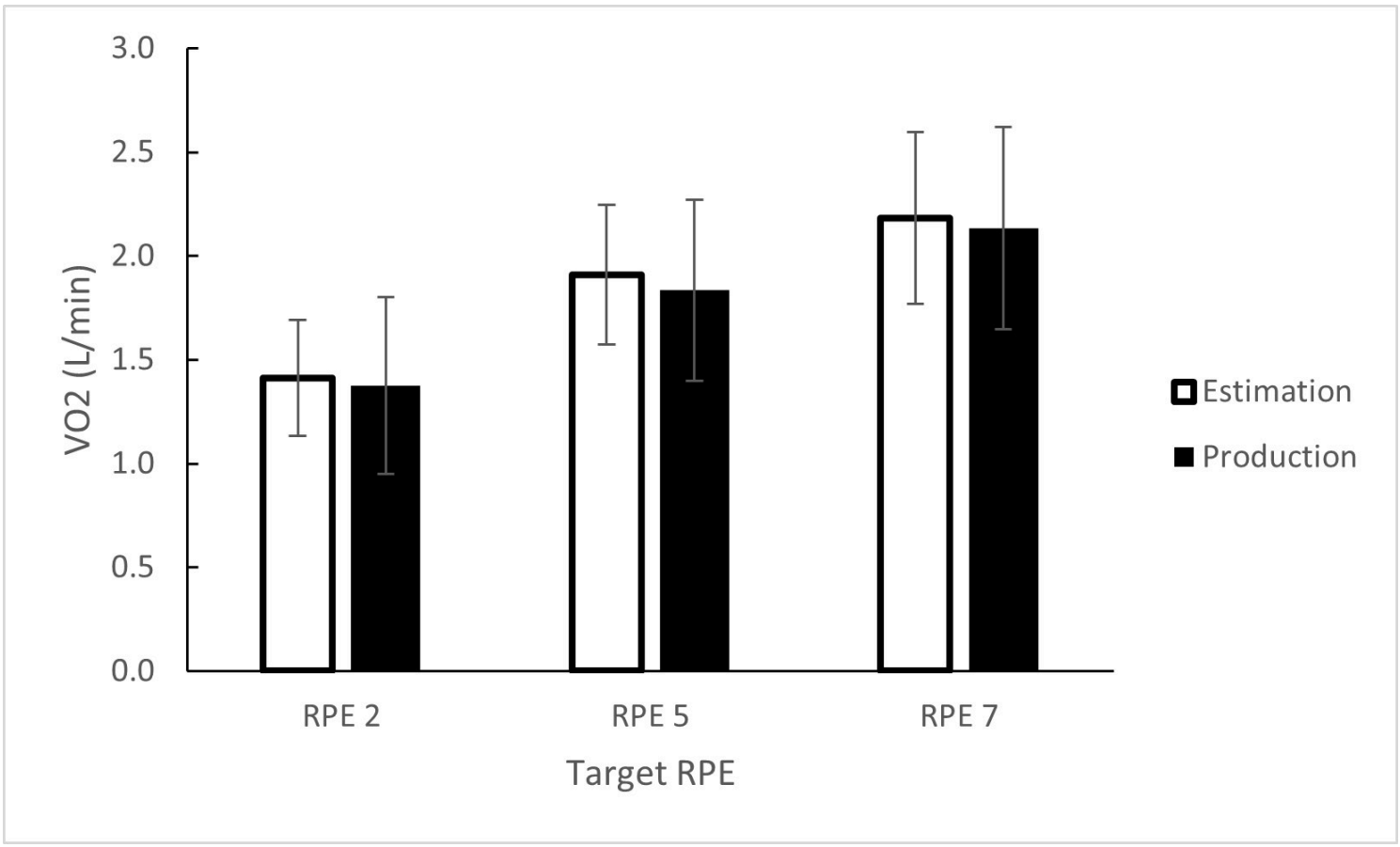

Figure 2

Comparison of oxygen uptake between estimation and production trial from experimental group. Data are means ± SD. Values of oxygen uptake are averaged across participants of experimental group. *Indicates significant difference between production and estimation trial at $p < 0.05$

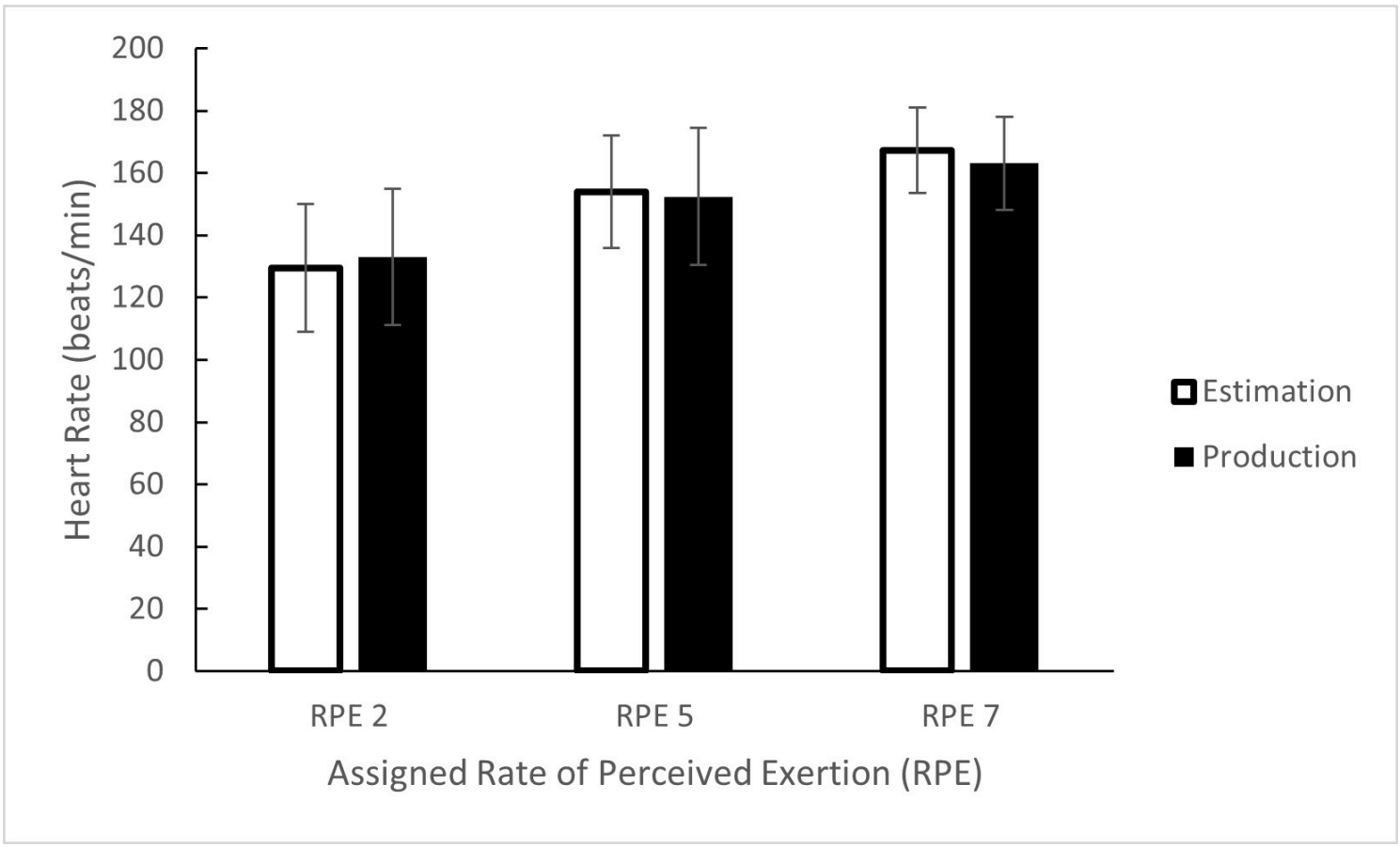

Figure 3

Comparison of heart rate between estimation and production trial from experimental group. Data are means ± SD. Values are averaged across participants of experimental group. *Indicates significant difference between production and estimation trial at $p < 0.05$

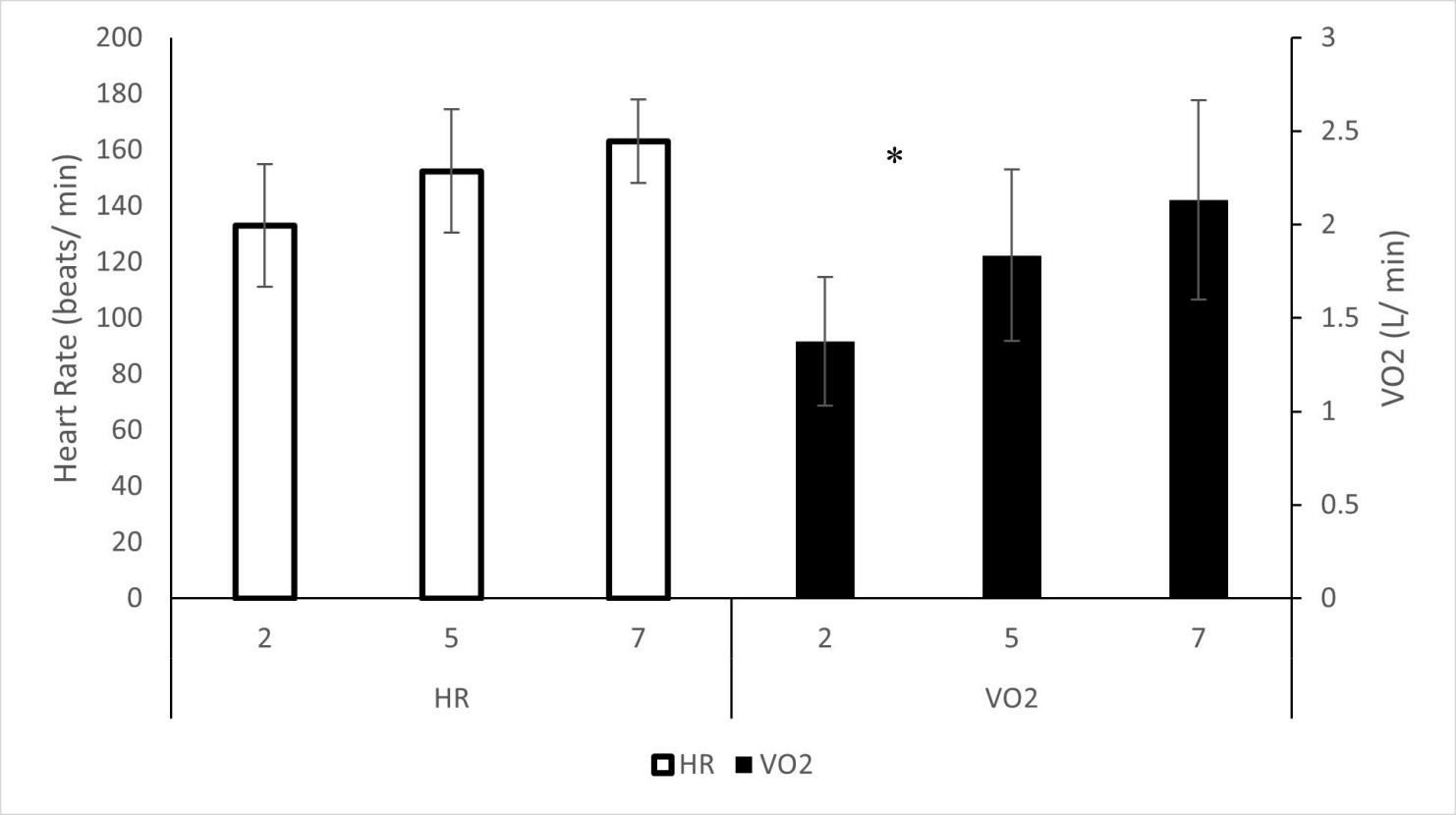

Figure 4

Comparison of oxygen uptake and heart rate responses between different RPE during production trial. Values of oxygen uptake and heart rate were averaged across participants of experimental group. Data are means ± SD. *Indicates significant difference between RPE 2 and 5 at $p < 0.05$. #Indicates significant difference between RPE 5 and 7 at $p < 0.05$