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COMPARISON OF TWO RATING OF PERCEIVED EXERTION SCALES FOR EVALUATING TRAINING

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Clinical Exercise Physiology

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By Blaine E. Arney

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology

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ABSTRACT

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The Borg 6-20 Rating of Perceived Exertion (BORG-RPE) and Category-Ratio 10 (BORG-CR10) scales are the most well-known and widely used Rating of Perceived Exertion (RPE) scales in the field of exercise. However, no studies have compared the scales directly. **PURPOSE:** To compare the BORG-RPE and BORG-CR10 on an intraindividual level in varying training sessions using concurrent validity, verbal anchor and numerical categorical comparisons. **METHODS:** Fourteen subjects completed an initial maximal incremental exercising testing to determine maximal physiological values. Subjects then participated in six, varying intensity (two easy, two moderate, two hard), interval exercise sessions. The BORG-RPE and BORG-CR10 were used separately on different occasions for each exercise intensity. Regression analysis was used to determine concurrent and construct validity of the two scales. **RESULTS:** A strong non-linear correlation was identified between the two scales (r = .95). Strong, linear correlations were identified between both scales and heart rate [BORG-RPE (r = .85); BORG-CR10 (r = .83)]. Good, linear correlations were identified between both scales and blood lactate [BORG-RPE (r = .74); BORG-CR10 (r = .78)]. **CONCLUSION:** A high degree of equivalence and interchangeability was identified between the BORG-RPE and BORG-CR10 for perceived effort during exercise training.

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INTRODUCTION

Adaptation to exercise is highly influenced by three prescription components of exercise, frequency, duration and intensity. Of these three, intensity is considered to be the most complex, and most important. According to the American College of Sports Medicine (ACSM), exercise at less than a minimum intensity will result in little to no change in an individual's physiological parameters (Riebe, Ehrman, Liguori, Magal, 2017). For these reasons, it is understood that methods for determining and monitoring exercise intensity are of great importance to exercise prescription.

Objective physiological measurements related to exercise intensity include heart rate (HR), oxygen consumption (VO_2) and blood lactate (BLa). These measurements provide individualized, objective data that can be easily compared on an interindividual level. However, VO_2 and BLa measurements require proper equipment and specialized personnel that are not easily accessible. For this reason, HR has become the physiological measurement of choice for most prescription purposes. However, due to the relatively large standard error with age predicted HR methods, dependence on HR monitoring equipment and large intraindividual variations of HR due to ambient temperature, psychological stress, caffeine, medications and changes in cardiorespiratory fitness (CRF), using HR as a prescriptive tool for exercise intensity can be impractical (Noble & Robertson, 1996). For this reason, subjective measures of intensity, such as Rating of Perceived Exertion (RPE), are becoming preferred.

The two most commonly used RPE scales to date are the Borg 6-20 RPE scale (BORG-RPE) and Borg CR-10 scale (BORG-CR10) (Noble & Robertson, 1996). Both scales are of practical value for RPE, but have considerably different constructs. Since the development of these scales, much debate has arisen concerning which should be the preferred method for exercise prescription. Both have been shown as valid measures of intensity (Borg, 1998; Noble, Borg, Jacobs, Ceci, Kaiser, 1983; Chen, Fan, Moe, 2002; Scherr et al., 2013). To investigate this question further, the construct and purpose of the two scales must be taken into consideration.

Borg initially created the first scale to be globally utilized for the purpose of measuring perceived exertion, the BORG-RPE (Borg, 1998). This scale was created with the intention of providing a relatively easy to use scale that accurately represented the linear relationship between HR and work load (Borg, 1982). The BORG-RPE is a 15-grade category scale with a numerical range from 6-20. Categorical verbal anchors are placed at corresponding numerical values to provide intersubjective meaning and structure to the scale. These verbal anchors range from “No exertion at all” corresponding with a 6 to “Maximal exertion” corresponding with a 20.

The BORG-RPE was successful in representing interval data such as HR and VO_2 due to its linear function. However, it did not represent the curvilinear function of perceptual and physiological variables observed during exertion, such as BLa and pulmonary ventilation (V_E) (Noble & Robertson, 1996). In response, Borg created the BORG-CR10. The BORG-CR10 is a category-ratio scale with a numerical range of 0-10, but is constructed with no perceptual cap. This is denoted by the 11 and dot after the number 10 on the scale and allows individuals to rate perceptual exertion past 10. This is a result of the idea that most individuals exercise with a physiological reserve (Swart et al., 2009). Due to the perceptual comparison to past experiences to determine present levels perceptual exertion, it is always possible that an individual can exercise to a higher perceptual intensity than previously experienced. The scale also has categorical verbal anchors placed with corresponding values to add meaning and structure to the scale (Borg, 1990). Verbal anchors range from “Nothing at all” corresponding with a 0 to “Absolute maximum” signified by the dot.

In an effort to directly compare the scales, Borg (2001) compared the BORG-RPE and BORG-CR10 using 1-minute stage increment cycle tests to determine altered scale rating habits as a result of the short duration stages with each scale. The correlation between HR and the BORG-RPE scale was r=0.78, whereas HR and the BORG-CR10 was r=0.59. A transformation equation was derived for the BORG-RPE and BORG-CR10 based on interindividual data which allows scale ratings from one scale to be transformed to the other. Furthermore, Borg & Kaijser (2006), using similar methods, reported HR as the largest contributing factor to BORG-RPE ratings, whereas both BLa and HR were reported as largest contributing factors to BORG-CR10 ratings. Due to the specific constructs of each scale, these studies demonstrate supporting evidence of the purposes for each. Although both studies compared the scales in incremental exercise and showed general congruence among the scales, these comparisons were conducted on an interindividual level. No current studies have investigated the BORG-RPE and BORG-CR10 on an intraindividual level in exercise training regarding scale equivalence. This is of importance to determine intrarater variability when comparing the two scales. Additionally, it is also of interest and importance to determine the interchangeability of the two scales. Currently, the only proposed literature for BORG-RPE and BORG-CR10 interchangeability and transformation is presented by Borg (1998) and Borg (2001) in the form of a scale transformation table and equation. The scale transformation table has not been verified by supporting literature. Therefore, the purpose of this study was to compare the BORG-RPE and BORG-CR10 on an intraindividual level during training bouts of varying intensity using concurrent validity, verbal anchor and numerical categorical comparisons. It was hypothesized that there would be a regular and predictable pattern between ratings using the same scale.

METHODS

Subjects

The subjects for this study were 14 recreationally-active, apparently healthy men and women ages 18-30, each performing at least 30 minutes of moderate exercise, 3 times a week. American College of Sports Medicine risk stratification procedures were conducted for each subject. This included completion of the American Heart Association Health/Fitness Pre-Participation Screening form by each subject to determine contraindications to participation. Written informed consent was provided by each subject prior to testing. Before initiation of the study, approval was obtained from the Institutional Review Board for the Protection of Human Subjects at the University of Wisconsin La Crosse.

Procedures

For initial subject testing, each subject performed maximal incremental exercise testing on an electronically braked cycle ergometer (Lode, Groningen, Netherlands). Tests were conducted to determine maximal heart rate (HR_{max}), maximal oxygen consumption (VO_2max) and peak power output (PO_{peak}). Subjects were tested in a 3-hour postprandial state and were instructed to abstain from alcoholic consumption and heavy exercise 24 hours prior to testing. Subjects were also instructed to abstain from caffeine 3 hours prior to testing. Prior to maximal incremental testing, subject demographics (height, weight, resting HR) were measured. Tests consisted of 2-minute stages with incremental increases in workload of 25 Watts (W). During each test, VO_2max and V_E were measured using open-circuit spirometry using a Moxus metabolic cart (AEI Technologies, Bastrop, TX). During the last 10 seconds of each minute, HR was measured using radio telemetry (Polar Electro Oy, Kempele, Finland). During the last 10 seconds of each stage, the subject was asked to rate perceived exertion using the RPE scale selected for that test. Each subject was instructed on the use of the scale prior to testing following Borg's (1998) protocols for RPE use.

After the conclusion of testing, each subject participated in six randomly selected (3 BORG-RPE, 3 BORG-CR10) 30-minute interval training sessions varying from easy (~50% of PO_{peak}), moderate (~75% of PO_{peak}) and hard (~85% PO_{peak}) intensities. Scale instructions were provided preceding each training session for the BORG-RPE and BORG-CR10 scale respectively. Each training session consisted of four, 4-minute intervals set at ~50%, ~75% or ~85% of PO_{peak} with a 1-minute inter-set rest period set at 25 W. In addition to the four intervals, a 5-minute warm-up and cool-down was conducted for a total session duration of 30 minutes. Each subject was given a least 48-hour rest period between training sessions. Throughout each training session, HR was measured pre-exercise and HR and RPE, using either the BORG-RPE or BORG-CR10, was recorded during the last 10 seconds of the peak warm-up and cool-down intensity (100 W) and during the last 10 seconds of each interval. Blood lactate was sampled pre-exercise, immediately following the peak warm-up and cool-down intensity (25 W), and immediately following interval bouts during the 25 W resting period using dry chemistry (Lactate Plus, Nova Biomedical Corporation, Waltham, MA). In addition, session RPE (sRPE) was obtained 30 minutes post-exercise in accordance to Foster et al. (2001) for sRPE.

To better visualize the training sessions, one subject completed all testing using open-circuit spirometry to represent responses during each interval bout. Workloads, physiological and perceptual responses during interval bouts, including VO_2 and HR, are presented in Figures 1-3.

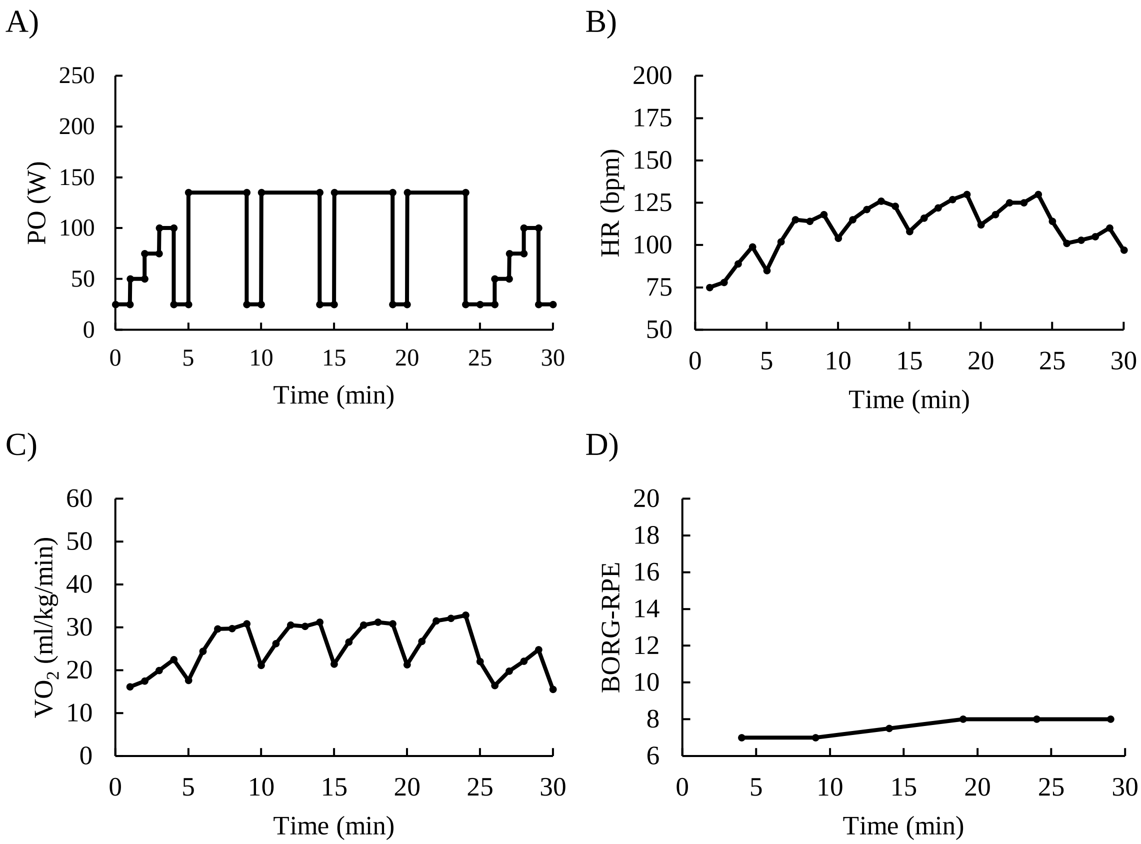

Figure 1. Easy interval session representation. A) time vs. power output (PO); B) time vs. heart rate (HR); C) time vs. oxygen consumption (VO_2); D) time vs. BORG-RPE.

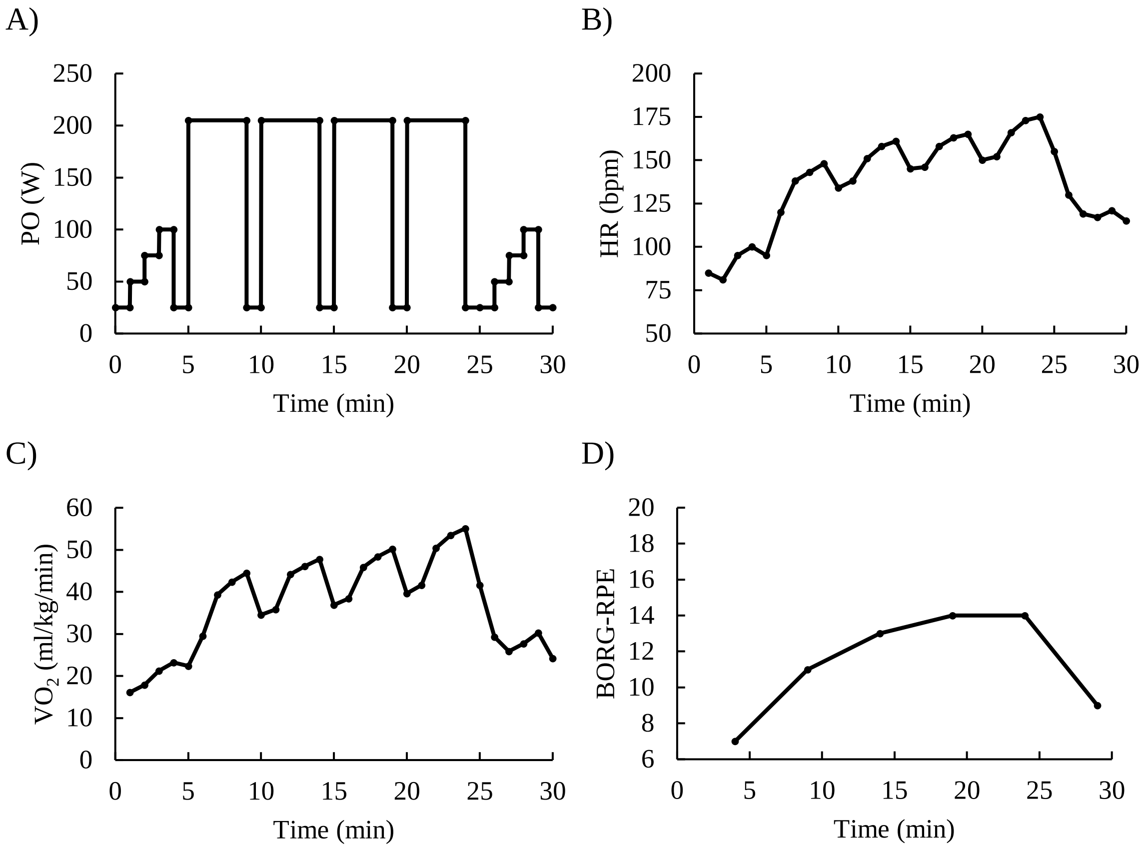

Figure 2. Moderate interval session representation. A) time vs. power output (PO); B) time vs. heart rate (HR); C) time vs. oxygen consumption (VO_2); D) time vs. BORG-RPE.

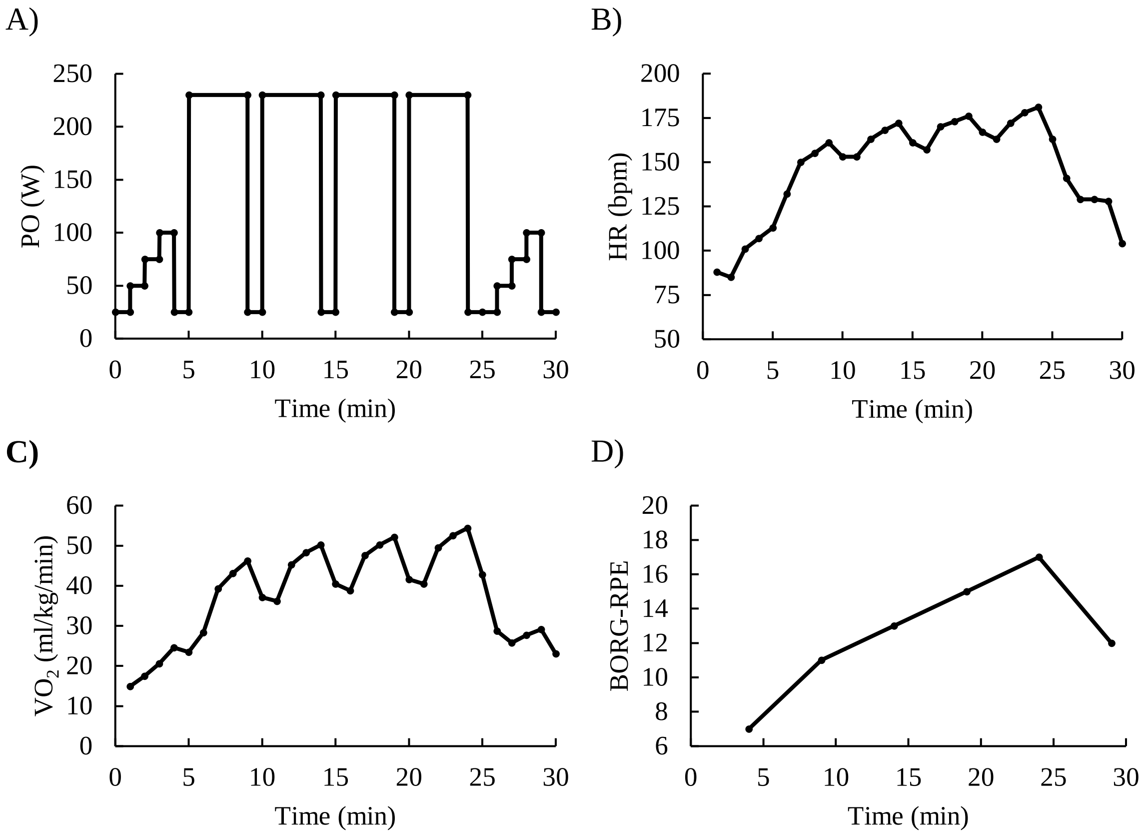

Figure 3. Hard interval session representation. A) time vs. power output (PO); B) time vs. heart rate (HR); C) time vs. oxygen consumption (VO_2); D) time vs. BORG-RPE.

Statistical Analysis

Descriptive characteristics of subjects as well as physiological and perceptual responses from maximal incremental exercise testing were calculated as mean ± standard deviation (SD). Differences between the gender means were compared with an independent groups t-test. A comparison of physiological and perceptual responses (BORG-RPE, BORG-CR10, HR and BLa) during easy, moderate and hard interval exercise sessions was made using a one-way ANOVA with repeated measures. Pairwise comparisons were made using Tukey's post-hoc tests. Regression analysis was used to analyze the relationship between the BORG-RPE and BORG-CR10 as well as criterion variables with BORG-RPE and BORG-CR10 ratings to determine concurrent validity. A Fisher's r-to-z transformation was conducted to compare concurrent validity between the both scales. Regression analysis was used to analyze the relationship between percent heart rate reserve (%HRR) and sRPE with each scale. A Fisher's r-to-z transformation was conducted to compare correlations found between %HRR and sRPE with each scale. Alpha was set at .05 to achieve statistical significance.

RESULTS

Descriptive characteristics as well as physiological and perceptual responses from maximal incremental testing is presented in Table 1. It was found that the male group was significantly taller, heavier and had a higher PO_{peak} than the female group. A significant F ratio was found between the three interval exercise intensity sessions for all physiological and perceptual variables (BORG-RPE, BORG-CR10, HR and BLa). It was found that all variables for the moderate interval session were greater than the easy interval session, and all variables for the hard interval were greater than the moderate interval session.

Physiological and perceptual data for interval exercise sessions are presented in Table 2. Regression analysis revealed a strong, non-linear correlation for RPE ratings during interval exercise using the BORG-RPE and BORG-CR10 ($r = 0.95$) (Figure 4.). Figure 5 presents verbal anchor associations between the BORG-RPE and BORG-CR10. Regression analysis of concurrent data also revealed strong, linear correlations for RPE and HR, and good, linear correlations for RPE and BLa for both the BORG-RPE and BORG-CR10.

Correlations for physiological and perceptual data are presented in Tables 3-6 for easy, moderate and hard interval sessions as well as all interval session data. No significant differences were found between concurrent validity for the BORG-RPE and BORG-CR10. Regression analysis of %HRR and sRPE revealed good, linear correlations for both the BORG-RPE and BORG-CR10 (Figures 6-7.). No significant differences were found between correlations derived for %HRR and sRPE for the BORG-RPE and BORG-CR10.

Table 1. Descriptive characteristics and physiological and perceptual responses of men and women during maximal increment exercise testing (N = 14).

	Male (n = 8)	Female (n = 6)
Age (yrs)	21.9 ± 3.52	21.5 ± 1.38
Height (cm)	180.3 ± 5.96*	164.7 ± 8.41
Weight (kg)	80.8 ± 9.18*	63.9 ± 7.75
VO_2max (mL/kg/min)	49.0 ± 7.87	45.0 ± 8.11
Heart Rate Max (bpm)	188 ± 4.9	192 ± 2.5
Peak Power Output (W)	272 ± 31.3*	207 ± 44.5
Max BORG-RPE Rating	18.5 ± 1.04	19.0 ± 0.55
Max BORG-CR10 Rating	9.3 ± 1.11	9.4 ± 1.36

Values represent mean ± standard deviation.
*Significantly different than females ($p < .05$).

Table 2. Physiological and perceptual responses during easy, moderate and hard interval exercise sessions.

	Easy	Moderate	Hard
BORG-RPE Rating	10.4 ± 1.70*#	13.9 ± 1.28*	15.7 ± 1.41#
BORG-CR10 Rating	2.5 ± 0.59*#	5.0 ± 1.03*	6.9 ± 0.89#
Heart Rate (bpm)	139 ± 9.3*#	170 ± 7.9*	180 ± 8.7#
Blood Lactate (mmol/L)	3.2 ± 1.03*#	8.0 ± 1.82*	10.9 ± 2.45#

Values represent mean ± standard deviation.
*Significantly different than hard ($p < .05$).
Significantly different than moderate ($p < .05$).

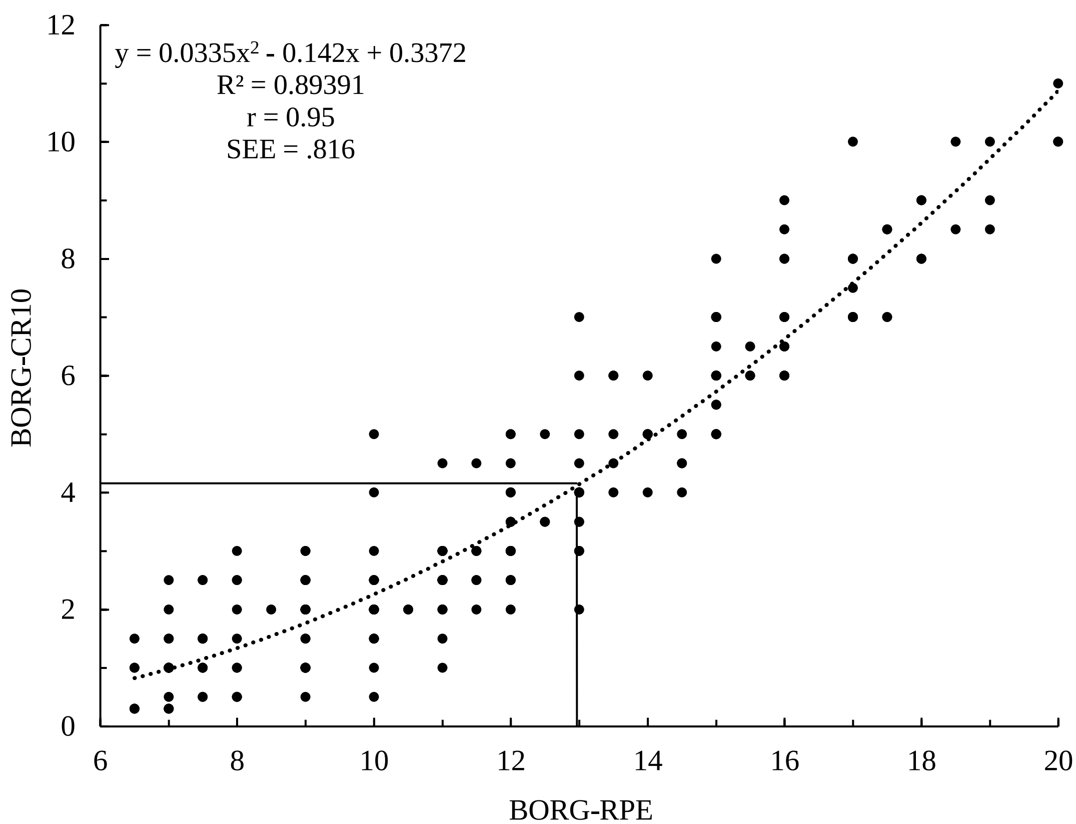

Figure 4. Comparison of BORG-RPE and BORG-CR10 during interval training sessions with BORG-RPE rating 13 equivalence plotted ($r = 0.95$).

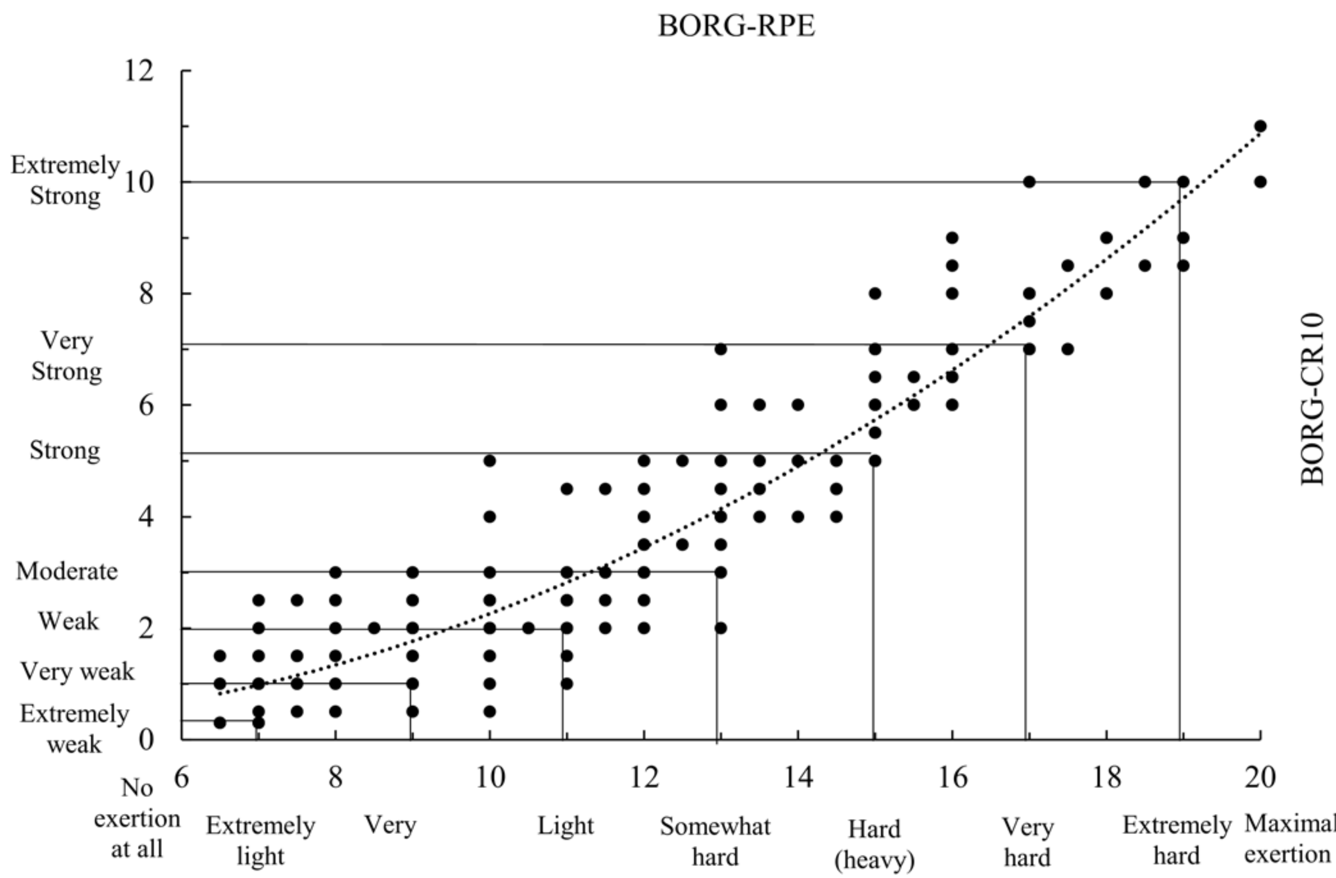

Figure 5. Verbal anchor comparison of BORG-RPE and BORG-CR10 during interval training sessions.

Table 3. Correlation matrix for physiological and perceptual variables during easy interval exercise sessions.

	Heart Rate	**Blood Lactate**	**BORG-RPE**	**BORG-CR10**
Heart Rate	1	0.16	0.33	0.02
Blood Lactate	0.16	1	0.13	0.26
BORG-RPE	0.33	0.13	1	0.69
BORG-CR10	0.02	0.26	0.69	1

Table 4. Correlation matrix for physiological and perceptual variables during moderate interval exercise sessions.

	Heart Rate	**Blood Lactate**	**BORG-RPE**	**BORG-CR10**
Heart Rate	1	0.64	0.42	0.62
Blood Lactate	0.64	1	0.44	0.51
BORG-RPE	0.42	0.44	1	0.85
BORG-CR10	0.62	0.51	0.85	1

Table 5. Correlation matrix for physiological and perceptual variables during hard interval exercise sessions.

	Heart Rate	**Blood Lactate**	**BORG-RPE**	**BORG-CR10**
Heart Rate	1	0.65	0.73	0.60
Blood Lactate	0.65	1	0.55	0.59
BORG-RPE	0.73	0.55	1	0.88
BORG-CR10	0.60	0.59	0.88	1

Table 6. Correlation matrix for physiological and perceptual variables during all interval exercise sessions.

	Heart Rate	**Blood Lactate**	**BORG-RPE**	**BORG-CR10**
Heart Rate	1	0.78	0.85	0.83
Blood Lactate	0.78	1	0.74	0.78
BORG-RPE	0.85	0.74	1	0.95
BORG-CR10	0.83	0.78	0.95	1

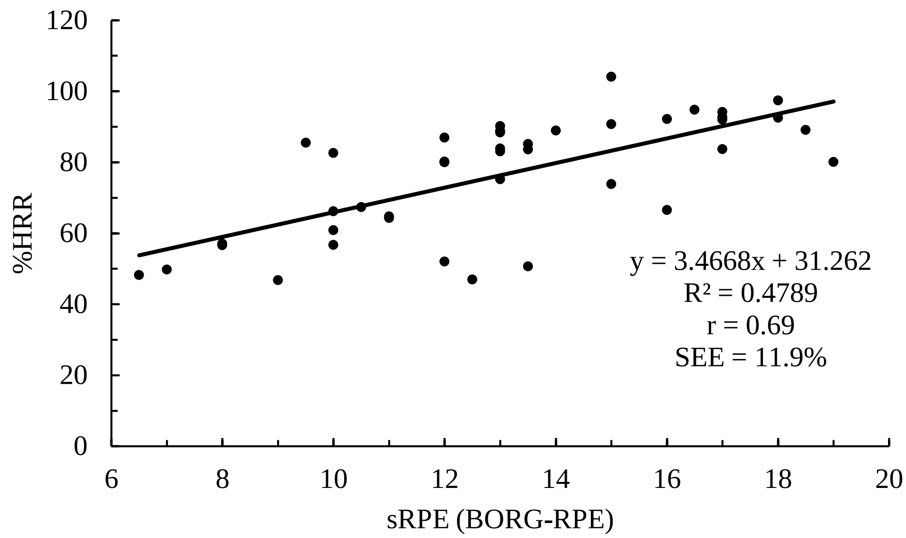

Figure 6. Comparison of mean percent of heart rate reserve (%HRR) and session rating of perceived exertion (sRPE) with BORG-RPE during interval training sessions (r = 0.69).

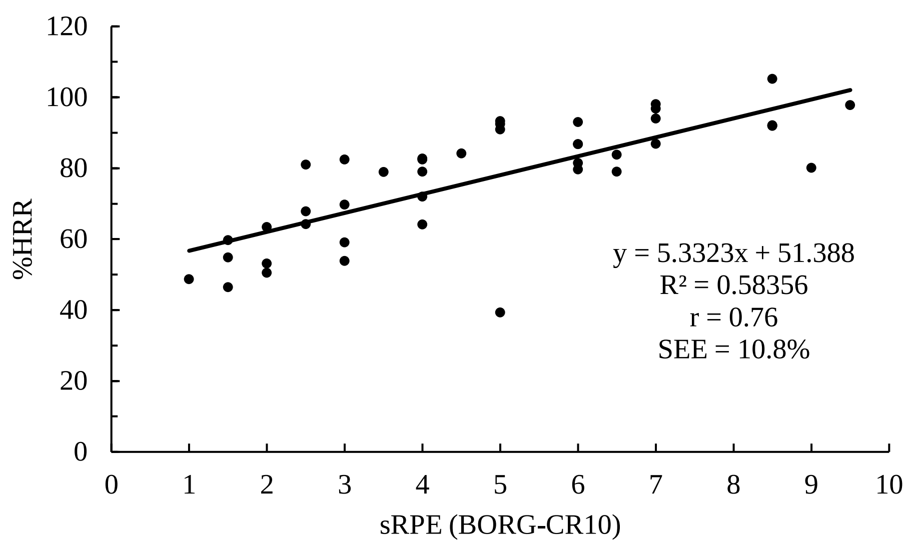

Figure 7. Comparison of mean percent of heart rate reserve (%HRR) and session rating of perceived exertion (sRPE) with BORG-CR10 during interval training sessions (r = 0.76).

DISCUSSION

The purpose of this study was to compare the BORG-RPE and BORG-CR10 on an intraindividual level in varying training intensities using concurrent validity, verbal anchor and numerical categorical comparisons. When the construct paradigm was examined between the two scales, a strong, positive correlation was found between the BORG-RPE and BORG-CR10 scales when using a non-linear regression (r=0.95). These results demonstrate the interchangeability between the two scales and mimic, but do not replicate, the scale transformation table presented by Borg (1998) (Table 7.). For this reason, an alternative scale transformation was derived from regression analysis conducted in this study between the two scales to create Table 8:

$$[\text{BORG-CR10} = 0.0335(\text{BORG-RPE})^2 - 0.142(\text{BORG-RPE}) + 0.3372]$$

Borg (2001) also presents a transformation equation derived from interindividual comparisons and states that ratings can be transformed from one scale to the other:

$$[\text{BORG-RPE} = 6 + 2.8(\text{BORG-CR10} - 0.3)^{.79}]$$

Although Borg's transformation equation is in line with the theoretical relationship between the two scales, the values contradict Borg's (1998) transformation scale and produce highly unreasonable transformations with upper ratings (Table 9). Values produced in the alternative scale transformation table from this study were rounded to the nearest .5 to allow rating ease. Additionally, when following the regression equation derived from this study, a 6 on the BORG-RPE was identified as 0.7

on the BORG-CR10. However, 6 is identified as no exertion and as such should be transformed to a rating of 0 on the BORG-CR10 as done in this study. Participants in this study were restricted from rating a 6 on the BORG-RPE or a 0 on the BORG-CR10 when exertion was present.

Table 7. Borg (1998) scale transformation.

BORG-RPE	BORG-CR10
6	0.0
7	0.0
8	0.5
9	1.0
10	1.5
11	2.0
12	3.0
13	3.5
14	4.5
15	5.5
16	6.5
17	7.5
18	9.0
19	10.0
20	12.0

Table 8. Proposed scale transformation.

BORG-RPE	BORG-CR10
6	0.0
7	1.0
8	1.5
9	2.0
10	2.5
11	3.0
12	3.5
13	4.0
14	5.0
15	6.0
16	6.5
17	7.5
18	8.5
19	10.0
20	11.0

Table 9. Borg (2001) scale transformation.

BORG-RPE	BORG-CR10
6	0.0
7	0.5
8	1.0
9	1.5
10	2.0
11	2.5
12	3.0
13	3.5
14	4.0
15	4.5
16	5.5
17	6.0
18	6.5
19	7.5
20	8.0

When comparing the two scale transformation tables, minor variability is identified between the two. This variability is mostly identified with lower scale ratings and begins to diminish at a BORG-RPE rating of 12 with slight variation past this point. The early variability could be accounted for by the decreased physiological cuing that occurs during low intensity exercise (Noble and Robertson, 1996). This could result in increased rating variability with lower intensity exercise. When comparing the transformation of the rating 20 on the BORG-RPE, variability is present but is not of great importance. According to Borg's concept of the dot above a rating of 10 (Maximal exertion) on the BORG-CR10 and explanation of 20 on the BORG-RPE, any rating greater than a 10 on the BORG-CR10 (the dot) should equate to a 20 on the BORG-RPE (Borg, 1998). Nevertheless, variability from the proposed transformation table could be associated with a lack of understanding of the dot present in the BORG-CR10, with only one rating given by a subject above a 10. This finding could also be a result of inadequate physical stress from interval sessions to evoke a perceptual rating above 10. With physically active individuals, the individual is often accustomed to high intensity activity. Therefore, exercising at an intensity that is to an evident degree harder than previously experienced may be difficult to produce.

One scale rating of significant importance for the BORG-RPE regarding exercise prescription is 13. This rating is identified by Parfitt, Evans, and Eston (2012) as a subjective exercise intensity that elicits improvements in health and fitness measurements (VO_2max, Body Mass Index, Mean Arterial Pressure, and Total Cholesterol) in sedentary individuals. The rating of 13 has been shown to equate to an intensity of 50% - 70% of VO_2max. This rating has also been identified as a "pleasant" intensity for exercise while establishing a sense of autonomy in participants. This is of particular importance when considering an individual's adherence to exercise. For these reasons, a perceptual rating equivalence for the BORG-CR10 is desired due to the scale's regular use for exercise intensity regulation. In Borg's scale transformation (1998), an RPE of 13 is equivalent to a rating of 3.5 on the BORG-CR10. The results of this study suggest the equivalence of an RPE of 13 was identified as a rating of 4 on the BORG-CR10. This finding suggests that exercise professionals using the BORG-CR10 scale in practice following the BORG-RPE prescription proposed by Parfitt may need to prescribe a 4 on the BORG-CR10. This rating may also be viewed as more practical regarding the BORG-CR10 for the value is presented on the rating scale, whereas 3.5 is not. This may allow an individual to identify this essential perceptual intensity with a greater degree of ease.

When examining the verbal anchors associated with each scale and the equivalence of these verbal anchors, variance is once again present. Due to the driving value of the verbal anchors for the scales, one would assume that ratings would align at the verbal anchors making the two scales highly interchangeable. One possible explanation of the found variance could simply be accounted to intrarater variability. Verbal anchors for each scale also include differences in language (e.g. easy vs. weak) which could also contribute to verbal anchor rating variation. Furthermore, subjects may have rated without the use of the verbal anchors. If subjects neglect the use of verbal anchors, which structure the scales, as instructed, ratings may compromise the original structure of the scales. Due to the societal norms of linear ratings with given scales, individuals could easily rate linearly when using the BORG-CR10 if a verbal anchor is not present. This would compromise the curvilinear structure of the scale which is derived by the verbal anchors. Therefore, verbal anchor equivalence between the BORG-RPE and BORG-CR10 would be compromised.

When examining the concurrent paradigm between the two scales, results show strong, linear correlations between both scales and HR [BORG-RPE ($r = 0.85$); BORG-CR10 ($r = 0.83$)]. A good, linear correlation was also present between both scales and BLa [BORG-RPE ($r = 0.74$); BORG-CR10 ($r = 0.78$)]. These results support previous literature investigating the concurrent paradigm of the two scales (Borg, 1998; Noble et al., 1983; Scherr et al., 2013). When compared, there was no significant difference found between the scales regarding concurrent validity. Conversely, Borg and Kaijser (2006) suggest that the BORG-RPE is of practical use when understanding and interpreting linear variables such as HR, whereas psychophysical variables such as pain and dyspnea are best represented by the psychophysical scaling of the BORG-CR10. The BORG-CR10 could also be of practical use when representing curvilinear variables such as BLa and V_E.

Concurrent regression analysis of mean %HRR and sRPE identified good, linear correlations with both scales [BORG-RPE ($r = 0.69$); BORG-CR10 ($r = 0.76$)]. These results are in agreement with Foster et al. (1995) with mean %HRR compared to sRPE for a 30-minute steady-state running session ($r = 0.65$). These results present general congruence and interchangeability between the BORG-RPE and BORG-CR10 in reference to sRPE.

One potential limitation to this study included a limited subject sample size. The appropriate sample size for this study would be 30 subjects. This could have potentially resulted in type II error. Future studies should look to increase subject sample size to prevent such possibilities. Future studies should also evaluate a BORG-CR10 rating of 4 to determine effectiveness of this scale rating to elicit health and fitness improvements and be deemed as a pleasant intensity for exercise as found by Parfitt et al. (2012) with the rating of 13 using the BORG-RPE.

CONCLUSION

The results of this study indicate a high degree of equivalence and interchangeability between BORG-RPE and BORG-CR10 for rating during exercise training. Though this is the case, slight variability was identified with verbal anchor and numerical comparisons, while there was not a significant difference in concurrent validity. Regression analysis helped to identify interchangeability between the BROG-RPE and BORG-CR10 that mimics, but does not replicate the scale transformation created by Borg (1998). For this reason, an alternative scale transformation is suggested for use.

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APPENDIX A

INFORMED CONSENT

1. INFORMED CONSENT FOR “Comparison of Two Rating of Perceived Exertion Scales for Evaluating Training”

Principal Investigator: Blaine Arney
UW-La Crosse
738 Hillview Avenue
La Crosse, WI 54601
812-486-9749

2. I, _________________________________, give my informed consent to participate in this study designed to compare two widely used rating of perceived exertion scales for measuring exercise intensity during training. I have been informed that the study is under the overall direction of Carl Foster, Ph.D. who is a professor in the Department of Exercise and Sport Science at the University of Wisconsin-La Crosse. I consent to the presentation, publication and other release of summary data from the study which is not individually identifiable.

3. I have been informed that my participation in this study will require me to:
   a) Perform, on several occasions, workouts on an exercise bicycle from submaximal up to maximal training sessions of ~30 minutes duration, in which interval exercise with varying workloads will be performed
   b) Wear a scuba breathing value that allows the investigators to measure my metabolic rate
   c) Wear a chest strap that transmits my heart rate via radio waves to a specialized wristwatch
   d) Have several small blood samples taken from my finger tip

4. I have been informed that there are no foreseeable risks associated with this study other than the fatigue associated with heavy exercise and the discomfort wearing the breathing value and providing the fingertip blood samples.

5. I have been informed that there are no primary benefits to myself other than knowledge about my fitness. Based on the results of this study, exercise professionals may be able to better guide the training of exercisers.

6. I have been informed that the investigator will answer questions regarding the procedures throughout the course of the study.

7. I have been informed that I am free to decline to participate or to withdraw from the study at any time without penalty.

8. Concerns about any aspect of this study may be referred to Blaine Arney at 812-486-9749, the principle investigator, or his advisor Dr. Carl Foster at 608-785-8687. Questions about the protection of human subjects may be addressed to Dr. Bart Vanvoorhis, Chair of the UW-L Institutional Review Board at 608-785-6892.

Investigator:___________________________ Signature:________________________________
Date:___________________

Participant:_____________________________ Signature:________________________________
Date:___________________

APPENDIX B

AMERICAN HEART ASSOCIATION HEALTH/FITNESS PRE-PARTICIPATION SCREENING FORM

American Heart Association
Health/Fitness Facility Pre-Participation Screening

Assess your health needs by making all
TRUE statements.

History

You have had:

- ☐ A heart attack
- ☐ Heart surgery
- ☐ Cardiac catheterization
- ☐ PTCA
- ☐ Pacemaker/ICD/rhythm disturbance
- ☐ Heart valve disease
- ☐ Heart failure
- ☐ Heart transplantation

Symptoms

You experience:

- ☐ Chest discomfort with exertion
- ☐ Unreasonable breathlessness
- ☐ Dizziness, fainting, blackouts
- ☐ You take heart medications

If you have marked any of the statements at the left, you should consult your health care provider before engaging in exercise. You may need to use a facility with medically qualified staff.

CV Risk factors

- ☐ You are a male and over 45
- ☐ You are a postmenopausal female not on estrogen therapy
- ☐ You smoke
- ☐ You blood pressure is >200
- ☐ You don't know your cholesterol
- ☐ You have a blood relative who has heart problems
- ☐ You are a diabetic
- ☐ You are physically inactive
- ☐ You are more than 20 pounds overweight

If you check two or more of the following, you should consult your health care provider before engaging in exercise. You should probably use a facility with a professionally qualified exercise staff.

Other health issues

- ☐ You have musculo-skeletal problems
- ☐ You have concerns about the safety of exercise
- ☐ You take prescription medication
- ☐ You are pregnant

- ☐ None of the above is true

You should be able to exercise safely without needing to consult with your health care provider in almost any facility that meets you exercise program needs.

APPENDIX C

BORG RATING OF PERCIEVED EXERTION SCALE

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

APPENDIX D

BORG RATING OF PERCIEVED EXERTION SCALE INSTRUCTIONS

RPE Scale Instructions

While exercising we want you to rate your perception of exertion, i.e., how heavy and strenuous the exercise feels to you. The perception of exertion depends mainly on the strain and fatigue in your muscles and on your feeling of breathlessness or aches in the chest.
Look at this rating scale; we want you to use this scale from 6-20, where 6 means “no exertion at all” and 20 means “maximal exertion.”

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

9 corresponds to “very light” exercise. For a normal, healthy person it is like walking slowly at his or her own pace for some minutes
13 on the scale is “somewhat hard” exercise, but it still feels OK to continue.
17 “very hard” is very strenuous. A healthy person can still go on, but he or she really has to push him- or herself. It feels very heavy, and the person is very tired.
19 on the scale is an extremely strenuous exercise level. For most people this is the most strenuous exercise they have ever experienced.

Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Don’t underestimate it, but don’t overestimate it either. It’s your own feeling of effort and exertion that’s important, not how it compares to other people’s. What other people think is not important either. Look at the scale and the expressions and then give a number.
Any questions?

APPENDIX E

BORG CATEGORY-RATIO 10 SCALE

0	Nothing at all	“No P”
0.3		
0.5	Extremely weak	Just noticeable
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	“Max P”
11		
~		
●	Absolute maximum	Highest possible

APPENDIX F

BORG CATEGORY-RATIO 10 SCALE INSTRUCTIONS

CR-10 Scale Instructions

We want you to rate your perception of exertion, that is, how heavy and strenuous the exercise feels to you. The perception of exertion depends mainly on the strain and fatigue in your muscle and on your feeling of breathlessness or aches in the chest.

We want you to use this scale from 0 to 10 and “•”, where 0 means “no exertion at all” and 10 means “extremely strong – max P”, that is, the maximal exertion you have previously experienced.

1 corresponds to “very light” exercise. For a normal, healthy person it is like walking slowly at his or her own pace for several minutes.

3 on the scale is “moderate” exercise, it is not especially hard, it feels fine, and it is no problem to continue exercising.

5 corresponds to “heavy” exercise; it feels hard and you are tired, but you don’t have any great difficulties in going on.

7 is “very hard” and very strenuous. A healthy person can still go on but he or she has to push him- or herself a lot. It feels very heavy and the person is very tired.

10 on the scale is an extremely strenuous exercise level. It is “max P”. For most people this is an exercise as strenuous as they have ever experienced before in their lives.

• The dot denotes a perceived exertion that is stronger than 10, “extremely strong.” It is your “absolute maximum,” for example, 12, 13, or even higher. It is the highest possible level of exertion.

Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Don’t underestimate it, but don’t overestimate it either. It’s your own feeling of effort and exertion that’s important., not how it compares to other people’s. What other people think is not important either. Look at the scale and the expressions and then give a number.

What “max exertion” – your “max P” – have you previously experienced in your life? Use that a “10”.

Any further questions?

APPENDIX G

REVIEW OF LITERATURE

Purpose

The purpose of this paper is to review the literature pertaining to subjective measures of intensity regarding the similarities and differences of the Borg 6-20 and Borg CR-10 RPE scales.

Introduction

In the field of exercise physiology, exercise intensity is a significant facet to individualized treatment plans. In some individuals, intensity can be the difference between an effective training session and a heart attack. Exercise intensity is a crucial aspect to the prescription paradigm created by the American College of Sports Medicine (ACSM) (Riebe, Ehrman, Liguori, Magal, 2017). This is known as the FITT-VP principle. This principle includes exercise frequency, intensity, time, type, volume and progression as components of exercise prescription. Amongst these, prescription of exercise intensity is considered to be the most complex. According to the ACSM, exercise under a minimum intensity will result in little to no change in an individual's physiological parameters. Within these concepts, methods to regulate and measure exercise intensity are of importance for the field of exercise. This gave rise to two methods, objective and subjective (Borg, 1998).

Objective measurements of intensity can be broken down into two categories; mechanical measurements such as power, work, or velocity and physiological measurements such as heart rate (HR), oxygen consumption (VO_2), or ventilation. These methods provide accurate, assuming properly calibrated equipment is employed, numerical data that is easily comparable on an interindividual level. Although both methods are valid means of determining intensity, physiological measurements are the primary sources for prescription (Noble & Robertson, 1996). This is due to the relative nature of physiological methods in reference of an individual's specific cardiorespiratory fitness (CRF). Subjective methods of intensity include rate of perceived exertion (RPE) and the Talk Test. Subjective methods allow for direct, individualized measures of relative exercise intensity (Borg, 1998). Both objective and subjective measures of intensity are of importance when monitoring exercise intensity and help to provide a fuller picture of the physical strain regarding a physical load (Borg, 1990).

The use of physiological measurements as accurate prescriptive tools for intensity rely greatly on relative measurements (heart rate reserve (HHR) and VO_2 reserve (VO_2R)) and thresholds (ventilatory threshold (VT) and respiratory compensation point (RCP)) which require a direct measurement of physiological responses (Riebe et al., 2017). The equipment needed to assess VO_2 and determine threshold values is often expensive and requires proper knowledge of calibration and administration. For this reason, HR values derived from graded exercise testing (GXT) and age predicting methods are often applied. With the relatively large standard error associated with age predicted HR values, a decrease in administered GXTs, and a dependency on HR monitoring devices. Along with this are the large variations of HR on an intraindividual level associated with factors such as ambient temperature, psychological stress, caffeine, medications and changes in CRF that also contribute to the impractical nature of HR as a pulsing time tool (Nobel & Robertson, 1996). For this reason, subjective measures of intensity such as RPE and the Talk Test are becoming more preferred.

Rating of Perceived Exertion

Perceived exertion is defined as the act of detecting and interpreting sensations from the body that result from a disturbance of homeostasis, such as exercise (Noble & Robertson, 1996). The pathways and mechanisms involved with perceived exertion are multifaceted and involve internal communication processes. A stimulus such as exercise leads to an interplay of physiological signals along with other psychological, performance and exertional factors (Noble & Robertson, 1996). These factors are then compared to past exertional experiences. This leads to a present perceived exertion that is used to regulate physical effort and can be used as a subjective measure of intensity with proper scaling techniques.

An individual's rating of perceived exertion can be broken down into two separate contributing factors, central and local (Robertson, 1982). Central factors originate from the cardiopulmonary systems and include physiological cues such as ventilation and HR. One can think of it this way, if increases of HR and ventilation occur as a result of an increased workload, these cues will influence the individual's perception of physical exertion. Likewise, local factors originate from the musculoskeletal system and include physiological cues such as muscular fatigue and soreness. As increases in muscular fatigue and soreness increase, these cues will influence the individual's perception of physical exertion. Both central and local factors contribute to overall perceived exertion. It has been suggested, however, that local factors override central factors (Noble, Borg, Jacobs, Ceci, & Kaiser, 1983)

Historical Background

In the mid 19th century, the field of psychophysics was established at the hands of Ernest Weber and Gustav Fechner (Borg, 1998). Psychophysics is the study of sensory perception as a result of varying stimuli (Borg, 1990). The varying stimuli studied in the field of psychophysics is broad and ranges from taste and loudness to pain and physical exertion (Borg, 1998). In regard to physical exertion, this study would lead to the development of RPE scales.

In the 1950's, Gunnar Borg and Stanley Stevens, both psychologists, began to study how individuals perceive physical work (Borg, 1998). This was termed perceived exertion. Borg saw the importance of using subjective measures to better understand objective findings (Borg, 1982). For this to happen, Borg had to create a method for quantifying subjective symptoms for interindividual comparisons (Noble & Robertson, 1996). From this came the first scale to be used globally for the purpose of rating perceived exertion, the Borg RPE Scale. Later, Borg developed his CR-10 scale (Borg, 1998). Since the development of these scales, much debate has arouse concerning which should be the preferred method of subjective rating of exertion. To investigate this question further, the construct and purpose of the two scales must be taken into consideration.

In the field of perceived exertion, it is worth noting that the constructs of scales are often derived from stimulus-response (S-R) relationships that represent linear or curvilinear growth functions (Borg, 1998). To represent the physiological and psychophysical growth functions that occur in perceived exertion, S-R power functions were created.

Borg RPE Scale

In the 1960's, Borg created the first version of his RPE scale (Borg, 1998). Borg's idea was to create a scale that was relatively easy to use and accurately represented the linear function between HR and work load (Borg, 1982). The scale originally was structured as a 21-grade scale with the number 17 corresponding with a HR of 170 beats per minute (bpm) (Borg, 1998). The scale however failed to represent the linear function it was created for. For this reason, Borg restructured the scale into a 15-grade category scale ranging from 6 to 20 and oriented verbal anchors to represent a linear growth pattern. The numbers on the scale were created to represent corresponding HRs by multiplying the RPE value by 10. For example, a 6 on the RPE scale corresponded to a resting HR of 60 bpm. Verbal anchors were placed with corresponding numbers to add meaning to the number and structure to the scale. For example, the number 13 on the scale has no intersubjective meaning until "Somewhat hard" is added to it. Also, a numerical scale in itself gains a specific scalar construct with the addition verbal anchors, which produce the linear function of the scale. This newly formed scale was successful in representing the intended linear function. Borg (1998) further added to the precision of the scale by modifying the position of the verbal anchors and altering the verbal expressions. This created a range of verbal anchors, "No exertion at all" corresponding with a 6 to "Maximal exertion" corresponding with a 20. The RPE scale is presented in Figure 1. The RPE scale has been validated by a large number of studies making the scale well accepted by the exercise community (Borg, 1998; Chen, Fan, & Moe, 2002; Eston & Williams, 1988; Hetzler et al., 1991). According to the *ACSM Guidelines for Exercise*

Testing and Prescription, the Borg RPE scale is considered an acceptable adjunct measurement for exercise intensity (Riebe et al., 2017).

An equation is often used to represent the linear construct within the RPE scale (Borg, 1998). The equation is as follows: $R = a + cS$. In the equation, R represents perceived magnitude, S represents the physical stimulus, a represents a constant for the starting point or threshold of the function, and c is a measure constant (Borg & Kaijser, 2006). Although the equation may seem redundant, it is of importance when investigating the construct which is derived from it.

Further validating its use to prescribe exercise intensity, Scherr et al. (2013) evaluated 2,560 Caucasian males and females that completed incremental exercise tests on treadmill or cycle ergometers for cardiovascular screening. In the study, HR, blood lactate (BLa) and RPE were measured at the conclusion of each work load. The study investigated the relation between HR and BLa with RPE, mean RPE values at lactate thresholds (LT) and anaerobic thresholds (AT), RPE variance between male and female subjects and RPE variance between sedentary and physically active subjects. A subject was classified as physically active based on adherence to the ACSM's and American Heart Association's (AHA) recommendations of 30 minutes of moderate exercise 5 days a week or 20 minutes of vigorous exercise 3 days a week. Strong correlations were found between HR and RPE ($r = 0.74$) and BLa and RPE ($r = .83$). Mean RPE values for LT and AT were 10.8 ± 1.8 and 13.6 ± 1.8 respectively. Gender, age, coronary artery disease (CAD), physical activity level and exercise testing modality had no effect on RPE associations ($p < .05$). In conclusion, the Borg RPE scale was considered an appropriate measurement for monitoring and prescribing exercise intensity regardless of gender, age, activity status, presence of CAD and exercise modality.

Borg CR-10 Scale

The RPE scale successfully represented the linear relationship between HR and increases in workload, and was accepted as a valid measurement tool of perceived exertion. Despite this evidence, Borg realized that the scale had flaws that were related to psychophysical constructs (Borg, 1998). This is best demonstrated using a simple psychophysical example. If an individual is driving a car at a blinded speed 50 miles per hour (mph) and is asked to slow the car to half the speed, the resulting speed will be, on average, 35 mph compared to the desired 25 mph (Borg, 1998). This example represents a perceptual function that is curvilinear in nature. This curvilinear structure holds true for perceptual responses of physical stimuli, though each physical stimulus has its own specific exponential growth exponent (Noble & Robertson, 1996). This also applies to perceived exertion. In addition, physiological variables such as lactate accumulation and pulmonary ventilation increase with a positively accelerating function (Noble & Robertson, 1996). For the purpose of demonstrating the curvilinear growth function provided by psychophysical and physiological functions, Borg created a category-ratio scale (Borg, 1998). The scale is known as the CR-10 scale and is often recommended for the use of rating perceived pain and dyspnea (Riebe et al., 2017).

The CR-10 scale was constructed as a category-ratio scale numbered from 0 to10. Being constructed as a ratio scale allows for psychophysical mathematical calculations to be conducted (Borg, 1982). The ratio structure that represents a curvilinear construct is derived from a power function equation, much like the equation presented for linear growth such as the RPE scale (Borg & Kaijser, 2006). This equation is as follows: $R = a + c(S - b)^n$. Once again, *R* represents perceived magnitude, *S* represents the physical stimulus, *a* and *b* represent constants for the starting point or threshold of the function, c is a measure constant and *n* is the exponent derived from the S-R relation. This exponent is of importance when investigating the curvilinear construct of the S-R relation. It has been determined that perceived exertion on a cycle ergometer has an exponent of 1.5 to 1.7 (Borg, 1998). This value can be used to validate and investigate the construct of other S-R functions in psychophysics.

With the ratio structure, categorical additions in the form of verbal anchors were necessary for the creation of the scale (Borg, 1998). Verbal anchors range from “Nothing at all” corresponding with 0 to “Absolute maximum” corresponding with values higher than 10 and is represented by an 11 and a dot. The “Absolute maximum” category allows an individual to rate a perceived exertion higher than 10 and is a specialized component of the CR-10 scale (Borg, 1990). In other words, the scale has no perceptual cap. This is a result of the idea that individuals exercise with a physiological reserve (Swart et al., 2009). Due to the perceptual comparison to past experiences to determine present levels perceptual exertion, it is always possible that an individual can exercise to a higher perceptual intensity than what has been previously experienced. This is mostly found with ratings of pain. The scale also includes fractionated values to allow an individual more rating variability within the bottom of the scale (Borg, 1998).

The verbal anchors are of importance when adding meaning to the numerical values and also create the curvilinear function of the scale. The “Light” categories of the scale are included in the first 25% of the scale (Noble & Robertson, 1996). The following

75% of the scale includes categories representing “Somewhat hard” to “Absolute maximum”. This demonstrates positive accelerating curve that places an emphasis on higher ratings of exertion. The CR-10 scale is presented in Figure 2.

Much like the RPE scale, the CR-10 scale has been validated in numerous studies and is a widely-excepted scale for perceived exertion (Borg, 1998; Eston, 2012a; Noble & Robertson, 1996; Zamunér et al., 2011). An earlier category-ratio structured scale created by Borg also confirmed the validity of similar category-ratio scales by comparing the scale values to HR and BLa concentrations in 10 males that participated in exercise on cycle and arm ergometers (Borg, Hassmén, Lagerström, 1987). Due to its curvilinear function and decreased numerical range, Borg states that the correlations between HR and the CR-10 scale are lower than that of the RPE scale (Borg, 1998).

In a study conducted by Noble et al. (1983), muscle lactate (MLa), BLa and HR were compared to ratings of perceived exertion on the CR-10 scale. Ten physically active males performed a cycle GXT with 4 minute stages until voluntary exhaustion. During each stage, MLa, BLa, HR and RPE were measured with RPE being divided in three categories, leg effort (LE), cardiorespiratory effort (CE) and leg pain (LP). As expected, all ratings of perceptual exertion and lactate measurements showed positively accelerating curves, representing one another, while HR increased linearly. The curvilinear exponent collected from the perceptual responses ranged from 1.63 – 1.67, which represented the expected exponent of 1.6. In conclusion, the authors stated that CR-10 ratings corresponded well with lactate responses to exercise.

6	No exertion at all
7	
	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Figure 1. Borg RPE Scale

0	Nothing at all	"No I"
0.3		
0.5	Extremely weak	Just noticeable
0.7		
1	Very weak	Light
1.5		
2	Weak	
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	"Strongest I"
11		
•	Absolute maximum	Highest possible

Figure 2. Borg CR-10 Scale

OMNI Scale

A scale worth noting in this review of literature is the OMNI scale. Originally created for rating perceived exertion in children, the OMNI scale has since gained recognition in the RPE community as a valid subjective scale for measuring exercise intensity (Riebe et al., 2017). The OMNI scale is an 11-category perceived exertion scale with numerical values ranging from 0 to 10 (Robertson et al., 2004). The scale has a linear function similar to the RPE scale. Verbal anchors are placed with corresponding numerical values to add meaning and structure to scale. One unique aspect to the construct of the OMNI scale is the pictorial representations of each intensity provided with the scale. The pictorial representations follow changes in the given mode of exercise. This allows an individual to visually anchor themselves to the scale for more accurate ratings of exertion. The OMNI-Cycle scale for adults is presented in Figure 3.

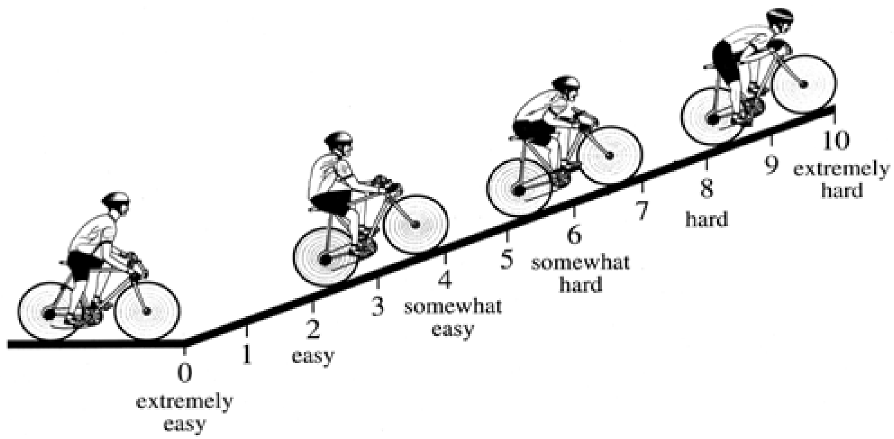

Figure 3. OMNI-Cycle RPE Scale for Adults

Numerous studies throughout the past decade have demonstrated the validity of the OMNI scale (Robertson et al., 2003; Robertson et al., 2004). A study conducted by Utter et al. (2004) investigated the construct (scale of interest (OMNI scale) vs. previously validated scale (RPE scale)) and concurrent (physiological variables (HR, VO_2, ventilation) vs. subjective scale (RPE)) validity in treadmill exercise. In the study, the RPE scale and OMNI scale were shown to have a strong correlation (r = .96) establishing construct validity. The OMNI scale was also shown to have a strong correlation to HR (r = .75) and % of maximal oxygen consumption (%VO_2max) (r = .86) establishing concurrent validity. Overall, the study concluded that the OMNI scale was a valid measure of exercise intensity in walking and running exercise.

Use of Scales

In the fields of exercise and sport science, both the RPE and CR-10 scales can be used for various purposes. Arguably one of the most important uses of the scales is for exercise prescription. In a study conducted by Parfitt, Evans and Eston (2012), subjects that were assigned to 30 minutes of aerobic exercise, three times a week at an RPE of 13 saw significant improvements ($p < .01$) in maximal oxygen consumption (VO_2max), mean arterial pressure, total cholesterol, and body mass index. This study identifies the practical use of RPE as a means of exercise prescription. Other studies have also identified VO_2max/peak predictable (Coquart, Garcin, Parfitt, Tourny-Chollet, & Eston, 2014; Eston et al., 2012b) and LT, VT and AT assessments (Fabre et al., 2013; Scherr et al., 2013; Zamunér et al., 2011) using RPE.

Session RPE

One final use of RPE worth mentioning in this paper is session RPE (sRPE). This method allows the quantification of an individual's training load by means of RPE. In 1975, Banister (1991) created a concept known as the training impulse (TRIMP). This concept was created to combine the training intensity and duration into a single value to quantify an individual's training load (Foster, Rodriguez-Marroyo, de Koning, 2017). The TRIMP method was successful in representing overall training load, but the requirement for HR monitoring and complex design and mathematics made the method impractical for regular use. Along with this, the TRIMP method is dependent on HR data collected from a training bout. If HR monitoring devices are forgotten or malfunction, the method will no longer stand (Foster et al., 2001a). For this reason, Foster et al. (1995) created a method with the same objective as the TRIMP method, to quantify training load. However, Foster's concept utilized a simplistic method combining an overall RPE and duration of an active training session. Session RPE is measured by asking an individual to rate their overall training bout 30 minutes post-training utilizing a modified

CR-10 scale. Rating of perceived exertion was gathered 30 minutes post-training to avoid influence from particularly difficult or easy elements of the exercise bout on the total outlook of the training bout (Foster et al., 2001a). This RPE is then multiplied by the total duration of the training bout to provide a numerical value that quantifies the overall training load of a session. The modified CR-10 scale that is utilized in sRPE is very similar in construct to the CR-10 scale. Verbal anchors in the scale were modified by exchanging exertional terms such as “light” or “severe” to idiomatic American English such as “easy” or “hard” (Foster et al., 1995). With these variations, it is suggested that this scale be referred to as the sRPE scale (Eston, 2012a).

Session RPE has been widely used in the fields of exercise and sport. The first study to use the sRPE method was conducted by Foster et al. (1995) which looked at the effectiveness of cross-training compared to specific training in running performance. Session RPE was used to quantify and compare training loads for three intervention groups conducting varying modes and durations of exercise. Since this study, sRPE has been employed and validated in many studies (Foster, Daines, Hector, Snyder, & Welsh, 1996; Foster, 1998; Foster, Heimann, Eston, Brice, & Porcari, 2001b; Foster et al., 2012; Rodríguez-Marroyo, Villa, García-López, Foster, 2012).

A key study in sRPE literature conducted by Foster et al. (2001a) examined the relationship between sRPE and HR-based methods of monitoring training loads, Banister’s (1991) TRIMP method. In part one of the study, 12 well-trained cyclists participated in eight cycling training bouts (30, 60, and 90-minute steady state bouts, five interval bouts of the same mean power output) while HR and sRPE was gathered for each bout. In part two of the study, HR and sRPE was monitored for 14 men’s basketball players in practice sessions and competitive events. Session RPE and Banister's TRIMP summated HR zones were compared in both groups. Due to the higher multipliers in the sRPE (0-10) compared to that of the TRIMP summated HR zone (0-5), sRPE values were significantly higher ($p < .05$) than the TRIMP summated HR values. For this reason, the two methods were deemed non-interchangeable. Although this was the case, after regression analyses were conducted, it was shown that both methods were highly correlated with one another. This high correlation demonstrated the validity of the method for quantify training loads.

Borg RPE and CR-10 Comparison Studies

Now that the constructs and purposes of the Borg RPE and CR-10 scales have been established, it is important to compare the scales on an intraindividual level. In other words, if an individual cycles at 200 watts (W) and is instructed to rate his perceived exertion using one scale, how will that rating compare to the other scale on a different day, with the same individual, at the same intensity? Due to the varying constructs of the two scales, it is of particular interest how concurrent validity and use of verbal anchors compare between the two scales in varying training bouts and incremental exercise. Only few studies have investigated components of this question.

In a study conducted by Borg and Kaijser (2006), the primary objective was to compare the Borg RPE and CR-10 in a short duration (1 and 3 minutes), incremental exercise test. Twenty-four men and 16 women were divided into two groups, one using the Borg RPE scale and one using the CR-10 scale. Rating of Perceived Exertion, HR and BLa were measured periodically throughout the GXT. The men started at a power output of 20 W and increased every minute by 20 W until voluntary termination, whereas the women started at a power output of 15 W and increased every minute by 15 W until voluntary termination. Stimulus-Response functions were investigated using equations that represent the growth functions of each scale, $R = a + cS$ for the Borg RPE scale and $R = a + c(S - b)^n$ for the CR-10 scale. Heart rate was shown to be the largest contributing factor to Borg RPE ratings, whereas BLa and HR were shown to be the largest contributing factors to CR-10 ratings. This is to be expected considering the construct of the scales. In conclusion, the authors stated that the RPE scale is accurate and easy to use for interval data such as HR. If the linear relationship between HR and work load is lost, this advantage of the scale is lost. The CR-10 scale was considered to be beneficial for representing psychophysical functions and peripheral metabolic process due to its ratio structure. This makes the CR-10 scale important for the use of demonstrating perceptions of dyspnea and pain. The study suggests that the CR-10 scale is of practical use for perceived exertion.

Another study by Borg (2001) compared the Borg RPE and CR-10 scales in short duration cycle GXTs with stages of 1 minute durations with 15 W increases each stage for men and 10 W increases each stage for women. Thirty-two subjects (16 men, 16 women) were split into two groups. Each group utilized either the RPE scale or the CR-10 scale. Watts at a HR of 170 beats per minute (bpm) (W_{170}) and W at RPE's of 17 (W_{17}) using the Borg RPE scale and 7 (W_7) using the CR-10 scale were used to determine the correlations between HR and RPE. Correlations were found to be r = .778 between W_{170} and the RPE scale and r = .587 between W_{170} and the CR-10 scale. In this study, a transformation equation was derived for the RPE and CR-10 scales based on interindividual data. This, in theory, allows scale ratings from one scale to be transformed to the other. A scale transformation table has also been proposed by Borg (1998) to allow RPE and CR-10 scale transformations. The scale transformation table has not been verified by supporting literature.

Although both studies compare the RPE and CR-10 scales, the studies do not compare the scales on an intraindividual level. With this, the question of how individuals will rate using the different scales and how the scales will compare in varying training bouts and incremental exercise remains unanswered.

Summary

In conclusion, RPE is an easy to use, validated tool for measuring exercise intensity. Throughout the history of RPE, both the RPE and CR-10 scales have become the scales of choice in exercise and sports science. Although it is known how the scales compare both with construct and in purpose, it is unknown how the scales compare on an intraindividual level in varying training bouts and in incremental exercise using concurrent validity, verbal anchor and numerical categorical comparisons.

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