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ORIGINAL ARTICLE

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The use of ratings of perceived exertion for regulating exercise levels in rowing ergometry

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Abstract The purpose of this study was to examine the validity of the use of ratings of perceived exertion (RPE) to estimate and regulate exercise intensity during rowing ergometry. Nine competitive male rowers [mean age 28.6 years, (SD 6.3)] completed two rowing trials on an ergometer. The first trial (*estimation*) consisted of an incremental protocol designed to elicit a range of work outputs (WO) and heart rates (HR). The subjects indicated their perception of effort using a 15-point scale at each intensity level. In the second trial (*production*), 7–14 days later, the subjects were asked to produce exercise intensities corresponding to five levels of RPE: 15, 11, 17, 13, and 19. Data analysis revealed high Pearson correlation coefficients between HR and RPE ($r = 0.95, P < 0.01$) and WO and RPE ($r = 0.96, P < 0.01$) during the estimation trial. In addition, significant correlations ($P < 0.01$) were obtained between the estimation and production trials for HR ($r = 0.82$) and WO ($r = 0.84$) . Posthoc analysis of variance revealed that the observed differences in mean HR were not significant ($P > 0.05$) at three of the five intensity levels (RPE 15, 17 and 19), but were at the two lowest RPE levels (11 and 13). Significant mean differences in WO were seen at all but RPE 17. These data support the validity of the RPE scale as a measure of physiological strain among competitive male rowers, and offer support for its use as a method of regulating the intensity of rowing ergometry, especially at higher levels.

Key words Competitive male rowers · Ratings of perceived exertion estimation · Ratings of perceived exertion production · Heart rate · Power output

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Introduction

Ratings of perceived exertion (RPE) are a means of quantifying subjective, self-reported estimates of effort expended, with numerous scales having been devised for this purpose. Carton and Rhodes (1985) have stated that Borg (1962) was the first to study the perception of effort during aerobic exercise employing large muscle masses. Borg devised a 21-point category rating scale with verbal expressions describing the different numerical ratings of exertion. The scale was based upon a positive correlation between perceived exertion and heart rate, with correlation coefficients of 0.80 to 0.90 being reported. In an attempt to increase the linearity between the perceptual ratings, heart rate and exercise intensity, Borg later devised a 15-point scale (Borg 1970) which has since become by far the most frequently used rating scale for adults (Watt and Grove 1993). Borg (1982) has written that many studies since have obtained correlations of ratings and heart rates within the same range (0.80–0.90) with this scale. More specifically these strong linear relationships have been reported for the exercise modalities of cycle ergometry (Skinner et al. 1973; Morgan and Borg 1976), arm ergometry (Borg et al. 1987), walking and running (Robertson 1982).

RPE has been used primarily to estimate the perception of exertion during physical work, for example during tests of aerobic capacity. This use of RPE is consequently termed *estimation*. Until recently, a less common use of RPE has been the *production* of exercise intensities by individuals who have been prescribed exercise at intensity levels specified as RPE values, i.e. for exercise intensity regulation. An early study validating this application of RPE during treadmill exercise has been carried out by Smutok et al. (1980). This has been reinforced by the findings of Chow and Wilmore (1984), Eston et al. (1987) and Dunbar et al. (1994). More recently this validity has been extended to include cycle ergometer exercise (Dunbar et al. 1992).

Although Harrison and Howe (1992) have investigated the accuracy of oarsmen rowing at what they perceived to be anaerobic threshold, to the authors' knowledge no reports have been published concerning the application of Borg's RPE scale to *rowing* exercise. Rowing consists of a strong simultaneous contraction of both the upper and lower body musculature followed by a relatively longer relaxation phase, making rowing a unique kind of exercise to study in this context. It is therefore the purpose of this study to examine the validity of using RPE to estimate and regulate exercise intensity during rowing ergometry.

Methods

Subjects

Nine competitive male rowers agreed to participate in this study, all of whom were members of a club squad in active training (8–10 sessions per week). Rowing experience of the subjects ranged from 9 months to 9 years. The mean age of the subjects was 28.6 years (SD 6.3), height 187.3 cm (SD 6.8) and body mass 82.3 kg (SD 5.6). Informed written consent was obtained from each subject prior to testing. The study was reviewed by the Chester College Ethics Committee and approval granted.

Experimental design

Each subject performed two rowing ergometer trials, the second trial being 7–14 days after the first. Both trials were conducted in a rowing club boathouse, a typical training environment for rowing ergometry.

Equipment

The trials were performed on two wind resistance braked Concept II model B rowing ergometers (Concept II, Morrisville, USA). All the subjects had previously trained regularly on this type of ergometer. The vents were shut and the larger of the two cogs was used, i.e. the easiest gearing. The monitor was set to display power output in watts. Heart rates were monitored by telemetry using Polar 'Edge' heart rate monitors (Polar Electro, Oy, Finland). Instructions on Borg's 15-point RPE scale, read by the subjects before each trial, were taken from Borg (1985). A copy of this scale was kept in full view of the subjects during each trial.

Trial 1 – estimation

The subjects completed a 5-min warm-up period on the rowing ergometer, at an intensity which elicited a heart rate of approximately 110 beats $\cdot$ min^{-1}. The subjects were able to see their heart rate readings on the monitor during this time and adjust their effort accordingly. This warm-up period enabled a baseline power output for each individual to be recorded, the first stage of the trial proper being at this baseline power output. This enabled the number of increments performed during the trial to be similar for all the subjects. Thereafter, the subjects completed a progressive incremental protocol to a voluntary maximum. Each stage lasted for 3 min, with the power output requested of the subjects increasing by 40 W each time. During the last 15 s of each stage the subject's RPE, final heart rate and mean power output over that stage were recorded. A short interval (10–15 s) between stages was necessary, while the ergometer monitor readings were reset and the subject instructed as to the next power output to be achieved. The subjects completed between seven and nine stages before their voluntary maxima were reached. During the trial the subjects could not see the monitor displaying their heart rates, but power outputs were visible to enable the subjects to maintain the required intensity levels.[1] However, as rowers generally regulate their training on the basis of time per 500 m, these power outputs conveyed only limited meaning to the subjects.

Trial 2 – production

The subjects completed a 5-min warm-up at a similar intensity to the warm-up period in trial 1. Each subject was then asked to produce exercise intensities at specified RPE levels, for 3 min at each intensity. The RPE levels were presented in an irregular order: RPE 15, 11, 17, 13 and 19. This order was chosen to test the sensitivity of the subjects' perceptions of exertion by markedly increasing or decreasing the effort required for each stage. Final heart rate and mean power output were recorded during the last 15 s of each exercise period. A short interval (30 s) between stages was necessary, while the ergometer monitor readings were noted, then reset, and the subject instructed as to the next RPE to be achieved. The subjects were again unable to see the monitor displaying the heart rate. For this trial the ergometer readings (other than elapsed time) were also hidden from the subjects by means of opaque tape, which was removed at the end of each 3-min exercise period to allow readings to be recorded by the experimenter.

Statistical analysis

To compare the heart rates and power outputs elicited in the estimation trial with those obtained in the production trial, individual regression equations for heart rate and power output were first obtained from the data collected in the estimation trial. Using these equations each subject's heart rate and power output values at RPE 11, 13, 15, 17 and 19 during the estimation trial were calculated. This was necessary as the subjects may not necessarily have rated their perception of exertion at all of these levels during the estimation trial. Repeated measures analysis of variance using the MANOVA procedure in SPSS for Windows (1993) was used to test for differences in the dependent variables (heart rate and power output) between the estimation and production trials. Further analysis, in the form of Tukey post-hoc tests, determined at which RPE levels significant differences occurred. Pearson product moment correlation coefficients were computed between RPE/heart rate and RPE/power output for both trials, also for heart rate and power output values between the estimation and production trials. These correlation coefficients reflected the simultaneous analysis of all the subjects' data during all exercise intensities. A probability of $P < 0.05$ was considered to be significant.

Results

Relationship of RPE to exercise intensity variables

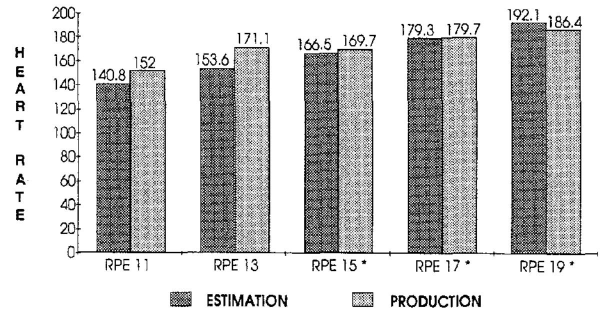
During the estimation trial the subjects exercised within a wide range of intensities, with mean heart rates

[1] Power outputs on the Concept II rowing ergometer cannot be fixed by the experimenter, as with a treadmill, but are subject-controlled.

Table 1 Correlation coefficients between ratings of perceived exertion (*RPE*) and dependent variables in both trials

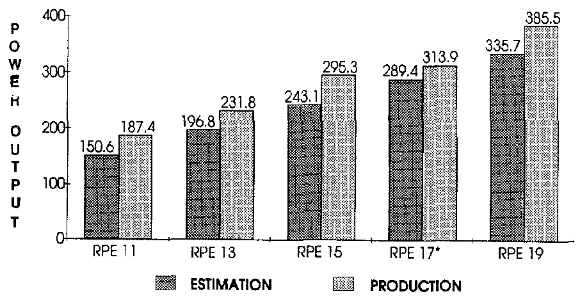
	Estimation trial	Production trial
RPE/Heart rate	0.95*	0.75*
RPE/Power output	0.96*	0.87*

* $P < 0.01$



* Indicates a non-significant difference between the estimation and production trials

Fig. 1 Histogram depicting mean heart rates (beats·min^{-1}) at specific ratings of perceived exertion (*RPE*) levels during the estimation and production trials



* Indicates a non-significant difference between estimation and production trials

Fig. 2 Histogram depicting mean power outputs (watts) at specific ratings of perceived exertion (*RPE*) levels during the estimation and production trials

ranging between 116.3 beats·min^{-1} (SEM 6.9) at the initial low exercise intensity and 186.7 beats·min^{-1} (SEM 8.0) at the highest. The corresponding mean RPE scores were 7.6 (SEM 0.9) and 18.9 (SEM 0.3). Significant linear associations were observed between RPE/heart rate and RPE/power output for both trials, but particularly for the estimation trial (Table 1).

Accuracy of exercise intensity production

Analysis of heart rate variance revealed significant main effects for trials: $F(1, 89) = 8.9$, $P < 0.01$; and RPE levels, $F(4, 89) = 67.8$, $P < 0.01$. Similarly, main effects relating to power output were found for trials, $F(1, 89) = 35.3$, $P < 0.01$; and for RPE levels,

Table 2 Actual and percentage differences in heart rate and power output between trials (*T*). *RPE* Ratings of perceived exertion

	Heart rate		Power output	
RPE	T2 – T1 (beats·min^{-1})	T2 – T1 (% difference)	T2 – T1 (watts)	T2 – T1 (% difference)
11	11.2	7.95	36.8	24.44
13	17.5	11.39	35.0	17.78
15	3.2*	1.92*	52.2	21.47
17	0.4*	0.22*	24.5*	8.47*
19	– 5.7*	2.96*	49.8	14.83

* Non-significant difference ($P > 0.05$)

$F(4, 89) = 99.8$, $P < 0.01$. Interaction effects (trials × RPE levels) were significant for heart rate: $F(4, 89) = 5.2$, $P < 0.01$, reflecting the discrepancies at RPE 11 and 13, but not for power output. However, Tukey *post-hoc* analysis revealed no significant differences ($P > 0.05$) for heart rate at RPE 15, 17 and 19 or for power output at RPE 17 (Figs. 1, 2, Table 2).

Significant ($P < 0.01$) correlation coefficients were obtained between the estimation and production trials for heart rate ($r = 0.82$) and power output ($r = 0.84$).

Discussion

The present study highlighted the existence of a strong positive relationship between exercise intensity and RPE during rowing exercise, when the intensity was measured either in terms of heart rate or power output, during both estimation and production tasks. The high correlation between RPE and heart rate during the estimation trial ($r = 0.95$) exceeded those reported for cycle ergometry ($r = 0.77$ to $r = 0.90$) by numerous authors (Arstilla et al. 1974; Bar-Or et al. 1972; Borg 1962; Edwards et al. 1972; Skinner et al. 1969) and for treadmill exercise ($r = 0.80$), by Bar-Or. This was probably due to the present subjects being part of an athletic population, who were perhaps more accustomed to perceiving the signals of exertion than less active populations. Support for this is provided by Turkulin et al. (1977), who have found RPE and heart rate to be more highly correlated in sportsmen ($r = 0.692$) than untrained men ($r = 0.589$) during cycling exercise.

As can be seen from Fig. 3, the RPE values obtained in the estimation trial do not correspond to the one-tenth relationship with heart rate reported by Borg (1970), heart rates at specific RPE values being considerably higher than this. For example, an RPE of 12 elicited an average heart rate of 146 beats·min^{-1}, and at an average heart rate of 172 beats·min^{-1} the RPE was 16. This was to be expected as the subjects in this study were much younger than the middle-aged people Borg referred to, and it has been shown that heart rate at a given RPE is higher in young adults than in

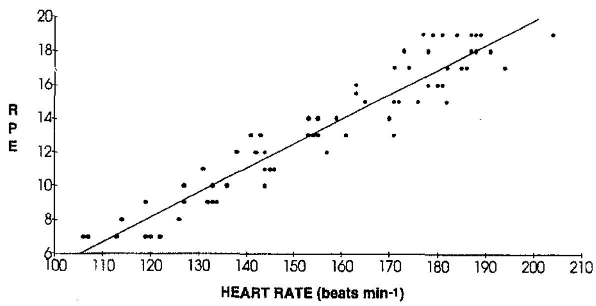


Fig. 3 Scatter plot showing the correlation between ratings of perceived exertion (*RPE*) and heart rate during the estimation trial

middle-aged men (Borg and Linderholm 1967). It has also been reported that athletes have a greater tendency to reduce perceptual ratings than less active individuals (Carton and Rhodes 1985).

The rationale underlying the second objective of this study was to investigate the accuracy with which competitive rowers can regulate rowing exercise intensity using RPE, in a manner analogous to the use of target heart rates. The results would suggest that RPE could be used by competitive rowers to regulate rowing exercise at heart rates equivalent to RPE 15 and above. Smutok et al. (1980) have found that the use of RPE to regulate treadmill exercise intensity was effective at heart rates of 150 beats $\cdot$ min^{-1} for healthy male subjects ($n = 10$). The subjects in the present study were relatively inaccurate in regulating exercise intensity at RPE 13, when the mean heart rate was 153.6 beats $\cdot$ min^{-1} (81% peak heart rate), the mean heart rate being 17.5 beats $\cdot$ min^{-1} higher in the production trial. This could possibly have been due to the lack of recovery between the RPE 17 and RPE 13 stages in the production trial, the subjects' heart rates still being at an elevated level from the higher intensity. As all the subjects' heart rates were higher at RPE 13 in the production trial compared to the estimation trial, but at all other RPE levels some heart rates were lower in the production trial, this would seem to support our reasoning.

The difference in group mean heart rates between trials ranged from 0.2% at RPE 17 to 11.4% at RPE 13 (see Table 2). These effort production errors are, on the whole, smaller than those of approximately 10%–15%, reported by Dishman (1994), for cycling and treadmill exercise.

Comparing the power outputs obtained during the two trials, only at RPE 17 were the rowers accurate in reproducing power output in the production trial. Given the near linear relationship of heart rate to exercise intensity, we may have expected the accuracy of intensity regulation in terms of power output to be similar to that of heart rate, (i.e. non-significant differences between trials at RPE levels 13, 15 and 17). The relative inaccuracy when exercise intensity was measured as power output might be explained as follows. In the production trial the power output recorded was the *mean* power output over the 3 min interval. However, the heart rate recorded was the obtained by the *end* of the interval, so that a steady-state heart rate could be reached. As the power output was subject-controlled, and could therefore vary during the course of each effort production interval, it is possible that the subjects overestimated the effort required at the start of each interval, reducing their effort during the latter minutes. Although the higher heart rates resulting from this early overexertion may have reduced by the end of the interval, as the power output recorded was a mean figure it would be higher than expected. The effort production errors in terms of power output were between 24.5 W at RPE 17 and 52.2 W at RPE 15 (see Table 2). These differences are of a similar magnitude to those reported by Dishman (1994), for cycling and treadmill exercise, i.e. approximately 10–50 W.

A further point worthy of comment is the finding that at RPE 19 there was a significantly higher mean power output in the production trial (385 W) compared to the estimation trial (335 W), whereas mean heart rates were almost identical. This inconsistency is difficult to interpret, but may be a consequence of the differences in the two exercise protocols. That is, subjects may have experienced less fatigue following the four production loadings prior to RPE 19, than the six to eight loadings prior to RPE 19 in the incremental estimation trial. Being less fatigued by the production protocol would explain the greater power outputs selected at this intensity.

The present findings generally agree with previous studies which have reported greater accuracy of regulation at higher exercise intensities (Bayles et al. 1990; Eston et al. 1987; Smutok et al. 1980), although Dunbar et al. (1992) did find greater accuracy at 50% maximal O_2 uptake ($\dot{V}O_{2max}$) than 70% $\dot{V}O_{2max}$ for cycle ergometer and treadmill exercise. In the present study, the inaccuracy at RPE 11 and 13 could be due in part to the unfamiliarity of the rowers with training on the ergometer at these low intensities. As Harrison and Howe (1992) have pointed out, much rowing training is carried out at "slightly" sub-maximal intensities. Furthermore, when the subjects were inaccurate at producing exercise intensities, they generally *over*-estimated the exertion required (the mean heart rate at RPE 19 in the production trial being the only exception to this). These results agree with those of Smutok et al. (1980), whose experimental method and sample were similar to those used in the present study. Conversely, Glass et al. (1992) have found that physically active men ($n = 15$) *under*-estimated the intensity required when attempting to produce an RPE equivalent to 75% of heart rate reserve (maximal heart rate − resting heart rate) during treadmill exercise. However, the production trial used in their study differed somewhat as it involved exercising at a single intensity for 10 min. Dunbar et al. (1994)

have also reported "underproduction", during cycling exercise at 60% $\dot{V}O_{2max}$ in healthy untrained men ($n = 9$). Again, the production trial was of a longer duration, in this case 25 min. With these findings in mind, it would seem that further research is needed to investigate the accuracy of oarsmen to regulate rowing exercise intensity of longer durations (around 30 min) using RPE.

In summary, the results of this study support the validity of Borg's RPE scale for *estimating* exercise intensity during rowing ergometry. For intensity *regulation* of rowing exercise, RPE appears to be effective at higher exercise intensities. As most rowing ergometry training by competitive rowers is carried out at these higher intensity levels, RPE has the potential to be a useful tool for these athletes. Further research establishing the reliability (repeatability) of RPE estimation and intensity regulation is required to support the validity of this application of RPE.

References

Arstilla M, Wendelin H, Vuori I, Valimaki I (1974) Comparison of two rating scales in the estimation of perceived exertion in a pulse-conducted exercise test. Ergonomics 17:577–584

Bar-Or O, Skinner JS, Buskirk ER, Borg G (1972) Physiological and perceptual indicators of physical stress in 41- to 60-year-old men who vary in conditioning level and in body fatness. Med Sci Sports Exerc 4:96–100

Bayles CM, Metz KF, Robertson R, Goss FL, Cosgrove J, McBurney D (1990) Perceptual regulation of prescribed exercise. J Cardiopulmon Rehabil 10:25–31

Borg GAV (1962) Physical performance and perceived exertion. Studia Psychologia et Paedogogica Serles Altera, Investigationes XI. Gleerup, Lund pp 39–40

Borg GAV (1970) Perceived exertion as an indicator of somatic stress. Scand J Med 2:92–98

Borg GAV (1982) Psychophysical bases of perceived exertion. Med Sci Sports Exerc 14:377–381

Borg GAV (1985) An introduction to Borg's RPE-Scale. Mouvement Publications, New York, pp 23–25

Borg GAV, Linderholm H (1967) Perceived exertion and pulse rate during graded exercise in various age groups. Acta Med Scand [Suppl] 472:194–206

Borg GAV, Hassmen P, Lagerstrom M (1987) Perceived exertion related to heart rate and blood lactate during arm and leg exercise. Eur J Appl Physiol 56:679–685

Carton RL, Rhodes EC (1985) A critical review of the literature on rating scales for perceived exertion. Sports Med 2:198–222

Chow RJ, Wilmore JH (1984) The regulation of exercise intensity by ratings of perceived exertion. J Cardiac Rehabil 4:382–387

Dishman RK (1994) Prescribed exercise intensity for healthy adults using perceived exertion. Med Sci Sports Exerc 26:1087–1094

Dunbar CC, Robertson RJ, Baun R (1992) The validity of regulating exercise intensity by ratings of perceived exertion. Med Sci Sports Exerc 24:94–99

Dunbar CC, Goris C, Michielli DW, Kalinski MI (1994) Accuracy and reproducibility of an exercise prescription based on ratings of perceived exertion for treadmill and cycle ergometer exercise. Percept Mot Skills 78:1335–1344

Edwards RHT, Melcher A, Hesser CM, Wigertz O, Ekelund LG (1972) Physiological correlates of perceived exertion in continuous and intermittent exercise with the same average power output. Eur J Clin Invest 2:108–114

Eston RG, Davies BL, Williams JG (1987) Use of perceived effort ratings to control exercise intensity in young healthy adults. Eur J Appl Physiol 56:222–224

Glass SC, Knowlton RG, Becque MD (1992) Accuracy of RPE from graded exercise to establish exercise training intensity. Med Sci Sports Exerc 24:1303–1307

Harrison D, Howe B (1992) Accuracy of perceived exertion in anaerobic threshold training for rowing. FISA Coach 3:5–9

Morgan WP, Borg GAV (1976) Perception of effort in the presecription of physical activity. In: Craig TT (ed) Humanistic and mental aspects of sports, exercise and recreation. American Medical Association, Chicago, pp 126–129

Robertson RJ (1982) Central signals of perceived exertion during dynamic exercise. Med Sci Sports Exerc 14:390–396

Skinner JS, Borg G, Buskirk ER (1969) Physiological and perceptual reactions to exertion of young men differing in activity and body size. In: Franks BD (ed) Exercise and fitness. Athletic Institute, Chicago, pp 53–66

Skinner JS, Hutsler R, Bergsteinova V, Buskirk ER (1973) The validity and reliability of a rating scale of perceived exertion. Med Sci Sports Exerc 5:94–96

Smutok MA, Skrinar GS, Pandolf KB (1980) Exercise intensity: subjective regulation by perceived exertion. Arch Phys Med Rehabil 61:569–574

SPSS for Windows (1993) Version 6.01. SPSS Inc, Chicago

Turkulin K, Zamlic B, Pegan U (1977) Exercise performance and perceived exertion in patients after myocardial infarction. In: Borg G (ed) Physical work and effort. Pergamon Press, Oxford, pp 357–366

Watt B, Grove R (1993) Perceived exertion – antecedents and applications. Sports Med 15:225–241