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Rates of Perceived Exertion Obtained From Cardiopulmonary Exercise Testing Are Not Reproduced during Prolonged Aerobic Bouts

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ABSTRACT

Monteiro WD, Cunha FA, Brasil IA, Joi S, Farinatti PTV. Rates of Perceived Exertion Obtained From Cardiopulmonary Exercise Testing Are Not Reproduced during Prolonged Aerobic Bouts. **JEPonline** 2019;22(4):29-38. This study investigated whether ratings of perceived exertion (RPE) determined during maximal exercise testing would be reproduced during prolonged aerobic submaximal exercise performed with different relative intensities. Twenty-eight healthy men (18 to 34 yrs) performed ramp-incremental cardiopulmonary maximal exercise testing (CPET) to determine VO_2R, followed by 40-min exercise bouts performed at intensities corresponding to 60%, 70%, and 80% VO_2R. Strong correlations were observed between RPE versus $\%VO_2R$ during CPET and all exercise bouts ($r = 0.86$ to 0.96; $P<0.001$). However, the RPE obtained for different $\%VO_2R$ in CPET did not correspond to scores assessed each 10 min during the submaximal exercise. In all conditions, the RPE increased over time ($P<0.001$) so that scores obtained in CPET were not reproducible during the three submaximal bouts. Acceptable agreements reflected by lack of statistical difference between expected and actual RPE were observed in only the 10-min part of the 40-min bouts. The RPE obtained during

CPET typically overestimated scores assessed at the beginning of submaximal exercise (1 to 5 points, $P<0.001$); whereas, an underestimation occurred after 20 min (1 to 3 points, $P<0.001$). In conclusion, although associated with the exercise intensity, the RPE corresponding to different $\%VO_2R$ as determined in CPET did not correspond to the actual RPE during the 40-min submaximal exercise. This discrepancy might lead to errors when the exercise intensity is controlled by perceived exertion.

Key Words: Aerobic training, Exercise intensity, Heart rate reserve, Oxygen uptake reserve

INTRODUCTION

General recommendations for aerobic exercise prescription include training intensity, duration, type, and frequency (14). Previous research has given particular attention to the manipulation of training intensity due to its importance in improving cardiorespiratory fitness (28) and as part of a weight management program (29). Training intensity is typically determined using the relationship between percentages of maximal heart rate (HR max) and maximal oxygen uptake (VO_2 max). More recently, the use of the relationship between percentages of heart rate reserve (%HRR) and VO_2 reserve ($\%VO_2R$) has been recommended since %HRR and $\%VO_2R$ seem to be more strongly related than %HR max and $\%VO_2$ max (10).

Another strategy for controlling the intensity of aerobic exercise is to determine the relationship between the physiological and perceptive responses by means of scales of perceived exertion (4,14). Classically, rates of perceived exertion (RPE) are obtained during maximal exercise testing and expressed as $\%VO_2R$. This relationship is used to ascertain whether the intensity of aerobic bouts actually correspond to what has been effectively prescribed (7). Evidently, this is a useful tool for practitioners, since resources to assess physiological data as HR or VO_2 during exercise are not always available.

The relationship between RPE and actual exercise intensity has most often been tested during maximal incremental exercise (1,22,27) or submaximal aerobic bouts with short-duration (23,26). However, it is important to note that the relationship between RPE and markers of exercise intensity (particularly VO_2) may not be the same during prolonged exercise bouts (5), especially since the effort perception has been shown to be influenced by factors such as the environmental conditions, body temperature, exercised muscle groups, and/or training level (16,19,25).

We did not find prior studies that had investigated the relationship between RPE and VO_2 during prolonged aerobic exercise. The few available studies emphasized the influence of isolating exercise duration by investigating the RPE during exercise performed with either similar (17,18) or different intensities (24,25). In practical terms, it would be useful to investigate the specific influence of exercise intensity during exercise bouts with similar duration. Assuming that the RPE may not be stable during prolonged exercise, the use of RPE-VO_2 relationships obtained during maximal exercise testing or short exercise bouts to control the exercise intensity would probably be inaccurate and lead to errors in the exercise prescription.

The purpose of the present study was to investigate whether the relationship between RPE versus VO_2 determined during maximal cardiopulmonary exercise testing (CPET) would correspond to the actual perceived exertion throughout prolonged exercise bouts performed with different relative intensities. We hypothesized that the perceived exertion during 40-min submaximal exercise bouts would not always correspond to the theoretical relationships obtained in CPETs.

METHODS

Study Design

Data collection occurred during five visits to the laboratory. During the first visit, the subjects underwent anthropometric assessments and VO_2 at rest was determined. Moreover, they underwent familiarization with the test protocols and devices. During the second visit, a maximal CPET was applied to assess VO_2 max and the relationship between RPE and $\%VO_2R$ was calculated. During the next three visits interspersed with 24 to 48-hr intervals, three 40-min exercise bouts with continuous work rates were performed in a counter-balanced randomized order. The RPE was determined at each 10 min, while VO_2 was continuously measured during the three submaximal exercise bouts. The same motorized treadmill (Inbramed™ Super ATL, Porto Alegre, RS, Brazil) was used for the CPET and exercise bouts. The laboratory temperature and humidity ranged between 19°C to 22°C and 50% to 70%, respectively.

Subjects

After advertising through social media, 28 healthy men volunteered to participate in this study [mean ± SD, age: 22 ± 4 yrs (18 to 34); height: 176 ± 7 cm (163 to 189); body mass: 71 ± 8 kg (61 to 90); body fat: 11 ± 4 %(4 to 23); VO_2 at rest: 2.9 ± 0.4 $mL \cdot kg^{-1} \cdot min^{-1}$ (2.0 to 3.8); VO_2 max: 52.8 ± 4.2 $mL \cdot kg^{-1} \cdot min^{-1}$ (42.4 to 62.2)]. The following exclusion criteria were applied: (a) smoking or use of ergogenic substances; (b) presence of cardiovascular, respiratory or metabolic disease; and (c) bone, muscle, or joint problems that could preclude the performance of the aerobic exercise bouts. The study was approved by institutional review board (CAAE: 02220228000-11), and all subjects provided written informed consent before enrolling in the study, as stated by the Declaration of Helsinki.

Assessment of VO_2 at Rest

The VO_2 at rest was determined in the morning (between 7:00 and 11:00 am) prior to CPETs using well-controlled procedures described elsewhere (8). Initially, the subjects were placed at rest in a supine position for 10-min in a quiet room. Subsequently, the VO_2 was assessed in the same conditions during 40 min. The average of the last 5 min was recorded as the final result (within-subject coefficient of variation ≤10%) (11).

Cardiopulmonary Exercise Testing

A ramp-incremented maximal exercise test was performed to determine VO_2 max, as described elsewhere (13). An individualized ramp rate was applied so that each subject reached his limit of exercise tolerance within 8 to 12 min. The test was considered to have elicited peak capacity when at least three of the following criteria were observed (21): (a) VO_2 plateau (ΔVO_2 between two consecutive work rates <2.1 $mL \cdot kg^{-1} \cdot min^{-1}$); (b) ≥90% predicted HR max [220 - age] or HR plateau (ΔHR between two consecutive work rates ≤4 $beats \cdot min^{-1}$); (c) respiratory exchange ratio >1.10; and (d) RPE of 10 on the Borg CR-10 scale.

Pulmonary gas exchanges were determined breath-by-breath using a VO2000 metabolic cart (Medical Graphics™, Saint Louis, MO, USA), and subsequently averaged into 30 sec time bins. These time-average results provide a good balance between removing noise from the data while not masking the physiological trend. Gas analyzers were calibrated immediately before each test according to the manufacturer's instructions using a certified standard gas mixture (O_2 17.01%, CO_2 5.00%, nitrogen balance; AGA™, Rio de Janeiro, RJ, Brazil). Flows and volumes derived from the pneumotacograph were verified using a 3 L syringe (Hans Rudolph™, Kansas, MO, USA).

Submaximal Exercise Bouts

The three submaximal exercise bouts were performed at 60%, 70%, and 80% VO_2R, respectively. Target VO_2 was established using the following equation: (VO_2 max – resting VO_2) x (intensity %) + resting VO_2 (12). The running speed associated with the target VO_2 was derived from the ACSM metabolic equation for running: VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$) = 0.2 (speed $m \cdot min^{-1}$) + 0.9 (speed $m \cdot min^{-1}$) (grade %) + 3.5 ($mL \cdot kg^{-1} \cdot min^{-1}$) (2). Treadmill grade was set at 1% and the speed converted to $km \cdot h^{-1}$. Each exercise bout lasted 50 min and consisted of the following phases: (a) 5-min warm-up at 5.5 $km \cdot h^{-1}$; (b) 40 min performed with constant work rate with intensity corresponding to 60%, 70%, or 80% VO_2R; and (c) 5-min cool-down at 4.0 $km \cdot h^{-1}$.

The RPE was determined at 10-min intervals during the exercise bouts using the Borg's CR10 scale (4). In order to prevent bias, the subjects were blinded to treadmill speed. Standardized detailed instructions regarding the characteristics and correct classification of RPE were given to the subjects before the exercise bouts. The VO_2 was continuously assessed using the same procedures previously described for the CPET. Due to the difficulty in verbally expressing RPE while wearing the silicone facemask during the exercise bouts, the researcher pointed to the values on the RPE scale positioned in front of the subjects who indicated the RPE value by nodding his head.

Statistical Analyses

In order to determine the RPE corresponding to 60%, 70%, and 80% VO_2R, individual linear regressions were calculated between RPE and $\%VO_2R$ during the CPET. Values obtained at rest and during exercise (CPET and submaximal bouts) were used to calculate $\%VO_2R$, as follows: $\%VO_2R$ = (VO_2 submax - VO_2 at rest) ÷ (VO_2 max - VO_2 at rest) x 100; where VO_2 max is the highest VO_2 attained in the CPET and VO_2 submax is the VO_2 observed during the submaximal bouts. Homogeneity of variance and normality assumptions were confirmed using the Levene's test and Shapiro-Wilk test, respectively. All results are presented as mean ± SD. Pearson product-moment correlations were calculated to determine the RPE-$\%VO_2R$ relationship during the CPET and submaximal exercise bouts performed at 60%, 70%, and 80% VO_2R. A 2-way ANOVA for repeated measures (intensity x time) was used to test whether RPE increased over time during the submaximal exercise bouts and the extent to which any time effect was influenced by exercise intensity. *Post-hoc* pairwise comparisons were made in the event of significant F ratios, using Bonferroni-adjusted P values. Paired t-tests were used to compare predicted (i.e., RPE from linear regression models) and observed RPE at 10-min intervals during the submaximal exercise bouts at 60%, 70%, and 80% VO_2R. Two-tailed statistical significance was accepted as $P \leq 0.05$. The Statistica 6.0™ software (Statsoft, Tulsa, OK, USA) was used in all statistical analyses.

RESULTS

Pearson correlation coefficients for RPE-%VO_2R relationships during maximal CPET and throughout the 40-min exercise bouts performed at intensities corresponding to 60%, 70%, and 80% VO_2R were 0.93, 0.88, 0.86, and 0.86, respectively ($P<0.001$). As expected, the %VO_2R during maximal and submaximal exercise bouts was strongly correlated with RPE.

Figure 1 shows mean ± SD values of RPE at 10-min intervals for each of the 40-min exercise bouts. The RPE increased significantly over time, which was significantly influenced by exercise intensity ($F = 26.2$, $P<0.001$). The average increase in RPE at each 10 min was 0.6, 1.0, and 1.5 points in exercise bouts performed at 60%, 70%, and 80% VO_2R, respectively. The *t*-tests revealed that the RPE observed during submaximal exercise bouts did not match the %VO_2R obtained during the maximal CPET, with similar values occurring only at 20 min (60% VO_2R) or 30 min (70% and 80% VO_2R). Although there was a good overall correlation between RPE and markers of relative intensity, the perceived exertion assessed during most parts of the submaximal aerobic bouts did not reflect the actual exercise intensity, particularly in bouts performed with higher intensity.

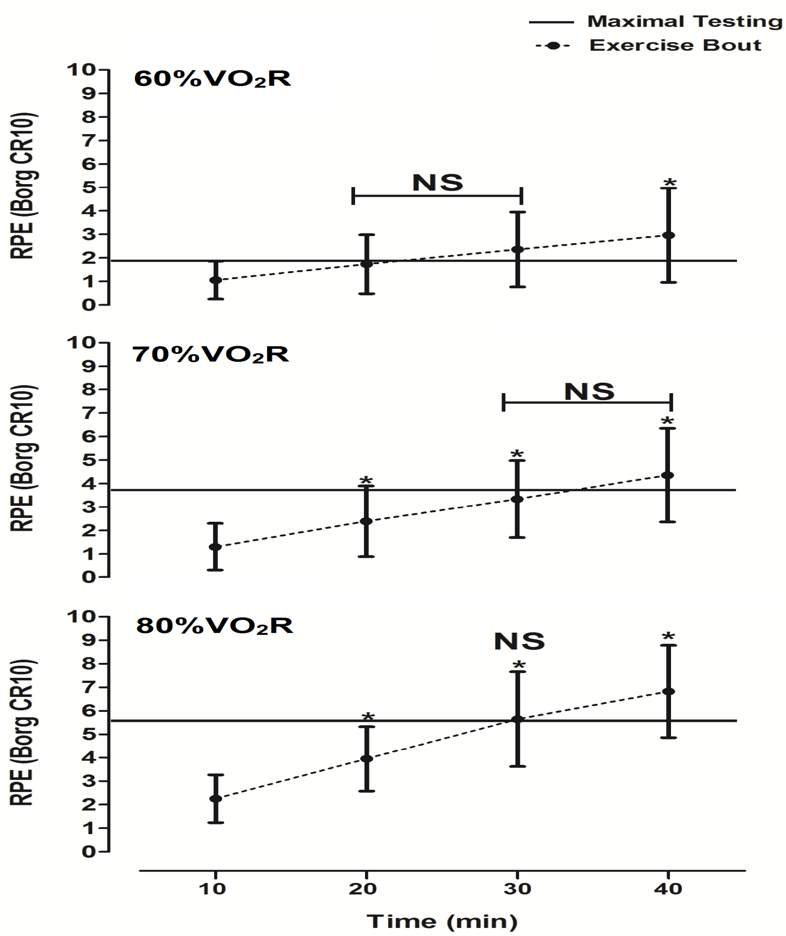

Figure 1. Mean ± SD of Rates of Perceived Exertion (RPE) during 40 min of Continuous Exercise Performed at Intensity Corresponding to 60%, 70%, and 80% VO_2R. NS = No significant difference ($P>0.05$) between values obtained within maximal cardiopulmonary exercise testing and during submaximal exercise. ***** = RPE significantly higher vs. previous value ($P<0.001$).

DISCUSSION

The purpose of this study was to investigate whether RPE determined during maximal CPET would be reproduced during prolonged submaximal exercise bouts performed with different relative intensities. In agreement with the current literature, the RPE was closely related to $\%VO_2R$ in both maximal CPET and submaximal exercise bouts. However, the findings indicated that the RPE assessed at specific work rates within incremental CPET did not correspond to the scores obtained throughout the prolonged submaximal exercise. In fact, the RPE augmented consistently over time, with higher slopes being observed at greater intensities.

Although few research studies have investigated the RPE-$\%VO_2R$ relationship, it is acknowledged that these two variables are strongly correlated so that the relative exercise intensity can be estimated from perceived exertion. Correlations above 0.9 are often reported in studies with healthy individuals (26) or patients with specific clinical conditions such as diabetes (7) or heart disease (23). These high correlations concur with our data. However, those studies have limitations regarding the potential application of the RPE-$\%VO_2R$ relationship to actual training sets. For instance, Colberg et al. (7) tested this relationship during maximal CPET, while Joo et al. (23) and Kaufman et al. (26) applied relatively short exercise bouts (10 to 15 min). Thus, there is a lack of data regarding the extent to which these results may be extrapolated to exercise bouts of 20 min duration at least, as typically performed as part of an aerobic training program (2).

The RPE during aerobic exercise is influenced by factors such as the type of exercise and fitness level, even during short-duration exercise of 10 to 15 min (23,26). Moreover, it may change due to several mediators of effort perception that include environmental conditions, body temperature, exercised muscle groups, and individual training status (16,19,25). In practical terms, this means that the RPE seems to be specific for the modality of exercise irrespective of the intensity (15,30). The exercise duration, however, is a variable that has been less investigated. In fact, some studies (17,24) with either short or prolonged aerobic bouts claim that the exercise duration would have a minimal impact on the accuracy of using the $\%VO_2$ max-RPE relationship to prescribe and/or control the exercise intensity.

The present study provides new insight on this topic and disagrees with the above mentioned premise. Although there is a strong relationship between RPE versus $\%VO_2R$ during continuous exercise performed with different relative intensities, our findings indicate that the exercise duration indeed influenced the RPE. Actually, as the duration of activity increased, there was a corresponding increase in the perceived exertion for a given relative workload, particularly after 20 min of exercise (Figure 1). In short, the RPE scores continuously increased during the 40-min submaximal exercise, with greater slopes being observed for higher intensities. Moreover, the RPE for a given $\%VO_2R$, as determined during the CPET, was not reproduced in most parts of the submaximal exercise bouts. An acceptable agreement was observed in no more than 10 min of each 40-min bout. The RPE obtained during the maximal CPET typically overestimated the RPE at the beginning of submaximal exercise, whereas an underestimation was observed after approximately 20 min.

The mechanisms underlying the changes in RPE during prolonged exercise have not been fully elucidated. It seems that as fatigue develops, the brain informs that the effort is becoming more intense, even though the work rate remains unaltered (3,9). The physiological and neurological pathways of such feedback perception are yet to be clarified (20). However, they are probably related to multiple afferent signals derived from the following variables: (a) cardiopulmonary (VO_2, ventilation, HR, etc.); and (b) metabolic (blood lactate concentration, pH, muscle damage, body temperature, carbohydrate availability, muscle tension, etc.) (6,20). Thus, either the peripheral or the central factors may act first to inform the central nervous system (i.e., the brain) of the increased effort depending on exercise specificity and individual cardiorespiratory and/or muscle fitness that plays a major role as independent 'triggers' of increased RPE (20). The present study suggests that these triggers are not only activated by the exercise relative intensity, but also by its duration.

The rate of increase in RPE was greater during the exercise bouts performed with higher intensities. Therefore, it can be speculated that the individual fitness level played a role in moderating the RPE responses. As previously discussed, Kaufman et al. (26) have shown that cardiorespiratory fitness may influence the physiological responses at a given RPE. Green et al. (18) compared overall and local RPE in trained and untrained men during prolonged cycling performed at 90% of the work rate associated with the ventilatory threshold. The increase in RPE over time was greater in the untrained men compared to the trained men after 30 min of exercise. This is an important feature within aerobic training programs, particularly for untrained individuals, since local muscle fatigue may occur before the desire to stop exercising due to central factors (e.g., 'heavy or painful legs' before 'being out of breath') (6,9,20).

Limitations in this Study

First, the sample was composed of recreationally trained men with previous experience in treadmill running. Although the perceived extension tends to be higher in individuals with lower versus higher fitness, we cannot be assured that our findings would be the same in untrained individuals. Moreover, the facemask used to assess the VO_2 may have influenced the RPE during CPET and submaximal exercise due to physical discomfort such as throat dryness. However, it is reasonable to expect that our findings were not affected by this factor, since this potential source of error was systematic across all the exercise conditions. Furthermore, the subjects were told that this kind of discomfort should not be considered when assigning RPE scores.

These findings suggest that the exercise duration is an independent determinant of perceived exertion. In practical terms, this means that the use of the RPE-%VO_2R relationship to maintain a target work rate during prolonged exercise is not recommended. In fact, the RPE assessed at the beginning of submaximal aerobic bouts will probably underestimate the RPE obtained from CPETs. On the other hand, the RPE assessed after 20 to 30 min of exercise will probably overestimate the actual intensity, particularly during vigorous exercise. This information is useful for practitioners that prescribe aerobic training and should be considered when it is not possible to control the exercise intensity by means of HR and VO_2 responses.

CONCLUSIONS

Although strongly associated with the exercise intensity, the RPE corresponding to 60%, 70%, and 80% VO_2R, as determined during maximal CPET, did not correspond to the actual

RPE during the 40-min submaximal aerobic exercise bouts. The relationship between RPE versus VO_2R during prolonged exercise was influenced by both exercise intensity and duration. Even though RPE was consistently increased along all submaximal exercise bouts, the rate of the increase was greater in the exercise bouts with higher intensities. Further research is warranted to investigate how peripheral and central factors of RPE respond to exercise performed with different combinations of duration and intensity. It is important to ascertain the pros and cons of using RPE as a marker of exercise intensity within aerobic training, particularly among untrained individuals.

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