Original Article

Rating of perceived exertion in cycle ergometer: effect of maximal capacity difference

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Aim: The purpose of this study was to evaluate cardiopulmonary responses of individuals with different fitness levels according to predetermined rating of perceived exertion (RPE) scores and to investigate the correspondence between the heart rate reserve percentage (HRR%) and the RPE scale by using fit and unfit subjects.

Materials and methods: RPE scores of sedentary volunteers were recorded at different HRR% levels during graded exercise tests on a cycle ergometer. Following the tests, subjects were divided into 2 groups, high metabolic equivalent [(MET) MET ≥ 10; n = 9] and low MET (MET < 10; n = 11), according to maximal O_2 uptakes (VO_{2max}). Participants performed the steady-state exercise test at the 13th-14th level of their perceived exertion 48 h after the first test. Variance and regression analyses were performed.

Results: For all HRR% values, RPE levels were not different between groups. During the graded exercise test, perceived exertion was significantly higher in the low MET group than in the high MET group. Predetermined RPE score results were significantly greater in the low MET group with relative O2 consumption as compared to the high MET group (P < 0.05-0.001).

Conclusion: In individuals with different VO_{2max} levels, exercise intensity can be prescribed using HRR% or RPE scale methods while adjusting for individual differences in oxygen consumption.

Key words: RPE scale, bicycle, VO_{2max} differences

Introduction

The rating of perceived exertion (RPE) provides a convenient method for exercise intensity estimation and prescription. It has been shown that Borg's 6-20 scale is a valid tool to evaluate RPE, and it is widely used by specialists in the field of exercise science (1). Borg's scale is associated with physiological parameters measured during exercise such as heart rate (HR) (1) and oxygen consumption (1,2). Since Borg's scale is used clinically in cardiac patients (3), obese adults (4), patients receiving b-blocker treatment (3), and patients with diabetic autonomic neuropathy (5), its application in individuals with different fitness levels draws considerable attention.

Several studies suggested that RPE estimations appear unaffected by fitness. For example, Hill et al. demonstrated that RPE at the ventilatory threshold is not affected after 6 weeks of training despite an increase in ventilatory threshold (6). Seip et al. (7) investigated RPE differences between runners and nonrunners at different blood lactate concentrations (2, 2.5, and 4 mM) and found no differences between the groups. On the other hand, Held and Marti (8) indicated that at a blood lactate concentration of 4 mmol L^{-1}, untrained subjects had lower RPE values compared to trained runners at the same lactate concentration. In another study, fit individuals were reported to have lower RPE values at 40%,

50%, 60%, 70%, and 80% of their VO2 (max) values than individuals with low fitness levels (9). Green et al. (10) recently found that lower aerobic fitness magnifies RPE values at individualized relative intensities when cycling extends beyond 30 min. These findings suggest that the RPE responses obtained from trained and untrained individuals may be altered by the duration of exercise as well as by the previously determined physiological parameter. Furthermore, the aforementioned studies employed RPE scores under predetermined conditions, and it is equally important to know the changes in physiological parameters at a given RPE level, because in practice this is how the RPE scale is used for exercise prescription. Surprisingly, data regarding changes in physiological parameters such as oxygen utilization, heart rate percentage (HR%), and heart rate reserve percentage (HRR%) in trained and untrained subjects at a given RPE are limited, and this topic requires further investigation. Moreover, it is important to know the changes in cardiopulmonary load following exercise prescription according to the RPE scale, because individuals with different fitness levels may have variant cardiopulmonary capacities and/or limitations. Therefore, the purpose of this investigation was to evaluate the metabolic demands and cardiopulmonary responses of individuals with different fitness levels according to predetermined RPE scores and to investigate the correspondence of HRR% with the RPE scales of fit and unfit subjects.

Materials and methods

Subjects

Twenty adult, healthy, sedentary volunteers (14 male, 6 female), aged 20-41 years (mean: 26.9), participated in the study. Sedentary life style was defined as normal daily activity without any programmed physical activity, including walking. Participants had their meals at least 3 h before performing their activity. Age, height, and body mass index (BMI) measurements were recorded, and body fat percentage was estimated using a skinfold caliper (Holtain skinfold caliper, Holtain Tanner/Whitehouse, UK) using the 7-site method (11). None of the subjects received any medication. This study was approved by the ethics committee of Marmara University's School of Medicine.

Procedures

Graded exercise test

Each subject visited the laboratory on 2 occasions. On the first day, subjects were familiarized with the Monark cycle ergometer (type 818E; Monark Exercise AB, Sweden) and the proper seat height (12) for cycling was determined by having the subject sit on the cycle ergometer; this height was recorded for the standardization of both tests. Following a resting electrocardiogram (ECG), metabolic and hemodynamic measurements [oxygen consumption (VO_2), metabolic equivalent (MET), heart rate] were recorded every 15 s; blood pressure was measured every 3 min during the rest, warm-up, exercise, and recovery periods. ECG recordings were made continuously. Every 3 min, power was increased by 50 W. The participants kept within the recommended pedal speed of 60 rpm. The incremental cycling protocol was followed until subjects achieved volitional exhaustion or could no longer maintain the required cadence. RPEs were collected at different HRR% values. HRR% was calculated by the Karvonen formula (13) and HR% was expressed using subjects' peak heart rates. At the end of the graded exercise test, the subjects were divided into 2 groups according to maximal O_2 uptakes. The high MET group (n = 9) had MET values equal to or greater than 10, and the low MET group (n = 11) had MET values lower than 10.

Rating of perceived exertion (RPE)

On the first exercise day, subjects were familiarized with Borg's 6-20 RPE scale (14) before the test. During the progressive exercise test, they were asked to rate the total amount of exertion that they felt at 40%, 50%, 60%, 70%, 80%, and 85% of their HRR%. They were instructed to concentrate on the total feeling of exertion and not any single factor or organ. During the steady-state exercise test, subjects were asked to remember their feelings of physical exertion during the graded exercise test and to give a performance at a perceived exertion level of 13-14 on the Borg scale. They were asked to exercise at this level of exertion until the end of the test.

Steady-state exercise test

Both groups performed the steady-state exercise test 48 h after the graded exercise test. Following

the baseline ECG, VO_2, MET, heart rate, and blood pressure measurements, a warm-up session and steady-state exercise at a constant workload were performed. The participants were instructed to perform at a perceived exertion level of 13-14 by increasing or decreasing the workload of the cycle ergometer. The subjects maintained this level of exercise for 15 min.

Statistical analysis

The results are expressed as mean ± standard error of the mean (SEM). The InStat statistical package (GraphPad Software, USA) and SPSS (SPSS, Inc., USA) were used. Some of the values analyzed during the steady-state exercise session are shown as a percentage of peak values observed during the graded exercise test. Multiple comparisons were done by one-way analysis of variance (ANOVA), and the Tukey-Kramer post hoc test was used to evaluate the level of statistical significance between the groups. For regression analysis, the mean values for intercepts, slopes, and Pearson's r correlations were determined. Student's t-test was used to determine whether the mean intercepts and slopes differed from 0 and 1, respectively. Differences were considered statistically significant at P < 0.05.

Results

Descriptive characteristics of subjects

Subjects' mean age, weight, height, BMI, percentage of body fat, and skinfold measurements are presented in Table 1. Body fat percentage and total skinfold measurements were significantly higher in the low MET group than in the high MET group (P < 0.001 and P < 0.01, respectively). Peak heart rates were not significantly different between the groups; however, resting heart rates were higher in the low MET group (P < 0.05).

Graded exercise test

Peak VO_2 values for the high MET group (3297 ± 185 mL min^{-1}) were significantly higher than in the low MET group (2081.5 ± 172 mL min^{-1}; P < 0.001), indicating peak performance differences between the 2 groups. The duration of the graded exercise test tended to be higher in the high MET group, but there was no statistical significance. RPE, MET, and HR% values at different HRR% levels are shown in Table 2. There was a significant increase in RPE during incremental exercise (P < 0.001), except at 80% and 85% of HRR% in both groups (low and high MET). The power of the test was 1.00 and the

Table 1. Descriptive characteristics of subjects (n = 20).

Variables	Mean ± SEM	
	MET ≥ 10 group (n = 9)	MET < 10 group (n = 11)
Age, years	26.6 ± 2.36	27 ± 1.53
Mass, kg	76.16 ± 4.07	73.09 ± 4.5
Height, cm	179.3 ± 2.5	170.7 ± 2.8*
BMI, kg m^{-2}	23.53 ± 0.84	25.07 ± 0.88
Body fat, %	12.56 ± 1.06	23.18 ± 1.66***
Σ skinfold measurement, cm	90.06 ± 6.25	142.64 ± 13.58**
Exercise time, min	12.89 ± 1.26	11.17 ± 0.37
Peak heart rate, bpm	171.89 ± 2.64	172.8 ± 4.85
Peak VO2, mL min^{-1}	3297 ± 185	2081.5 ± 172***
R value at peak exercise	1.23 ± 0.04	1.29 ± 0.04
Resting heart rate, bpm	75.5 ± 2.05	81.7 ± 1.6*

BMI: body mass index; skinfold measurement: total skinfold measurement calculated by 7-site method (triceps, pectoral, midaxillary, abdominal, iliac, thigh, subscapular); exercise time: duration of graded exercise test; VO2: oxygen uptake; R value: VCO_2/VO_2. *P < 0.05, **P < 0.01, ***P < 0.001 compared to MET ≥ 10 group.

Table 2. RPE, MET, and HR% values at different HRR levels during graded exercise test (n = 20).

HRR%	RPE		MET		HR%	
	MET ≥ 10 group	MET < 10 group	MET ≥ 10 group	MET < 10 group	MET ≥ 10 group	MET < 10 group
40%	10.8 ± 1.0	9.9 ± 0.8	5.8 ± 0.3	4.1 ± 0.4*	70.5 ± 1.7	71.9 ± 1.8
50%	12.7 ± 1.2	11.5 ± 0.7	7.1 ± 0.3	5.4 ± 0.3*	77.8 ± 1.7	78.9 ± 1.7
60%	14.3 ± 1	13.8 ± 0.7	8.1 ± 0.4	5.5 ± 0.2*	84.5 ± 1.7	85.4 ± 1.9
70%	16.1 ± 0.8	15.3 ± 0.7	9.4 ± 0.4	6.6 ± 0.3*	91.8 ± 1.4	91.7 ± 1.2
80%	17.2 ± 0.7	16.1 ± 0.9	10.9 ± 05	7.0 ± 0.3*	97.1 ± 0.9	95.6 ± 1.3
85%	18.0 ± 1.0	16.1 ± 0.8	10.2 ± 1.0	6.9 ± 0.3*	97.4 ± 0.3	95.7 ± 1.0

HRR%: percentage of heart rate reserve, [(220 – age – resting heart rate) + resting heart rate]%; RPE: rating of perceived exertion; MET, metabolic equivalent; HR%: percentage of heart rate. *P < 0.05 compared to MET ≥ 10 group.

effect size (partial eta-squared) was 0.831. There was no interaction between the dependent variables (P > 0.1). Multiple comparison shows that MET measures significantly increased (P < 0.001) during incremental exercise, except at 50% and 60% of HRR%, in both groups. There was a significant difference between groups (P < 0.05), and the power was 0.845 with an effect size of 0.737. Multiple comparison also shows that HR% measures significantly increased (P < 0.001) during incremental exercise, except at 80% and 85% of HRR%, in both groups. The low MET group had lower MET values compared to the high MET group at all HRR% levels (P < 0.01-0.001). RPE

and HR% values were not significantly different in the 2 groups at different HRR% levels.

When correlation between RPE and MET were investigated for low and high MET groups, the slopes were significantly different from each other (P < 0.05) (Figure 1).

Steady-state exercise test

Subject responses during steady-state exercise are presented in Figures 2-4. VO_2 and HRR% measurements are expressed as relative VO_2 and relative HRR% values. The relative VO_2 value is the percentage of peak VO_2 level [(VO_2 / peak VO_2) ×
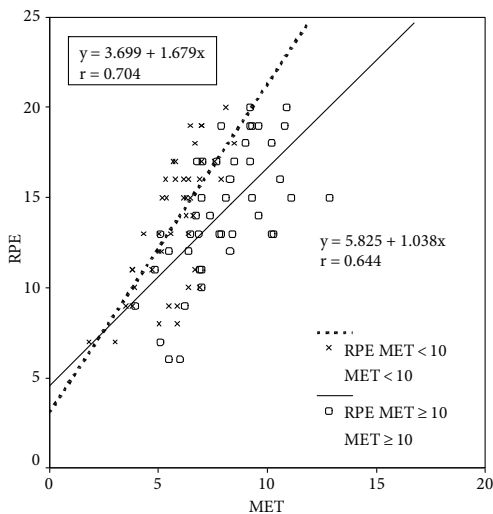

Figure 1. Scatter plot of RPE and MET data for 9 low MET (MET < 10) subjects and 11 high MET (MET ≥ 10) subjects. The 2 regression equations are the average for each group; the regression slopes were different from each other (P < 0.05: t-test for regression slopes).
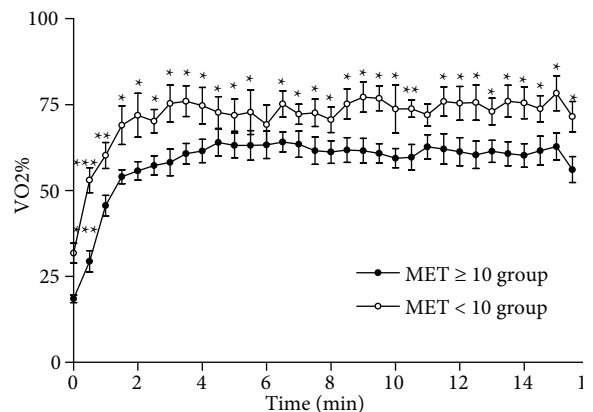

Figure 2. Relative VO_2 levels during steady-state exercise rated as perceived exertion of 13-14 on cycle ergometer (number of subjects = 20). *P < 0.05, **P < 0.01, ***P < 0.001 compared to MET ≥ 10 group.
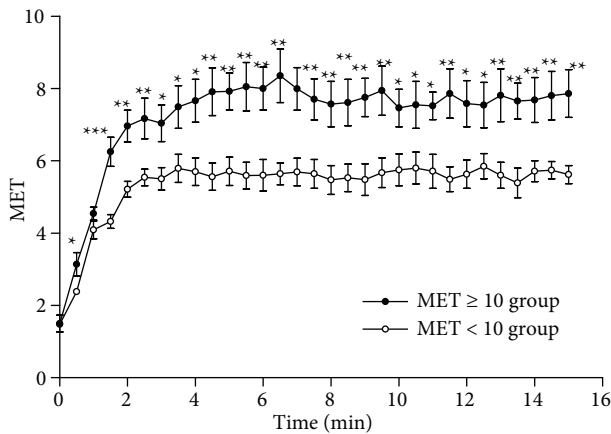
Figure 3. MET values during steady-state exercise rated as perceived exertion of 13-14 on cycle ergometer (number of subjects = 20). *P < 0.05, **P < 0.01, ***P < 0.001 compared to MET < 10 group.

Figure 4. Relative HRR levels during steady state exercise rated as perceived exertion of 13-14 on cycle ergometer (number of subjects = 20).

100] reached during the graded exercise test. As seen in Figure 2, the low MET group exercised at higher relative VO_2 values compared to the high MET group (P < 0.05-0.001). When MET values were compared, the high MET group continued the steady-state exercise at higher MET values (P < 0.05-0.001) (Figure 3). There was no significant difference in relative HRR% values determined at a perceived exertion level of 13-14 between the 2 groups (Figure 4).

Discussion

The current study was undertaken to evaluate the metabolic demands and cardiopulmonary responses of individuals with different fitness levels according to predetermined RPE scores and to investigate the correlation of HRR% with the RPE scales of fit and unfit subjects. Our data support the previous observations that RPE values have positive associations with physiological variables such as heart rate, HRR%, and oxygen utilization. We have shown that the low MET group exercised at lower MET values at certain HRR% levels compared to the high MET group during the incremental cycling (Table 2). Our study also reveals that a subject's perceived exercise intensity is influenced by their VO_{2max} level when exercising on a cycle ergometer at a given RPE level, indicating that individuals with different cardiopulmonary capacities may experience different
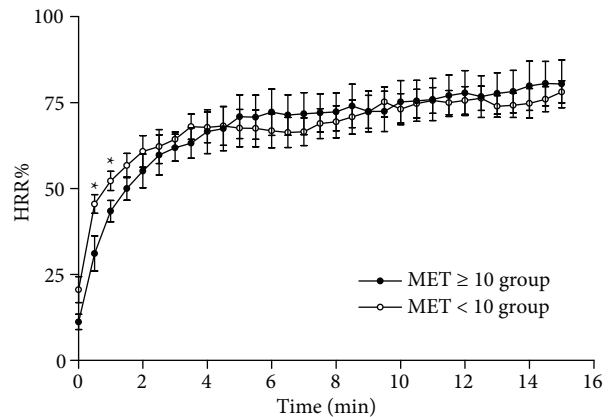
loads at the same RPE level. This information could be particularly useful when RPE score is used for exercise prescription in unhealthy individuals for whom exercise load is extremely important.

In order to address whether RPE consistently translates to the same intensity for individuals who vary in VO_{2max}, we determined RPE values at given HRR% levels in individuals with different VO_{2max} values. Although there was no significant difference in RPE scores between high and low MET groups, subjects with a high exercise capacity had slightly higher RPE scores when compared to results published previously. For example, in our study at 80% and 85% of HRR% (Table 2), subjects cycled at 10.9 and 10.2 MET and perceived 17.2 and 18 RPE values, respectively. These values seemed slightly higher than some of the RPE rates reported by Howley (15). On the other hand, in the low MET group, some RPE values seemed slightly lower than the values published in the previous work.

The exercise perception and production capability of individuals may have been influenced by several factors, including feedback from previous trials or practice and learning, as well as sociocultural backgrounds. In the present study, a questionnaire was used, and education, income level, and previous exercise history were evaluated. Two of the participants were university students, and the others were university graduates who were currently

employed. All of the participants were previously involved in leisure-time physical activity, including basketball, football, squash, and tennis. It should be emphasized that all subjects were sedentary individuals, and neither the high nor low MET group members had been engaged in a regular exercise program for the last 3 months. Our results suggest that when exercise prescription is organized according to the HRR% method, exercise intensity may be perceived similarly in individuals with different fitness levels, despite different oxygen consumption levels. When regression analyses were performed between RPE and MET (Figure 1), it was seen that the low MET group perceived the exercise as more intense compared to the high MET group as MET increased. These findings also indicate that at a given HRR%, subjects with lower fitness levels consume less O_2 than more fit subjects, and this may be associated with the observed similar RPE scores between groups. It is conceivable that at similar MET values, different HRR% values would be observed (Table 2).

Another approach used in the present study involved the determination of physiological responses at a fixed perceived exertion score. Maximal progressive exercise protocol was used to anchor the perceptual range. Subjects then performed a second exercise test at a self-selected intensity gauged by a perceived exertion level equal to that obtained at RPE 13-14 by manipulating the workload of the cycle ergometer. During the production trial, MET, VO_2, and HRR% values were not different than those obtained during a previous graded exercise test, indicating that anchoring the perceptual range during the maximal test was adequate to estimate the produced intensity during the subsequent test. Furthermore, a steady-state condition was observed in MET, VO2, and HRR% levels in each group during the 15 min of exercise. In a study by Batte et al. (1), an elliptical fitness cross-trainer was used and physiological responses were observed for 15 min as subjects were asked to maintain constant RPE scores. As seen in our study, although the groups were not divided into high or low fitness categories, VO_2 and HR% levels remained steady until the end of the exercise period.

In Figures 2 and 3, it is shown that the high and low MET groups cycled at different VO_2 percentages

and METs. Accordingly, comparisons such as MET and VO_2% values were affected by the maximum capacity differences of the subjects. As seen in Figure 2, the low MET group exercised at higher relative VO_2 values compared to the high MET group. However, the MET values matching the VO_2% (Figure 3) were lower in the low MET group than in the other group. Past studies on the effect of different fitness levels on exercise perception generally used either an incremental exercise protocol and searched for a corresponding exercise perception level, or examined RPE scores according to a predetermined physiological variable such as ventilatory threshold (6), lactate level (7,8), or percent VO_{2max} (9). Although it is often presumed that a given RPE level results in different VO_2 consumption in subjects with different fitness levels, to date, this remains uncertain; the degree of variation in oxygen consumption is unclear even among healthy individuals (16). Thus, the present study shows that even for sedentary individuals with different fitness levels, considerable differences in oxygen uptake can be observed at certain RPE levels. Although the RPE scale is used clinically in cardiac patients (3), obese adults (4), patients receiving b-blocker therapy (17), and patients with diabetic autonomic neuropathy (5), it should be emphasized that differences in oxygen consumption may be more dramatic in an unhealthy population. In Figure 4, it is seen that the high and low MET groups cycled at similar HRR% levels according to a given RPE score. Thus, it is likely that the exercise intensity of groups with different maximal oxygen consumption levels can be prescribed either by HRR% levels or by the RPE scale, remembering that individual oxygen consumption may differ. One of the limitations of the current study is that we were unable to analyze sex differences between groups due to the small sample size. Sex differences were emphasized in some previous studies indicating that RPE estimations appear to be unaffected by sex (18,19), while Moyna et al. (20) found a significant influence of sex on RPE.

Our results suggest that exercise prescription based on RPE produces similar HRR% and VO_2R% (because it is based on individualized maximal and basal values) in either fit or unfit individuals despite the fact that corresponding oxygen consumption (VO_2) may be different among individuals. This has practical implications for those who use RPE without

measuring metabolic capacity. Moreover, the present study provides new information that a predetermined RPE results in a marked difference in oxygen uptake, even in sedentary individuals with different fitness levels.

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