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Rating of perceived exertion at the ventilatory anaerobic threshold in people with coronary heart disease: A CARE CR study

Abstract

Background. Exercise prescription guidelines for individuals undergoing cardiovascular rehabilitation (CR) are based on heart rate training zones and rating of perceived exertion (RPE). United Kingdom guidelines indicate that patients should exercise at an intensity of RPE 11 to 14.

Objectives. We aimed to determine the accuracy of this approach by comparing this RPE range with an objectively measured marker of exercise intensity, the ventilatory anaerobic threshold (VAT), and examine whether baseline directly determined cardiorespiratory fitness (CRF) affects the association between VAT and RPE.

Methods. Participants underwent a maximal cardiopulmonary exercise test before an 8-week community-based CR programme. Peak oxygen uptake ($\dot{V}O_{2peak}$) and VAT were recorded, and RPE at the workload at which VAT was identified was recorded. Data were then split into tertiles, based on $\dot{V}O_{2peak}$, to determine whether RPE at the VAT differed in participants with low, moderate or high CRF.

Results. We included 70 individuals [mean (SD) age 63.1 (10.0) years; body mass index 29.4 (4.0) kg/m^2; 86% male]. At baseline, the mean RPE at the VAT (RPE@VAT) was 11.8 (95% confidence interval 11-12.6) and significantly differed between low and high CRF groups

(P<0.001). The mean RPE@VAT was 10.1 (8.7-11.5), 11.8 (10.5-13.0), and 13.7 (12.5-14.9) for low, moderate and high CRF groups, respectively.

Conclusions. When using RPE to guide exercise intensity in CR populations, one must consider the effect of baseline CRF. Mean RPEs of ~10, 12 and 14 correspond to the VAT in low, moderate and high- fit patients, respectively.

Key words: cardiac rehabilitation; exercise prescription; cardiorespiratory fitness; ventilatory anaerobic threshold; RPE.

Introduction

Cardiovascular rehabilitation (CR) is a multi-disciplinary intervention that typically includes an individualised exercise training programme alongside educational support and psychological counselling. The “dose of exercise” received by the patient can be affected by manipulating a number of factors including exercise frequency, duration of each session, type/mode of training, and, probably the most challenging aspect of prescribing, exercise intensity [1]. In the United Kingdom, current exercise training guidelines issued by relevant professional bodies recommend exercise intensities between 40% and 70% heart rate reserve (HRR) or a rating of perceived exertion (RPE) from 11 to 14 (“light” to “somewhat hard” by using verbal anchors) on an interval scale from 6 to 20 [2-4].

There are 2 assumptions for this range: 1) that these intensities will be at or above the ventilatory anaerobic threshold (VAT), and 2) for a new or physically inactive individual and/or high-risk individuals, it is safer and more psychologically tolerable to start a new exercise regime at lower intensities (40-50%), knowing that they will work at a minimum level to gain some training benefit [5]. The strongest correlation between physiological responses and RPE was reported to be percentage of maximum oxygen uptake and respiration rate in healthy adults [6]. On this basis, the RPE 6-20 scale is chosen when simple inexpensive intensity monitoring tools are required to represent a relative target heart rate (%HRR), peak oxygen consumption ($\dot{V}O_{2peak}$), or the VAT [7-9]. The association between RPE and exercise intensity remains stable regardless of health status [10-13] and is sensitive to changes elicited by exercise training [10]. Thus, RPE is a reasonably sensitive perceptual marker that can be used to guide exercise prescription in individuals with coronary heart disease (CHD).

Exercise training studies have identified that training at or above the VAT (or so-called VT_1) can induce physiological adaptation leading to improvements in cardiorespiratory fitness (CRF) and other cardiovascular risk factors [14, 15]. Recently, we showed that in 112 individuals with CHD, baseline CRF was an important factor for identifying when VAT occurs within exercise prescription guidelines (between 40 to 70% HRR) [16]. Those classified as having low CRF, determined from a treadmill-based cardiopulmonary exercise test (CPET), achieved VAT at 26% to 49% of their HRR. However, those classified as having high CRF achieved VAT at 52% to 78% HRR. Therefore, we were concerned that current exercise training recommendations for prescribing exercise intensities based on an RPE range of 11 to 14 needed to be verified for the association between the lower and upper ends of the CRF/risk continuum, within a standard CR population.

Thus, in this study, we aimed to determine the accuracy of the RPE threshold approach (range 11 to 14) for prescribing exercise intensity by comparing it with an objectively measured marker, the VAT, and determine whether baseline directly determined CRF mediated this relationship.

Methods

Ethical approval was provided by the Yorkshire and Humber–Sheffield National (12/YH/0072) and Humber Bridge National Health Service (12/YH/0278) Research Ethics Committees. All participants gave their informed consent to be in the study. The methods for this study were previously published [17]. Briefly, individuals were recruited to the CARE CR study [17] after a referral for CR for angina, myocardial infarction (MI), coronary artery bypass graft, or percutaneous coronary intervention. Participants attended a baseline study assessment, at which written informed consent was obtained. All available baseline data were included in this sub-study. CPET was conducted on a treadmill following the modified Bruce protocol [18], adopting previously outlined test termination and maximal effort criteria [19,20]. Directly determined HRR was calculated by subtracting resting heart rate (HR) from peak HR achieved during the CPET. Estimated HRR was calculated as follows [3]:

((206 – (0.7 x age)) – resting heart rate (minus 30 if taking beta blockers)

Breath-by-breath metabolic gas exchange data were collected by using the Oxycon-Pro metabolic cart (Jaeger, Hoechburg, Germany) calibrated according to the manufacturers' instructions and current recommendations [21]. Peak values were averaged over the final 30 sec of the CPET. $\dot{V}O_{2peak}$ was reported in absolute values ($L \cdot min^{-1}$) and standardised to each participant's body mass (ml/kg/min). Individualised VAT was independently determined by 2 investigators (by using a data-smoothing technique incorporating the average of the middle 5 of every 7 breaths), with ventilatory $\dot{V}CO_2/\dot{V}O_2$ plotted by using the V-slope method, and verified with the ventilatory equivalents ($\dot{V}E/\dot{V}CO_2$ and $\dot{V}E/\dot{V}O_2$) [19, 22]. When investigators reported different VAT values, a third reviewer was consulted and the VAT threshold value was agreed upon by consensus. The VAT was expressed as a percentage of directly determined and predicted $\dot{V}O_{2peak}$ [23].

We have previously reported when VAT occurred within the exercise training intensity guidelines [16]. Participants were sub-classified based on equally distributed tertiles of baseline $\dot{V}O_{2peak}$ into low, moderate, and high CRF categories. We reported VAT as a percentage of $\dot{V}O_{2peak}$. Before the maximal CPET, participants were given a standardised explanation of the RPE scale. This included “anchoring” the bottom and top of the RPE sale. An RPE of 6 was explained as no exertion at all, such as sitting down and not taking part in any activity. An RPE of 20 was explained as feeling extreme shortness of breath, severe burning sensations in muscles, as though participants would have to terminate exercise imminently. Participants were asked to provide an RPE score at rest, in the last 10 sec of each 3-min stage throughout the CPET, and at peak exercise. The RPE value corresponding to the stage at which VAT occurred was noted as the RPE at VAT (RPE@VAT). When the VAT occurred in the first minute of a stage, the RPE from the final 10 sec of the previous stage was noted as the RPE@VAT. RPE@VAT values are reported for the entire cohort, then by CRF category.

Data analysis

We followed STROBE guidelines for the reporting of this study (Appendix A1) [24]. Statistical analysis involved using SPSS v26 (IBM, NY, USA). Normality of data distribution was visually assessed and statistically assessed with the Shapiro-Wilk test. When data were not normally distributed, normalisation was attempted with $\log_{10}$ transformation. Logarithmically transformed data were analysed in the transformed state and reported as an arithmetic mean to allow for meaningful interpretation. Normally distributed and transformed data were analysed by one-way ANOVA with a Bonferroni correction factor to identify between-group differences (low-, moderate- and high-fit groups). We calculated Cohen’s *d* effect sizes for RPE@VAT values in the low-, moderate- and high-fit groups [25]. Significance was set at an arbitrary level ($P<0.05$) and data are presented as mean (SD or 95% confidence interval [CI]). A power analysis was not conducted for this exploratory analysis of baseline data collected for the CARE CR study [26].

Results

We included 70 participants [mean [SD] age 63.1 (10.0) years; body mass index 29.4 (4.0) kg/m^2; 86% male; 98.6% White British]; 16 (23%) had ST-elevation MI (STEMI), 22 (31%) had non-STEMI, and 19 (27%) had elective percutaneous coronary intervention. Seven (10%) participants were medically managed for stable angina, and 6 (9%) had undergone coronary artery bypass graft.

Table 1 shows the baseline clinical and CPET characteristics for participants according to CRF levels. In the low-fit group, mean $\dot{V}O_{2peak}$ was 17.3 (2.7) ml/kg/min (equivalent to ~5 metabolic equivalent of task [METs]); in the moderate-fit group, $\dot{V}O_{2peak}$ was 22.9 (2.7) ml/kg/min (equivalent to ~6.5 METs); and in the high-fit group, $\dot{V}O_{2peak}$ was 30.0 (4.0) ml/kg/min (equivalent to ~8.5 METs). The low-fit group was older, had higher N-terminal pro B-type natriuretic peptide (NT-proBNP) level, completed less exercise time on the treadmill, and had a lower VAT than the moderate- and high-fit groups (Table 1).

Respiratory exchange ratio (RER) at peak and HR values (indices of effort during maximal CPET) were lower in the low- than moderate- and high-fit CRF groups, despite similar RPE. For 36% of participants with low CRF, the VAT occurred at 40% to 70% of predicted HRR. For 57% of those with moderate CRF, the VAT occurred at <40% of predicted HRR. For 50% of high-fit participants, the VAT occurred at 40% to 70% of predicted HRR, for 20% at <40% HRR, and for 30% at >70% HRR.

The RPE at VAT (RPE@VAT) was 11.8 (95% CI 11-12.6) for all participants. The mean RPE@VAT for the low-, moderate- and high-fit groups was 10.1 (95% CI 8.7-11.5), 11.8 (10.5-13.0) and 13.7 (12.5-14.9), respectively (Table 2). However, RPE@VAT significantly differed between low- and high-fit groups (*P*<0.01; *d* = 1.183; large effect) and moderate for high-fit groups (*P*<0.01; *d* = 0.682; moderate effect; Figure 1 and 2). We noted that 37% of all participants achieved the RPE@VAT at RPE <11, lower than the minimum RPE exercise training guidelines for cardiac patients. Overall, 70% of low-fit participants had an RPE@VAT <11. Also, 26% of all participants (35% of high-fit participants) achieved the RPE@VAT at RPE >14, which is higher than the maximal RPE exercise training guidelines for cardiac patients.

Discussion

When CPET is unavailable, the British Association for Cardiovascular Prevention and Rehabilitation recommends that exercise prescription for patients undertaking CR is often guided by the HRR, RPE, and MET relationships found in a submaximal assessment of functional capacity. In this case, the exercise is guided by the estimated MET values that correspond to the zones of 40% to 70% HRR and/or RPE 11 to 14 ("light to somewhat hard") [2,3]. We aimed to determine the accuracy of this approach by comparing this range with the VAT as an objective marker of exercise intensity and suggested as the minimum training stimulus needed to increase CRF [16]. We also determined whether the RPE at the VAT differed among people with low, moderate and high CRF. Our findings indicate clear differences as to when the RPE@VAT occurred based on baseline CRF levels. In the low-fit group, the mean RPE@VAT was 10.1 (95% CI 8.7-11.5); in the moderate-fit group, it was 11.8 (10.5-13.0); and in the high-fit group, it was 13.7 (12.5-14.9). Thus 37% of all participants achieved their RPE@VAT at RPE <11, which is lower than the minimum RPE exercise training guidelines for cardiac patients. Also, 26% of all participants (35% of high-fit participants), achieved their RPE@VAT at RPE >14 which is higher than the maximal RPE exercise training guidelines for cardiac patients. These findings have important implications for exercise training guidelines in patients with CHD.

In the United Kingdom, individuals are initially stratified for risk of a cardiac event during exercise and are placed in a category of low, moderate or high risk by using the British Association for Cardiovascular Prevention and Rehabilitation risk stratification criteria [27], or the equivalent American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) risk criteria [28]. Although both these criteria are similar, they do exhibit differences. For example, with the AACVPR criteria, individuals are classified at low risk if they have a functional capacity ≥7 METs and moderate risk if they have a functional capacity < 5 METs. Our low-fit group had a mean (range) MET score of ~5 METs, thus automatically at moderate risk according to AACVPR criteria [28]. On the basis of this risk category, and data presented in our study, exercise professionals could prescribe a lower dose of exercise (e.g., RPE 10-11), legitimately due to health and safety concerns, and be confident that exercise was being prescribed at the VAT [16]. We acknowledge that some patients may be stratified into a moderate- or high-risk category because of other cardiac factors from the risk stratification criteria; however, our findings strengthen the requirement for baseline exercise capacity to be used as a guiding criteria for risk stratification in the United Kingdom and internationally.

From our findings, low-fit individuals who are about to start CR could start initial training intensity at an RPE threshold as low as 9 to 11 (very light to light), with exercise doses up-titrated based on individual progress. Current UK guidelines would indicate that patients should initiate exercise at an RPE threshold of 11 [3]. Conversely, in high-fit patients, current UK guidelines [3] of an RPE training threshold of 11 to 14 may be insufficient. From our findings, we recommend increasing the upper range of exercise prescription guidelines to RPE 15 (hard) and in some cases higher. This increase would provide greater scope for training progression in individuals who could tolerate it. It would also align UK exercise prescription guidelines closer to international guidelines [22].

A valid and reproducible baseline oxygen uptake/functional capacity value is key to stratifying patients based on baseline exercise testing. Thus, we strongly recommend that a baseline exercise test be conducted for each individual before commencing a CR programme. Individuals should then be provided with an individualised exercise prescription based on factors including baseline functional capacity, relevant symptoms and perceived exertion responses. Current exercise prescription guidelines in the United Kingdom may be inappropriate for many people with cardiovascular disease, especially those classified at low or high fitness. We speculate that this situation may contribute to the 23% attrition rate recently reported in UK CR [29], because some individuals exceed their training stimulus (i.e., low-fit patients), which may be uncomfortable, and some do not reach it (i.e., high-fit patients), thus providing minimal benefit, both of which may cause people to discontinue CR.

Limitations and conclusions

The lower peak RER observed in the low-fit group as compared with the moderate- and high-fit groups, may indicate that they did not exercise until the point of physical exhaustion. The low peak HR observed in the low-fit group may support this assertion but may also indicate chronotropic incompetence. Thus, the low peak RER and peak HR observed in the low-fit group could be due to a greater disease burden, thus preventing them from continuing to exercise to a greater physiological marker of physical exhaustion. This theory is supported by the high NT-proBNP and low haemoglobin levels reported in the sub-group. The peak RPE values were similar in all sub-groups, which suggests that similar rates of exertion were achieved. Also, participants in the low-fit group may have overestimated the effort required to conduct any given workload or they were more sensitive to the perception of symptoms associated with exercise above the VAT, including increased respiration and muscle fatigue. Nonetheless, our findings indicate that individual baseline CRF level should be used to determine which intensity of exercise patients with CHD should initiate their CR programmes and could be used to support the risk stratification process.

Training at or above the VAT, often referred to as the first ventilatory threshold, indicates the point above which further increments in work rate are increasingly supplemented by anaerobic metabolism [19, 30]. Despite being associated with mild metabolic perturbations [30], regular exercise bouts conducted at work rates equivalent to VAT are well tolerated [31] and induce physiological adaptation, leading to improved CRF and improvements in other cardiovascular risk factors [14,15]. We found distinct differences in RPE responses at the VAT in individuals with CHD during a maximal walking CPET: 37% of all participants achieved RPE@VAT at RPE <11, which is lower than the minimum RPE exercise training guidelines for cardiac patients. Also, 26% of all participants achieved RPE@VAT at RPE >14 which is higher than the maximal RPE exercise training guidelines for cardiac patients.

Availability of data and material. A request for the data can be made directly to the corresponding author.

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Conflict of interest. None declared.

Author contributions. SN, SC and LI contributed to the design of the work. SN collected the data. SN, BE and LI analysed the data and drafted the manuscript. SN, BE, SC, JB and LI interpreted the data. SN, SC, LI and JB critically reviewed the manuscript. All gave final approval and agree to be accountable for all aspects of work ensuring integrity and accuracy.

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Figure Legends

Figure 1. The mean rating of perceived exertion threshold (95% confidence intervals) where ventilatory anaerobic threshold occurs in patients with low, moderate and high baseline cardiorespiratory fitness. Note the clear separation between low and high fitness groups.

Figure 2. A) Scatterplot of individual ratings of perceived exertion at the ventilatory anaerobic threshold standardised to body mass. B) Ratings of perceived exertion at the ventilatory anaerobic threshold as a percentage of peak oxygen uptake. Blue, red and yellow circles indicate patients in the low, moderate, and high fitness categories, respectively.

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