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Different physiological, but similar affective responses, facing different workload quantification methods

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ABSTRACT

Backgroung: The literature provides support for several different method by which it is possible to quantify, prescribe and control the aerobic workload. **Objective:** To compare physiological and the affective response among training methods prescribed by VO2 reserve, HR reserve, and rating of perceived exertion (RPE) self-adjusted. **Methods:** 27 participants were submitted to two trail sessions. In the 1st, a maximum treadmill effort test was performed to determine the VO2max. In the 2nd, the participants were randomly divided into 3 situations of 5 min, with 5 min interval among the situations. In situation 1 (C1), the participants ran at the velocity correspondent to 65% of the VO2 reserve; in situation 2 (C2), participants ran at 60% to 65% of HR reserve and in situation 3 (C3), the participants self-adjustment the velocity by a RPE scale, in a moderate effort (RPE 3-4). The level of body activation and the affective response were obtained pre and post-stimulus administered. An ANOVA was performed and the magnitude of the differences established, with a significance level of $p \leq 0.05$. **Results:** There were no significant differences for velocity in the three situations ($p = 0.458$). The responses of HR induced by C1 and C3 were significantly higher vs. C2 ($p = 0.027$ and $p = 0.043$). The RPE did not show significant differences among the situations ($p = 0.118$). Finally, the level of activation and sensation perceived activity did not differ significantly ($p = 0.168$). **Conclusion:** It was concluded that the exercise responses from the HR reserve were significantly lower when compared to the VO2reserve and RPE. All prescription models provided similar affective responses.

Keywords: Aerobic exercise; VO2max; Heart rate determination; Affect.

BACKGROUND

The literature provides support for several different method by which it is possible to quantify, prescribe and control the aerobic workload. Among them, the following stand out, due to their wide applicability: a) heart rate (HR), b) rating of perceived exertion (RPE), and c) velocity associated with metabolic demand relative to the maximum oxygen consumption (VO_{2max}) or based on VO_2 reserve[1-4]. Such method exhibit advantages and limitations which may result to different impacts on training and, therefore, bringing different adaptations[1,5]. These can result in potentiated or underestimated outcomes, depending on the choice of the prescription strategy. In addition, depending on the population, the lack of precision on the exercise intensity can also provide low security due to excessive effort[6,7].

Traditionally, HR has played a prominent role as the most commonly used method within training and rehabilitation centers[8]. HR generally demonstrates a linear relationship with the administered workload and the VO_2. More recently, the reserve method has been proposed as a mean of prescription and the establishment of a proportionality relationship between VO_{2max} and HR (1:1 ratio)[4,9]. However, the proportion between these two variables still results from debates and is, therefore, questionable[10,11]. Moreover, HR is influenced by the environment (*"cardiovascular drift")*[5], nutritional factors[12], age[13], and psychological status (reflex autonomic activity)[14]. Thus, it is not an efficient method in unstable physiological conditions, mainly in the face of interval training.

On the other hand, the RPE can be considered a practical and easy method to control the training load [15]. Recent evidence also suggests that the self-selected workload based on the psycho perception of the internal physiological environment, could induce positive affective responses, and favor adherence to training[16,17]. However, although RPE response has the same linearity relationship demonstrated with HR and other prescription methods, the perceived effort can be influenced by less experienced practitioners as it depends on a prior learning and understanding the use of specific effort scales, that is, anchoring with said instruments[18].

Therefore, the training impulse (TRIMP - volume x intensity) could be considered to be underestimated or overestimated, producing unexpected psycho-affective responses[19]. Despite the practical advantages, we do not know whether the prescription based on self-selection of workload would produce different psycho-affective responses compared to other prescription models. This question still remains unclear.

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Thus, when we assume the limiting outcomes of the mentioned variables used, the use of metabolic demand, that is, external load expressed in power (Watts) or velocity ($km \cdot h^{-1}$) relative to VO_2max percentages or VO_2 reserve, would position itself as an alternative strategy of significant accuracy and independent of the others methods (e.g., HR and RPE)[18,20]. The limitations underlying the HR and RPE methods are removed from the objectivity provided by external load[20].

Considering the relationship and the apparent linearity between the three methods, especially when considering the reserve method (proportional ratio 1:1), it becomes reasonable to infer that the acute relative impact provided by all three methods would be similar[21]. However, as far as is known, there seems to be no studies that have investigated the relationship between these three methods together, as well as, whether they would generate differentiated physiological or psycho-affective demands, which could directly influence the work performed. Thus, our objective was to compare physiological and the affective response among training methods prescribed by the VO_2 reserve, HR reserve, and RPE self-adjusted. Considering the recent publications in the area of sports psychology[16,22], the affective responses will be obtained for the three methods, in order to establish possible affective differences related to the methods, and the concomitant potential for adherence to the exercise. We hypothesized that all methods will produce responses significantly different affective responses.

METHODS

The present study used as a reference the assumptions described by the International Committee of Medical Journal Editors (ICMJE) and respected all the items proposed in the "CONSORT" guidelines.

Participants

Thirty participants of both genders, physically active and non-smoking were invited to participate in the study. The participants answered the risk stratification questionnaire for coronary artery disease (CAD), as proposed by the American College of Sports Medicine (ACSM)[23], including only those participants characterized as low risk. Individuals who used psychoactive or ergogenic substance seven after communication, or who had predetermined musculoskeletal injuries (n = 3) were excluded, leaving the sample with twenty-seven participants. The study was approved by a local Ethics Committee under the number 48835315.0.0000.5289. Table I describes the sample characteristics.

Table 1. Sample characteristics

Sample Characteristics (n=27)	Mean and ± standard deviation
Age (years)	34.1 ± 5.9
Body Mass (kg)	65.5 ± 6.2
Height (cm)	170.7 ± 5.9
Body fat (%)	17.0 ± 4.2

Study Design

Twenty-seven participants performed two trails in different days. At the 1st day, measurements of resting HR and an indirect maximum progressive aerobic exercise test on the treadmill (EXCITE® RUN 1000, Technogym, Italy) were conducted to determine maximum HR, peak of velocity (Vpeak), and VO2max. On the 2nd day, the participants were randomly placed in 3 situations of running on treadmill characterized by a moderate effort with a total of 5 min each and 5 min interval between the situations. The 1st situation was configured using the velocity associated with the metabolic demand at 65% of the VO2reserve. In the 2nd situation, the HR reserve amplitude was used as a reference for prescription aiming at reaching 60 to 65%; in the 3rd situation, the participants were suggested that they position themselves in a moderate effort (RPE 3 to 4). All participants were already familiar with the scales used. At the end of each moment, the velocities, HR obtained, and the RPE achieved were recorded, as well as the level of activation (felt arousal scale - FAS) and sensation (felling scale - FS) obtained with the exercise. The experimental design is described in Figure I.

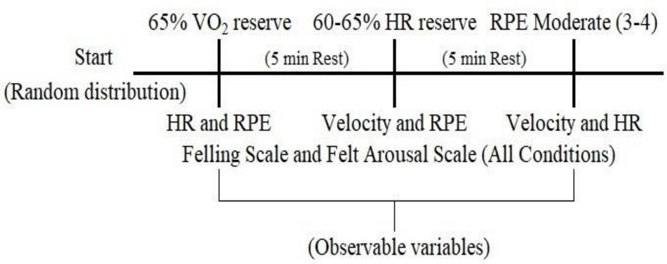

Figure 1. Experimental design

Experimental Procedures

Anthropometry

The standard assessment established by the International Society for the Advancement of Kinanthropometry (ISAK) was used to determine the following anthropometric measurements: body mass (kg), height (m) (Filizola, Brazil) and skinfold (Slim Guide, Rosscraft, Canada). We estimate body density using the Jackson and Pollock equation[24], and the percentage of body fat was determined using the Siri equation[25].

Cardiopulmonary Effort Test

The participants started walking on the treadmill at 5.0 $km \cdot h^{-1}$ and 0% slope for a period of 2 min. From this initial stage, increments of 1.0 $km \cdot h^{-1}$ (approx. 1MET) were administered every two minutes in order to achieve maximum performance and effort until voluntary exhaustion. Oxygen consumption was estimated using the metabolic running equation proposed by ACSM[23]. HR responses (Polar® monitor model RS800, Finland) were monitored and recorded every minute until exhaustion. The final HR values were used for calculations of HR reserve. The presence of signs or symptoms observed or mentioned, or self-maximum voluntary exhaustion were used to test termination criterion.

Exercise Prescription.

After a warm-up for all participants at 5.0 $km \cdot h^{-1}$ for 5 min on the treadmill, the three situations were administered in randomly order. For all conditions, velocity, RPE, and HR responses (Polar® monitor model RS800, Finland) were monitored and recorded in last minute, and were used for statistical calculation.

In the 1st situation, a trained professional adjusted the velocity corresponding to a demand of 65% of VO_2 reserve (VO_2max – VO_2rest). The velocity was estimated from the adjusted metabolic equation of the ACSM (Eq. 1).

Eq. 1. $V = [(VO_2max - VO_2rest) \div (0.2 + (0.9 \times \% \text{ slope})]$

In the 2ndsituation, the velocity was progressively adjusted until reaching 60% of HR reserve, aiming at the reach and stability of a HR around 65% of HR reserve. The 5 min of exercise in this situation was only computed after the initial 30 sec of adjustment.

Lastly, in the3rd situation, the participants self-selected and adjusted their work velocity to the level of effort required. A RPE scale remained available in front of the participant to self-regulate the effort of the task.

Pre and post conditions, the FS and FAS scales were presented to the participants, and the data were used in the final statistical calculation.

Measuring Instruments

RPE Scale

The adapted linear scale (0 to 10) was used as produced and described by Borg, where "0" refers to the perception of "extremely light" effort, and 10 represents "total fatigue".

Feeling Scale (FS)

The dimensions of affective responses were determined by the level of positive, neutral, or bad sensation, provided by aerobic exercise, being distributed on a bipolar ordinal scale, varying from zero (0) as a neutral position; +1 = reasonably good, +5 = very good; -1 = reasonably bad and -5 = very bad.

Felt Arousal Scale (FAS)

The analysis of the level of body activation was carried out based on the self-perception of excitation resulting from the three experimental situations before and after physical exercise performed. This scale varies linearly from 1 = little activated, to 6 = very active, with its intermediate values.

Statistical Analysis

Normality and homogeneity of the data were assessed using the Shapiro-Wilk and Levene's test, respectively. Considering that all variables had a normal distribution ($p > 0.05$). Data were expressed as means and standard deviations. ANOVA of repeated measures was performed between the dependent variables (velocity, HR, RPE, FAS and FS).

The hypothesis of sphericity was verified by Mauchly test, and when violated, the degrees of freedom are corrected by the Greenhouse–Geisser estimates. The magnitude of the effect of the comparisons was analyzed using Cohen's d test.[26]. All analyzes were performed using the SPSS 20.0 for Windows® software (Chicago, USA) with a statistical significance of $p \leq 0.05$.

RESULTS

There were no differences between the three velocity conditions prescribed by the VO_2 reserve (C1), HR reserve (60-65%) (C2) and the self-adjusted velocity by the RPE (C3) ($p = 0.458$). In addition, the magnitude of the HR response was different between the three conditions (C1 and C2: $p = 0.027$; C2 and C3: $p = 0.043$; C1 and C3: $p = 0.054$). The RPE did not show significant differences between the situations C1 x C2 x C3 ($p = 0.118$). Finally, both the level of activation and the perceived sensation of moderate activity (60-65%) produced similar positive responses ($p = 0.168$; $p = 0.904$, respectively for the level of activation and sensation). The results are shown in Table II.

Table 2. Means ± SD found in analyzed situations and the effect size

Variables	C1	C2	C3	ES_{C1xC2}	ES_{C1xC3}	ES_{C2xC3}
Velocity ($km \cdot h^{-1}$)	7.7 ± 1.7	7.4 ± 0.9	7.9 ± 1.9	0.18	0.12	0.56
HR (bpm)	158 ± 13	148*± 8	161 ± 16	0.77	0.23	4.33
RPE (score)	2.9 ± 0.6	2.6 ± 0.5	3.0 ± 0.1	0.50	0.20	0.80
FAS (score)	3.9 ± 0.9	3.1 ± 1.0	3.6 ± 1.2	0.89	0.33	0.50
FS (score)	3.3 ± 0.9	3.2 ± 1.1	3.3 ± 1.3	0.00	0.09	0.09

***Note:** HR – heart rate; RPE – rate of perceived exertion; FAS – Felt arousal scale; FS – Feeling scale; ES – effect size between conditions; * Significant differences.

DISCUSSION

The central scope of our study was to verify possible differences in the physical demand performed, as well as the responses related to internal loads and their association with the level of activation and affective responses (sensation) after the performance on three aerobic exercise prescriptions methods. Our hypothesis that different prescription methods would induce different physiological responses was partially accepted. Therefore, the main finding observed in the present study relates to the difference between HR obtained by the prescription using a working range of 60 to 65% of the VO_2max reserve compared to the other methods, with lower mean HR values and greater magnitude of differences being recorded. Despite this, the level of activation, as well as, the sensation perceived was positive and similar among the methods, as presented in the literature for the intensity pattern administered(26,27). This reinforce the idea that at least the domain of the exercise (moderate) in which it was worked out was similar among all situations.

Traditionally, HR has been used as a reference measure for training prescription in several training centers(6,7,28). Despite this, the literature positions itself with reservations regarding this variable and its limitations(1,3,5). In our study, we took care by controlling as many intervening factors as possible, such as the subject's familiarity with the ergometer and activity, exercise time, failure to maintain a steady state, as well as room temperature (21 to 23ºC). We understand that the differences observed in our study on the exercise perspective prescribed by the HR may indicate a failure in the proportionality relationship between VO_2reserve and HR reserve (1:1), not providing the same training impulse (TRIMP), according to previous literature(10,29).

Regardless of the limitations already mentioned, studies dealing with the issue show relative accuracy in the use of HR as a monitoring tool both in sedentary and trained subjects in different sports modalities(3,8,28), contrasting the findings of our research.

From another perspective our study provided cardiovascular overload significantly higher than the reference values for work between 65% of HR reserve. The literature is clear regarding the measurement error observed in VO_2max prediction from the metabolic running equations, and the predictive response appears to be effectively overestimated(30). Despite this understanding, the consistency of this prescription model (through the indication of the objective workload) can be reinforced by the absence of significant differences in comparison with the self-selection of work by the RPE (protocol C3). Today, we agree that the prescription by the RPE is feasible and is more related to adherence to training(26,27). Furthermore, the RPE represents the very manifestation of the internal physiological overload, and in this sense, the equivalence between the methods is notorious (RPE = 2.9 vs. 3.0 respectively for C1 and C3), supporting the objective prescription model.

In addition, the averages of velocity converted from the metabolic equation were apparently higher (7.7 ± 1.7 vs. 7.4 ± 0.9 $km \cdot h^{-1}$, respectively for VO_2reserve and HR reserve). Although not statistically significant between C1 x C2 x C3 velocity, the magnitude effect size shows was considered large between C1 vs. C2 (ES = 0.77) and C3 vs. C2 (ES = 4.33), which would manifest itself in different responses on the cardiovascular system. However, regardless of the different magnitudes of the effect observed, equal effort and exercise domain (moderate) were achieved. This domain is conceived in the literature because it generates a significant level of arousal and positive perceptions and affective responses, corroborating and supporting the idea postulated in the inverted "U" theory(26,27).

Finally, for reasons of external validity, the RPE prescription model, a method already established among coaches and athletes, shows advantages in some aspects, such as practicality, low cost, easy administration and control of internal exercise loads(31).

Furthermore, from the perspective of affective responses, the self-selected model is established as an important strategy for promoting positive affect[32]. The mechanism for this conception may be related to how the effort and the perception of fatigue are regulated by the human brain based on previous training experiences, that is, feedforward mechanism[33]. In summary, the self-selected velocity, in our consideration, produced corresponding precision with the C1, denoting that such a strategy can be used for the exercise prescription.

CONCLUSION

It was concluded that the exercise prescription responses from the HR reserve were significantly lower when compared to the VO_2reserve and the RPE. Despite this, all prescription models provided similar activation and affective responses, suggesting that they remain in the same exercise domain. For future research, it is encouraged that interventions in different domains of exercise are carried out, and compared to the different methods of training prescription, since the psycho-affective perceptions can suffer great negative influence in unstable physiological conditions.

Authors Contribution: Alberto Sá Filho and Alessandro Oliveira participated in the conception of the idea, data collection, and complete writing of the article; Gustavo de Conti was the principal advisor, and tutor of all trajectory of studies of the main author, designing all phases of the study; Fernanda Pereira, Sérgio Machado and Marcelo Sales participated in multiple reviews and the data collection process. Claudio Lira and Gustavo Pedrosa participated in numerous review processes, as well as data analysis and article translation. Pedro Augusto Inacio and Gabriella Vilela they are undergraduate students and participated in all study processes (configuration, collection, review).

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