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Research article

Assessment of subjective perceived exertion at the anaerobic threshold with the Borg CR-10 scale

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Abstract
The purpose of this study was to evaluate the anaerobic threshold (AT) with a graphic visual method for estimating the intensity of ventilatory and metabolic exertion and to determine the ratings of perceived exertion (RPE) on the Borg CR-10 scale during a continuous ramp type exercise test (CT-R). Forty healthy, physically active and sedentary young women (age 23.1 ± 3.52 years) were divided into two groups according to their fitness level: active group (AG) and sedentary group (SG) and were submitted to a CT-R on a cycloergometer with 20 to 25 W/min increments. Shortly before the end of each one-minute period, the subjects were asked to rate dyspnea (RPE-D) and leg fatigue (RPE-L) on the Borg CR-10 scale. After the AT was determined with the graphic visual method, the score that the volunteers gave on the Borg CR10 scale was verified. Data were analyzed using the Mann-Whitney and Spearman correlation tests with the significance level set at 5%. The mean ratings of RPE-L and RPE-D at the AT level were not significantly different between groups ($p > 0.05$). Significant correlations were found between VO_2, heart rate (HR), power output and RPE for both groups. The muscular and respiratory RPE, according to the Borg CR-10 scale, were correlated with the AT, suggesting that scores close to 5, which correspond to a "strong" perception, may be used as parameters for quantifying aerobic exercise intensity for active and sedentary individuals. The similar perception of exercise intensity, which corresponded to the AT of different individuals, makes it possible to prescribe exercise at an intensity equivalent to the AT by means of the RPE.

Key words: Rating of perceived exertion, anaerobic threshold, exercise test.

Introduction

The interest in identifying the critical intensity workload above which lactate accumulation occurs has a long history (Owles, 1930; Wasserman and Mclloroy, 1964). The level of physical exercise at which energy production by aerobic metabolism is supplemented by anaerobic metabolism is characterized as the anaerobic threshold (AT) (Beaver et al., 1986; Wasserman et al., 1999).

Lactate is a quantitatively important oxidizable substrate and gluconeogenic precursor as well as a means by which metabolism in diverse tissues is coordinated, especially during physical exercise (Brooks, 2009). Recognition that there exist both intra- and extracellular effects of lactate production and removal has led to renaming of the original 'lactate shuttle' hypothesis (Brooks, 1985) the 'cell–cell lactate shuttle' (Brooks, 1998).

The AT has been used as an internationally accepted physiological parameter for both assessing functional aerobic capacity and diagnosing degenerative, cardiovascular, pulmonary, muscular and metabolic diseases (Beaver, 1986; Svedahl and Macintosh, 2003), as well as for prescribing physical exercise for different populations (Sirol et al., 2005).

Three phases of energy supply and two intersection points can be defined with increasing exercise intensity (Gearheart et al., 2004). During the first phase of energy supply, greater oxygen extraction by the tissues is found resulting in a lower fraction of oxygen in the expired air. Therefore, a linear increase in oxygen uptake (VO2), carbon dioxide output (VCO2) and pulmonary ventilation (VE) is found.

During the phase II the oxidative capacity of the whole system is sufficiently high to scope with the incoming lactate. In phase III, a nonlinear increase in VCO2, and more pronounced in VE, is observed. At this point, hyperventilation cannot compensate adequately the rise in H+ (Binder et al., 2008). Thus, some studies have reported that the AT may be determined invasively by measuring blood lactate (Chicarro et al., 1997; Wasserman et al., 1999).

Others have emphasized that it can be noninvasively determined by means of heart rate (Marães et al., 2005, Pithon et al., 2006; Silva et al., 2005), muscle activity (Bearden and Moffatt, 2001; Lucía et al., 1997; Mateika and Duffin, 1994) and ventilatory and metabolic parameters obtained breath-by-breath during a protocol of continuous effort. The latter is considered one of the most accepted and acknowledged methods for determining the AT (Crescêncio, 2003; Higa et al., 2007; Wasserman et al., 1999).

Interest in quantitative and systematic determination of the AT is growing; however, studies measuring the AT by perceived exertion, are still unsubstantial (Borg, 1982; Esteve-Lanao et al., 2005; Nakamura et al., 2005; Robertson et al., 1986; Steed et al., 1994).

Borg (1982) demonstrated that the general perception of physical exertion comes from the integration of different symptoms arising from active muscles, cardiovascular and respiratory systems, joints, perspiration, possible pain, dizziness etc. The rating of perceived exertion (RPE) has been used in several studies to quantify training session or exercise intensity, as well as for predominantly aerobic activities guided by the Borg CR-10 scale.

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The CR-10 RPE scale has become a standard method for evaluating perceived exertion in exercise testing, training, and rehabilitation and has been validated against objective markers of exercise intensity (Borg et al., 1985, Noble et al., 1983). However, in our review of the literature, we found no studies in which the RPE score on the Borg CR-10 scale had been used to determine the AT.

The Borg CR-10 scale is a category scale with ratio properties consisting of numbers related to verbal expressions, which allows rate comparison between intensities as well as a determination of intensity levels, it has been used for more than two decades (Borg and Kaijser, 2006; Neely et al., 1992). The use of this scale is relatively simple and low-cost compared to the spiroergometry equipment utilized for AT determination (Crescêncio, 2003; Higa et al., 2007; Wasserman et al., 1999).

The aim of this study was to verify the relationship between ventilatory AT and RPE using the Borg CR-10 scale in physically active and sedentary women volunteers.

METHODS

Subjects

In this cross-sectional study we investigated 40 healthy young women (23.1 ± 3.52 years), all university students. The selected volunteers presented regular menstrual cycles and had not been taking oral contraceptives for at least ten months. Subjects were divided into two groups according to their fitness level: active group (AG) and sedentary group (SG). The active subjects had been engaged in resistance exercise (running and spinning, 4-5 times/week) and sedentary subjects had not been engaged in any regular exercise in the previous 12 months. This study conformed to Declaration of Helsinki guidelines. Ethical approval was granted by the Ethics Committee of the involved institution (protocol number 43/06), and written informed consent was obtained from all participants.

Experimental design

The experimental procedures were performed in an air-conditioned laboratory where the temperature and the relative humidity were kept at approximately 23 ºC and 60%, respectively. Volunteers were familiarized with the laboratory environment and with the experimental protocol, including instructions for using the Borg CR-10 scale (Borg et al., 1985). On the day of the test, they were questioned about their health condition, if they had a good night's sleep and if they had followed the instructions given on the previous day, which included avoiding alcoholic or stimulating beverages (coffee, tea, soft drinks) and suspending any unnecessary physical activity.

The experimental protocol was always conducted at the same time of the day (in the afternoon) to eliminate circadian influence on the variables studied. The volunteers were studied during the follicular phase of their menstrual cycle in order to avoid the influence of hormonal variation on the cardiopulmonary variables measured.

Before performing the protocol, the volunteers rested for 15 minutes in supine position, followed by arterial blood pressure and HR assessment to verify whether their basal condition was satisfactory for the experiment.

Experimental protocol

The experiment consisted of a continuous ramp type ergospirometric test (CT-R), performed on a cycle ergometer with electromagnetic braking (Quinton Corival 400, Seattle, WA, USA), with the seat adjusted to allow approximately 5 to 10 degrees of knee flexion. The volunteers were instructed not to perform an isometric contraction while holding onto the handle of the cycle ergometer, and to maintain the pedaling rate at 60 rpm.

The CT-R consisted of 1 minute pre-testing in the sitting, resting position on the cycle ergometer followed by a 4 minute warm-up period at 4 W and power output increments of 20 (SG) to 25 Watts per minute (AG) until physical exhaustion, which corresponded either to the point at which they were unable to maintain 60 rpm or to the manifestation of a limiting symptom or respiratory fatigue. Power output increments were determined for each subject according to the formula proposed by Wasserman et al. (1999): Power output increase (W) = [(height – age) x 14] – [150 + (6 x body mass)]/100.

During the test, ECG and HR were recorded beat-to-beat on a one-channel heart monitor (MINISCOPE II Instramed, Porto Alegre, RS, Brazil) and processed with an analog-to-digital converter (Lab PC + / National Instruments, Co., Austin, TX, USA), which acted as an interface between the heart monitor and a computer. The ECG signal was recorded in real time after analog-to-digital conversion at a sampling rate of 500 Hz (Silva et al., 1994).

Ventilatory and metabolic variables such as VO_2, VCO_2 and VE were obtained breath-by-breath during the ergospirometric CT-R by means of an expired gas measurement system (CPX/D, Medical Graphics, St Paul, Minnesota, USA) that was calibrated before each test. These variables were subsequently processed and calculated as moving means after every eight respiratory cycles for better kinetic observation of responses during the exercise.

After the ventilatory and metabolic measurements were obtained, aerobic capacity was evaluated by considering power output (W), relative and absolute VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$ and $L \cdot min^{-1}$ respectively), carbon dioxide output (VCO_2, $L \cdot min^{-1}$), ventilation (VE, $L \cdot min^{-1}$), HR (bpm), and the respiratory exchange ratio (RER) data obtained at the peak of the exercise test and at the AT level. Three properly trained observers evaluated the AT using a graphic visual method to estimate the disproportional increase in ventilatory and metabolic variables during the incremental dynamic exercise. The criterion adopted was a loss of parallelism between carbon output VCO_2 and VO_2 (Crescêncio et al., 2003; Higa et al., 2007) illustrated in Figure 1.

During the familiarization session, each subject was given instructions on the use of the Borg CR-10 scale, including anchoring procedures (Borg, 1998). Near the end of each one-minute period, the subjects were asked to rate dyspnea (RPE-D) and leg fatigue (RPE-L) respectively, according to the Borg CR-10 scale (Borg,

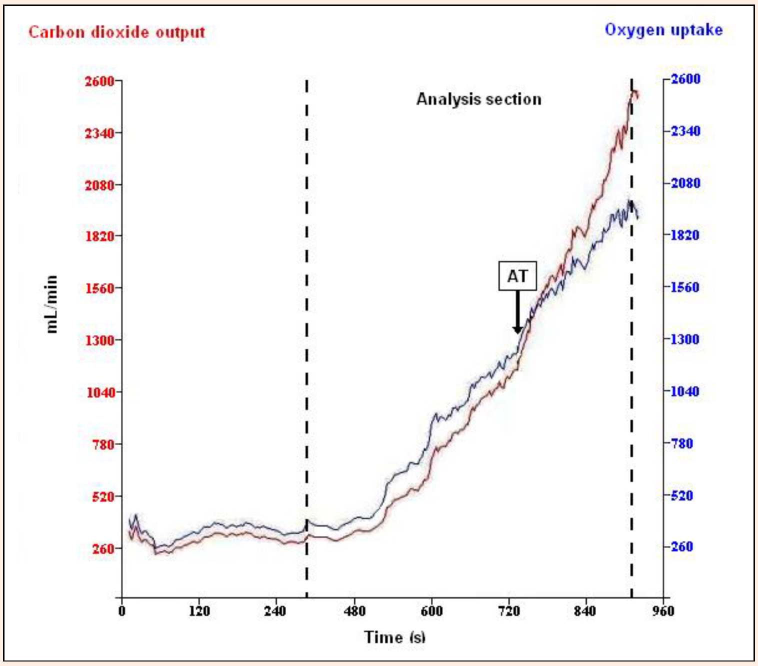

Figure 1. Oxygen uptake and carbon dioxide output responses during the continuous physical exercise dynamic test of the ramp type by one of the volunteers studied. The arrow indicates the time (s) of the disproportionate increase in carbon dioxide output relative to oxygen uptake in the anaerobic threshold (AT) determination.

1998). After determining the AT by the graphic visual method, the Borg CR10 score given by the volunteers was compared.

Statistical analysis

The statistical power analysis and the sample size were estimated using GraphPad StatMate 2.0 software for Windows, based on mean value and standard deviation of the VO_2 peak data obtained in previous studies. For an alpha error of 0.05 and test power of 80%, the recommendation was eight subjects in each group. All data were tested for normality distribution and variance homogeneity. Subjects' characteristics and cardiopulmonary variables were expressed in mean and standard deviation. Baseline differences between groups were evaluated. The Mann-Whitney and Spearman correlation tests were used with significance level set at 5%. All analyses were performed with the statistical software package SPSS 16.0 for Windows.

Results

Baseline characteristics including anthropometric variables, HR, BP (systolic and diastolic pressures), length anthropometric variables, length of menstrual cycle and time of exercise were comparable between the groups (Table 1). No significant differences in age, weight, height, BMI, BP (systolic and diastolic pressures), length of menstrual cycle or duration of exercise between groups were observed. However, in the AG, the HR supine data was lower than in the SG ($p < 0.05$).

The subjects of the active group presented higher power output and higher VO_2 at the peak of the ergospirometric test and at the AT level ($p < 0.05$; Table 1 and Table 2). However, the mean RPE-L and RPE-D at the AT level were not significantly different between groups ($p > 0.05$; Table 2 and Figure 2).

Significant correlations were found between VO_2,

Table 1. Characteristics of the subjects: baseline clinical features, cardiorespiratory and ventilatory responses to peak exercise during the performance test of active group (AG) and sedentary group (SG). Data are means (±SD).

	SG (n=20)	AG (n=20)
Age (years)	22.4 (3.7)	23.9 (3.3)
Weight (kg)	58.4 (8.2)	57.7 (7.0)
Height (m)	1.65 (.07)	1.63 (5.0)
BMI ($kg \cdot m^{-2}$)	21.4 (1.7)	21.7 (2.0)
Length of menstrual cycle (days)	29	29
Exercise (min/session)	---	141 (21.3)
Exercise (years)	---	6.4 (4.0)
Heart rate (bpm)	75 (13)	60 (7) *
Systolic blood pressure (mmHg)	109.3 (8.7)	110.0 (7.9)
Diastolic blood pressure (mmHg)	70.2 (7.7)	68.8 (2.5)
Power output peak (W)	135.5 (21.9)	180.4 (26.9) *
Heart rate peak (bpm)	181.8 (12.7)	182.1 (10.5)
VO_2 peak ($ml \cdot kg^{-1} \cdot min^{-1}$)	24.6 (2.5)	33.5 (2.5) *

BMI: body mass index; VO_2peak: oxygen uptake at the peak of the ergospirometric test. SG *vs.* AG: * $p < 0.05$.

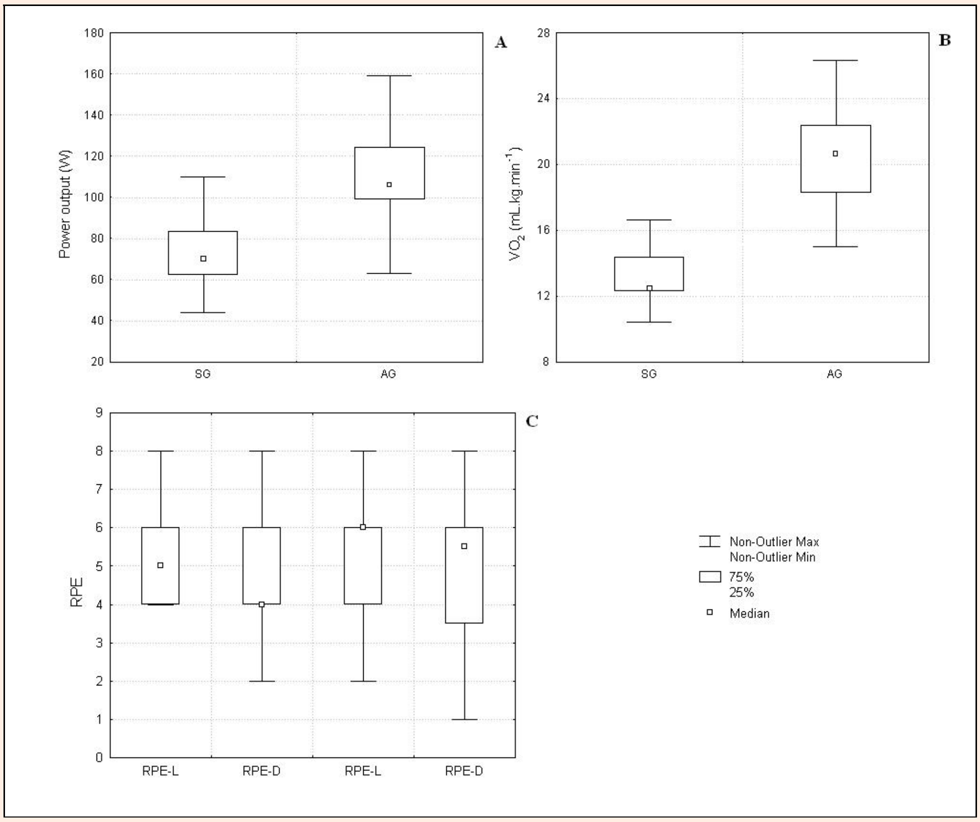

Figure 2. Power output (A), oxygen uptake (VO_2) (B) and ratings of perceived exertion for leg (RPE-L) and dyspnea (RPE-D) (C) at the anaerobic threshold of active (AG) and sedentary groups (SG).

HR, power output and RPE, and also a linear increase in RPE-L and RPE-D for both groups (Table 3; Figure 3).

Table 2. Power output, cardiorespiratory, ventilatory and RPE responses at the AT during the performance test. Data are means (±SD).

	SG (n=20)	AG (n=20)
Power output AT (W)	72.2 (16.2)	111.5 (21.1)*
HR AT (bpm)	131 (10)	138 (15)
VO_2 AT (ml.kg^{-1}.min^{-1})	13.2 (1.7)	20.3 (2.8) *
RPE-L AT	5.25 (1.25)	5.45 (1.60)
RPE-D AT	4.75 (1.29)	4.90 (1.77)

SG: sedentary group; AG: active group; VO_2 AT: oxygen uptake at anaerobic threshold; AT: anaerobic threshold; RPE-L: ratings of perceived muscle exertion; RPE-D: ratings of perceived respiratory exertion.. * SG *vs.* AG: p = 0.001

Discussion

In this investigation we sought to identify the RPE value on the Borg CR-10 scale as it related to the AT, which was determined by the ventilatory method.

The present study demonstrated that VO_2, power output and HR values at the AT were higher for the active group, although this was not observed in RPE-L or RPE-D values. This finding suggests that RPE at the AT does not depend on the individual's level of physical ability, as has been reported in some studies that have found similar RPE for power outputs fairly equivalent to AT among individuals with differing characteristics, such as gender (Purvis and Cureton, 1981) or level of physical ability (Felts et al., 1988; Garcin et al., 2004).

The changes in neuromuscular and mechanical factors, humoral activation, substrate levels and blood flow in the active muscle, associated with work output and metabolic demand are related to exercise intensity, which requires afferent feedback for appropriate cardiopulmonary and peripheral responses as well as RPE-L and RPE-D activation changes for different intensities of exercise (West, 2006) and, being relative to the physical fitness of each subject, allows the identification of the AT.

In the present study on healthy subjects, it was demonstrated no differences between perceived exertion and leg fatigue at AT within a tangible tendency for leg

Table 3. Spearman's correlation coefficients.

SG (n=20) Parameter	RPE	r_s	< p	AG (n=20) Parameter	RPE	r_s	< p
VO_2	Leg fatigue	.85	.0001	**VO_2**	Leg fatigue	.82	.0001
	Dyspnea	.86	.0001		***Dyspnea***	.73	.0001
HR	Leg fatigue	.79	.0001	**HR**	Leg fatigue	.84	.0001
	Dyspnea	.79	.0001		***Dyspnea***	.75	.0001
Power Output	Leg fatigue	.85	.0001	**Power Output**	Leg fatigue	.78	.0001
	Dyspnea	.86	.0001		***Dyspnea***	.71	.0001

SG: sedentary group; AG: active group; RPE: ratings of perceived respiratory; HR: heart rate; VO_2: oxygen uptake.

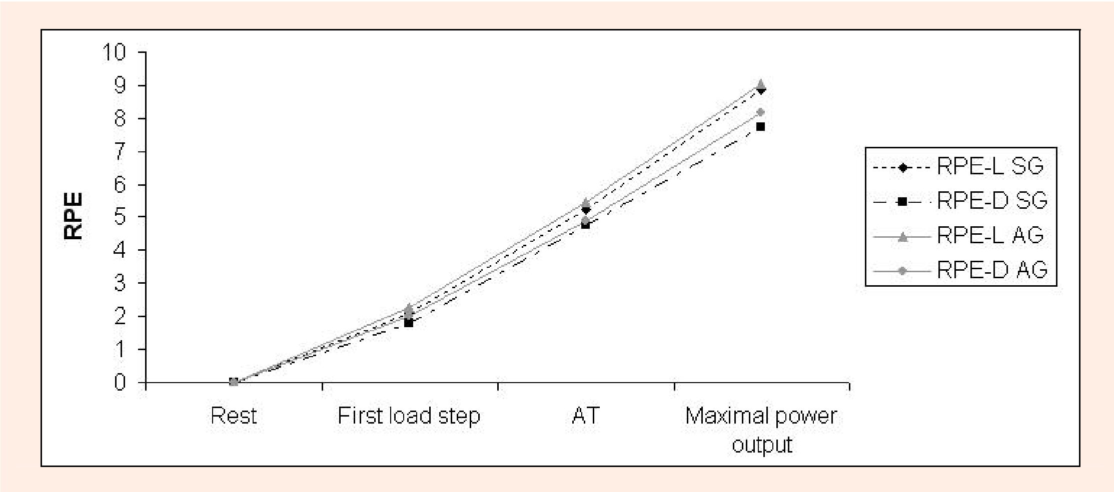

Figure 3. Time course of ratings of perceived exertion for leg (RPE-L) and dyspnea (RPE-D) at rest, at the first load step, at AT, and at maximal power output of active (AG) and sedentary groups (SG).

fatigue to be the dominating symptom at higher workloads. In healthy subjects, leg fatigue is the most common cause for discontinuing an incremental exercise test. Borg et al. (2009) demonstrated that the growth functions for breathlessness and leg fatigue during work are, however, almost parallel, with a tangible tendency for leg fatigue to be the dominating symptom at higher workloads. It should be recognized, however, that data might vary somewhat as a result of individual variation in fitness and muscle strength.

Hence, the RPE results obtained from the present study indicate that scores close to 5, referred as "strong" on the Borg CR-10 scale, may be related to the AT for the women whose characteristics were studied. In agreement with the present study, the American College of Sports Medicine reports that scores between 10 and 13 on the Borg 6-20 scale would be below the AT, whilst values between 14 and 18 would be above it. However, as far as we know, no other study has determined the AT value by the Borg CR-10 scale.

Another important finding of the present study is the correlation between VO_2, HR and power output relating to the RPE-L and RPE-D measures for both groups, which reaffirms the sensitivity of RPE to the intensity of the performed activity. This finding is partially compatible with Borg et al. (2009), who observed a stronger correlation between leg fatigue and breathlessness on the CR-10 scale with the physiological variables HR and blood lactate during an ergospirometric test performed on a bicycle ergometer.

Despite the fact that the analysis of the metabolic and ventilatory variable response represents an extremely well-studied and acknowledged technique in the literature for quantifying the AT (Crescêncio et al., 2003; Wasserman et al., 1999), it must be emphasized that the use of equipment capable of gathering such data is limited, by and large, to research centers because of its high cost and complex operational procedures. Therefore, the assessment of this important physiological parameter by means of simpler and less expensive methods is essential for determining the aerobic capacity of individuals engaged in aerobic physical training programs on a daily basis in private and outpatient clinics, as well as in fitness centers.

Studies have demonstrated that perceived exertion seems to result from the integration of a series of afferent signals from sensory receptors found in active skeletal muscles and in the cardiopulmonary system (Borg, 1982). These structures can be stimulated by metabolic acidosis associated with a decrease in blood and muscle pH (Robertson, 1986). Thus, an increase in efferent neuromotor activity should occur to compensate for the peripheral fatigue resulting from contractile failure, which also modulates perceived exertion (Wasserman et al., 1999).

Future studies are necessary to evaluate the physiological adaptations arising from physical activity at an intensity level close to 5 and to relate these to the subjective perception of muscular and respiratory exertion expressed on the Borg CR-10 scale.

Furthermore, an examination of whether the RPE is maintained at the same intensity level over time would be useful, since Bertuzzi et al. (2008) reported a destabilization of VO_2 and HR variables, and that RPE corresponds to AT power output. They credited this correspondence to the progressive increase in the recruitment of fast twitch fibers (type IIb), which are considered less efficient than slow twitch fibers (type I), and concluded that it leads to a reduction in required effort during constant workload exercise to physiologically stabilize these variables.

Conclusion

Muscular and respiratory RPE, as expressed on the Borg CR-10 scale, were correlated to the AT. Furthermore, the similar perception of exercise intensity, which corresponded to the AT of different individuals, makes it possible to prescribe exercise at an intensity equivalent to the AT by means of the RPE. Scores close to 5, which correspond to a "strong" perception, may be used as parameters for quantifying the aerobic exercise intensity of both active and sedentary women.

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Key points

- Interest in quantitative and systematic determination of the AT is growing, however, qualitative studies measure the AT by perceived exertion, are still unsubstantial.
- Borg CR-10 scale is a category scale with ratio properties consisting of numbers related to verbal expressions, which allows rate comparison between intensities as well as a determination of intensity levels.
- Scores close to 5 expressed on the Borg CR-10 scale, which correspond to a "strong" perception, may be used as parameters for quantifying the aerobic exercise intensity of both active and sedentary women.

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