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Original

Blood glucose threshold of the inspiratory muscles: is it possible to determine it by Borg?

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ABSTRACT

Objective: To test the hypothesis that it is possible to estimate the glycemic threshold (GT) of inspiratory muscles using the subjective perception scale to Borg's effort.
Methods: Observational association and cross-sectional study, in which 21 male individuals, eutrophic, irregularly active, aged between 18 and 30 years evaluated. All submitted to an incremental inspiratory muscle test to determine the GT. During the test, the traditional Borg scale was applied at each stage of the test. Pearson's test was used to verify the correlation between GT and Borg.
Results: A descriptive analysis that GT occurred 23±9.1% of MIP in an absolute load of 32±14.6cmH2O and was compatible with the score of 13±1.5 on the BORG scale (r=0.67) and (r=0.58) respectively.
Conclusions: Our results provide evidence that the Borg scale is a viable method to determine the GT of inspiratory muscles and consequently be used for prescribing Inspiratory Muscle Training.
Keywords: Breathing Exercises; Respiratory Muscles; Anaerobic Threshold; Blood Glucose.

Umbral de glucosa en sangre de los músculos inspiratorios: ¿es posible determinarlo por Borg?

RESUMEN

Objetivo: Probar la hipótesis de que es posible estimar el umbral glucémico (UG) de los músculos inspiratorios utilizando la escala de percepción subjetiva al esfuerzo de Borg.
Métodos: asociación observacional y estudio transversal, en el que se evaluaron 21 individuos del sexo masculino, eutróficos, irregularmente activos, con edades comprendidas entre 18 y 30 años. Todos sometidos a una prueba de músculo inspiratorio incremental para determinar el UG. Durante la prueba, se aplicó la escala de Borg tradicional en cada etapa de la prueba. Se utilizó la prueba de Pearson para verificar la correlación entre UG y Borg.
Resultados: Un análisis descriptivo que UG ocurrió 23 ± 9.1% de MIP en una carga absoluta de 32 ± 14.6cmH2O y fue compatible con la puntuación de 13±1.5 en la escala BORG (r=0.67) y (r=0.58) respectivamente. .
Conclusiones: Nuestros resultados proporcionan evidencia de que la escala de Borg es un método viable para determinar el UG de los músculos inspiratorios y, en consecuencia, se puede utilizar para prescribir el entrenamiento de los músculos inspiratorios.
Palabras clave: Ejercicios Respiratorios; Músculos Respiratorios; Umbral Anaerobio; Glucemia.

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Limiar glicêmico dos músculos inspiratórios: é possivel determiná-lo pelo Borg?

RESUMO

Objetivo: Testar a hipótese de que é possível estimar o LG dos músculos inspiratórios, por meio da escala de percepção subjetiva ao esforço de Borg.
Métodos: Estudo observacional de associação e corte transversal, no qual foram avaliados 21 indivíduos do sexo masculino, eutróficos, irregularmente ativos, com idades entre 18 e 30 anos. Todos foram submetidos a um teste muscular inspiratório incremental para determinação do LG. Durante o teste foi aplicado a escala de Borg tradicional em cada estágio do teste. Para análise descritiva foi utilizado a média e desvio padrão por se tratar de uma amostra linear. Utilizado o teste de Pearson para verificar a correlação entre o LG e o Borg.
Resultados: A análise descritiva mostrou que o LG ocorreu 23±9,1% da PImáx em uma carga absoluta de 32±14,6cmH2O e foi compatível com o escore de 13±1,5 da escala de BORG (r=0,67) e (r=0,58) respectivamente.
Conclusões: Nossos resultados fornecem evidências de que a escala de Borg é um método viável para determinar o Limiar Glicêmico dos músculos inspiratórios e consequentemente ser utilizado para prescrição do Treinamento Muscular Inspiratório.
Palavras-chave: Exercícios Respiratórios; Músculos Respiratórios; Limiar Anaeróbico; Glicemia.

Introduction

Anaerobic Threshold (AT) is one of the main parameters for exercise prescription[1]. The gold standard for determining AT is the blood lactate threshold (LT)[1]. However, to use it, it is necessary to have financial resources and high-cost materials, in addition to well-trained professionals to interpret it, which makes its application difficult. Given this difficulty, studies suggest the use of other methods to replace LT, which are low cost and have better reproducibility and interpretation. The Glycemic Threshold (GT) is one of the methods that can reliably replace the lactate curve for determining AT[2].

Inspiratory Muscle Training (IMT) is one of the most used exercises today to improve functional capacity, from individuals with heart disease[3] to athletes[4]. Conventionally, the prescription of IMT is based on the use of Maximum Inspiratory Pressure (MIP) as a parameter for determining the training load. However, our research group suggested the use of inspiratory muscle GT to determine the training load after cardiac surgery, obtaining a better result than that based on MIP[5]. However, it is also a method of low reproducibility due to the difficulty of its application.

One possibility of replacing GT is Borg's subjective perception of effort scale. This scale is widely used in cyclic exercises to determine the intensity of the exercise, due to its easy application, low cost, and high reproducibility. Some studies point to the correlation between Borg and AT[6-8], however, in a previous review we did not find in the literature articles that have studied the correlation between the Borg scale and the GT of inspiratory muscles.

Therefore, this study aims to test the hypothesis that it is possible to estimate the GT of inspiratory muscles using the subjective perception scale to Borg's effort. As a secondary objective, check if it is possible to estimate the exhaustion point (EP) of the inspiratory muscles using Borg.

Methods

Observational and cross-sectional association study, in which 21 male individuals, eutrophic, irregularly active, aged between 18 and 30 years were evaluated. To classify the volunteer as irregularly active, the International Physical Activity Questionnaire (long version) developed by the World Health Organization and the Center for Disease Control and Prevention in North America[9] was used. This questionnaire was chosen because it allows a detailed classification of the volunteer's physical state.

Height was measured with the aid of a Sanny® stadiometer, performed with bare feet and with the buttocks and shoulders supported vertically. Total body mass was measured by a Filizola® digital scale with a maximum capacity of 150kg, measured by Inmetro, with its certificate, specifying a margin of error of approximately 100g. The body mass index (BMI) was calculated with the measures of mass and height, according to the Quetelet equation: mass(kg)/height^2(m). The cut-off point for the adopted BMI was that recommended by the V Brazilian Guideline for Dyslipidemia and Atherosclerosis Prevention of the Department of Atherosclerosis of the Brazilian Society of Cardiology[10], that is: eutrophic (BMI: 18.5-24.9kg/m^2).

Exclusion criteria were individuals with cardiovascular changes, due to the potential decrease in cardiorespiratory fitness and cardiovascular risk on exertion. Musculoskeletal or pulmonary disorders that compromised ventilatory mechanics, kidney disease, history of smoking, diabetes, and use of stimulants or anabolic steroids due to the predisposition to metabolic changes, which can interfere with GT. Use of medications that can alter the patient's motor and cognitive activities.

The volunteers underwent a detailed anamnesis in which the history of smoking, kidney disease, diabetes, use of stimulants or anabolic and cardiovascular diseases was evaluated. In addition to the anamnesis, blood pressure was measured to assess cardiovascular changes using the adult Premiun® medium tensiometer, duly calibrated by the Instituto Nacional de Metrologia (INMETRO) and Premiun® duo-sonic stethoscope, electrocardiogram of rest collected by the Ecafix® electrocardiograph, heart rate (HR) and partial oxygen saturation (Spo2) by the digital pulse oximeter of the G-Tech® brand. To assess whether the individual had musculoskeletal or pulmonary changes, a detailed physical examination was performed, accompanied by the MIP measured by the POWERbreathe® K5.

The mean MIP of the volunteers was 140±36.7cmH2O, 21±2.1 years of age, and the BMI was 21±2.4kg/m^2.

Ethical Criteria

This study was submitted to and approved by the Ethics and Research Committee of the Adventist College of Bahia with the opinion number: 3,552,066 approved on August 31, 2019. All volunteers received information about the research, at which point the risks and benefits that work could generate according to the resolution of the National Health Council 466/12.

Data Collect

Before starting the test, the volunteer should rest for five minutes. Then, the biomechanics of inspiration was explained, teaching him to make the most of the diaphragm muscle and to express his effort on the Borg scale, instructing him on the meaning of each degree. It was explained what an incremental test is and that at the end of each cycle a digital puncture would be performed to collect blood glucose and the effort measured by the Borg scale.

Incremental Inspiratory Muscle Test (IIMT)

The resistance of the inspiratory muscles was assessed using an IIMT performed on the POWERbreathe® K5, properly connected to the BreatheLink® software. This characteristic non-continuous incremental test consists of up to 10 stages with an interval of 2 minutes between them. It starts with 10% of the maximum value, increasing 10% at each level, collecting blood glucose, Borg, BP, and HR at the end of each one. As the equipment imposes, only the load determined on the fourth inspiration, 19 incursions were made on each level, with a breathing cycle of 5 seconds guided by a beep of the device. The test was interrupted in the load in which the volunteer was unable to overcome or expressed an inability to continue the test, calling it the exhaustion point (EP).

Blood collection and analysis of the glycemic curve

Blood collections were performed by a puncture in one of the digital pulps, after asepsis with alcohol (70%), using lancets and gloves from disposable procedures. The blood glucose values were obtained by applying the blood on a test tape attached to the glucose monitor G-TECH free® (expressed in mg/dL), obtaining the result immediately after contact with the blood in the lancet.

The GT was determined by visual inspection, at the lowest value of the glycemic curve built in the test, according to Simões HG et al.[2], proposed.

Quantification of training intensity

To quantify the intensity of the IIMT was used the subjective effort scale Borg[11]. The Borg is a scoring scale that varies from 6 to 20 and can be used efficiently due to its relationship with HR[12]. For example, 60bpm would be equivalent to number 6 on the scale, just as 200bpm would be equivalent to number 20.

Study variables

For the analysis of primary data, the variables were: relative load referring to %MIP and absolute load given in cmH2O. As a secondary analysis: SBP, HR, and blood glucose. All variables refer to the two cutoff points adopted in our study, GT and EP, which refers to the last t stage of the IIMT completed.

Sample Sufficiency Calculation and Statistical Analysis

A pilot study with 10 people was previously carried out, in which the entire data collection protocol described in the methods was used. Thus, the sample size calculation was performed in the WinPep program version 11.65, adopting a 95% confidence level, an acceptable error of 7%, and using a standard deviation of 15.00 referring to the inspiratory muscle GT, obtained through the pilot study, totaling 21 participants.

For descriptive analysis, the mean and standard deviation were used because it is a linear sample, confirmed after D'Agostinho's normality test (k- samples). Comparisons between GT and EP were made using the two-way Student's t-test for related samples; the correlations between the Borg and the variables collected by visual inspection were made using Pearson's linear correlation coefficient. The BioEstat 5.0 program was used.

Results

Figure 1 shows that there was a loss of linearity in the cardiac work demonstrated by the increase in SBP and HR (b) after 30% of MIP, a stage in which the change from mild to moderate intensity (GT) occurred (a).

The behavior of blood glucose in this study made it possible to identify the GT of inspiratory muscles through individualized visual inspection of the lowest glycemic value. The respective Borg values, relative load, absolute load, SBP, and HR were extracted from the GT (Table 1). The same variables were collected in the EP of the IIMT. There was a statistical difference ($p<0.05$) between the Borg, the relative load, and the absolute load of the GT and EP, however, it is noted that the HR, SBP, and blood glucose did not obtain a statistically significant difference ($p\geq0.05$).

The analysis of Table 2 shows that there was a correlation between GT variables: Borg and relative load (%MIP) ($r=0.67$), Borg and absolute load (cmH2O), ($r=0.46$). In the EP, the crossings Borg and relative load and Borg and HR correlated ($r=0.48$) and ($r=0.44$) respectively, thus proving the main hypothesis of this work.

Figure 2 shows the main analysis variable for GT and EP. It observed that there was greater correlation power in GT, thus, proving the main hypothesis of this work.

Discussion

Our results indicate that it is possible to determine the GT of inspiratory muscles using the Borg subjective perception scale. We

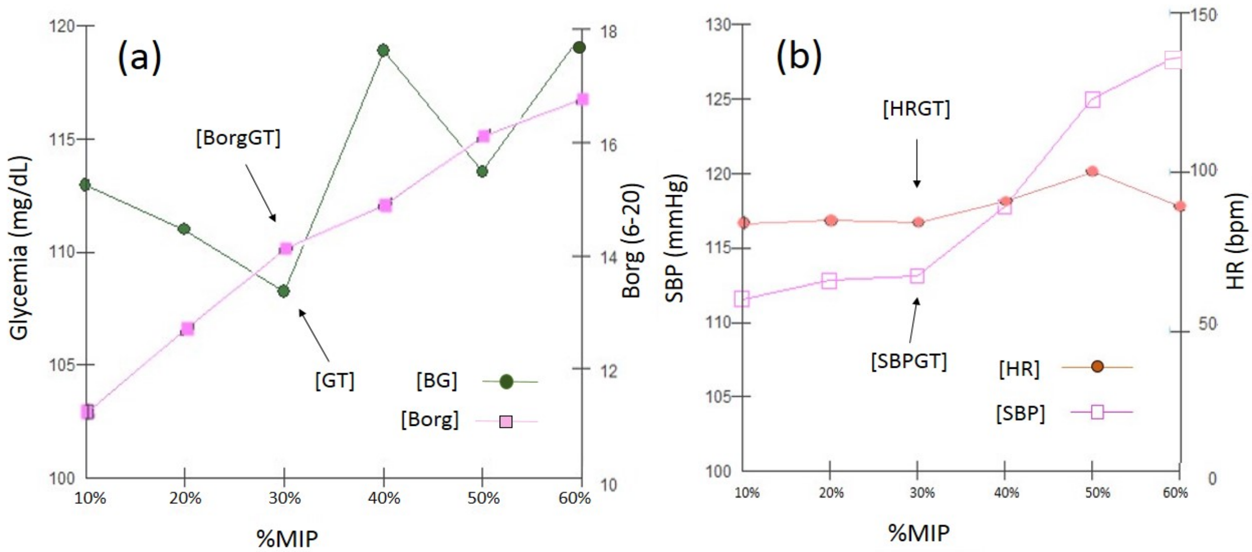

Figure 1. Borg's behavior, blood glucose ([BG]) (a), heart rate ([HR]), systolic blood pressure ([SBP]) (b), during the incremental inspiratory muscle test (IIMT). Borg at the glycemic threshold (BorgGT), Heart rate at the glycemic threshold [HRGT], systolic blood pressure at the glycemic threshold [SBPGT].

Table 1. Comparison of the glycemic threshold (GT) and exhaustion point (EP) variables by visual inspection in the incremental inspiratory muscle test (IIMT).

Variables	GT	95% CI	EP	95% CI	p-value*
Borg (6-20)	13±1.5	12-14	16±2.1	15-17	**<0.01**
Relative load (%MIP)	23±9.1	19-27	43±13.5	37-48	**<0.01**
Absolute load (cmH_2O)	32±14.6	25-38	58±15.3	50-64	**<0.01**
SBP (mmHg)	112±13.2	105-119	114±15.8	105-122	0.42
HR (bpm)	83±21.4	73-93	89±26.3	76-100	0.11
Glycemia (mg/dL)	98±21.7	88-108	106±22.7	96-117	0.10

BORG - subjective effort scale; GT - glycemic threshold; EP – exhaustion point; SBP - systolic blood pressure; HR - heart rate; CI - confidence interval. *bidirectional student t test for related samples.

Table 2. Correlation between Borg and the variables collected by visual inspection.

	Correlation coefficient (r)	95% CI	p-value*
GT			
Borg and relative load (%MIP)	0.67	0.34-0.86	**<0.01**
Borg and absolute load (cmH_2O)	0.58	0.20-0.81	**<0.01**
Borg and SBP	-0.46	-0.77-0.02	0.05
Borg and HR	-0.11	-0.52-0.33	0.61
Borg and glycemia	0.26	-0.19-0.62	0.24
EP			
Borg and relative load (%MIP)	0.48	0.06-0.76	**0.02**
Borg and absolute load (cmH_2O)	-0.01	-0.44-0.42	0.96
Borg and SBP	-0.06	-0.53-0.43	0.81
Borg and HR	0.44	0.02-0.74	**0.04**
Borg and glycemia	0.34	-0.10-0.68	0.12

BORG - subjective effort scale; GT - glycemic threshold; EP – exhaustion point; SBP - systolic blood pressure; HR - heart rate; CI - confidence interval. *Pearson's linear correlation coefficient.

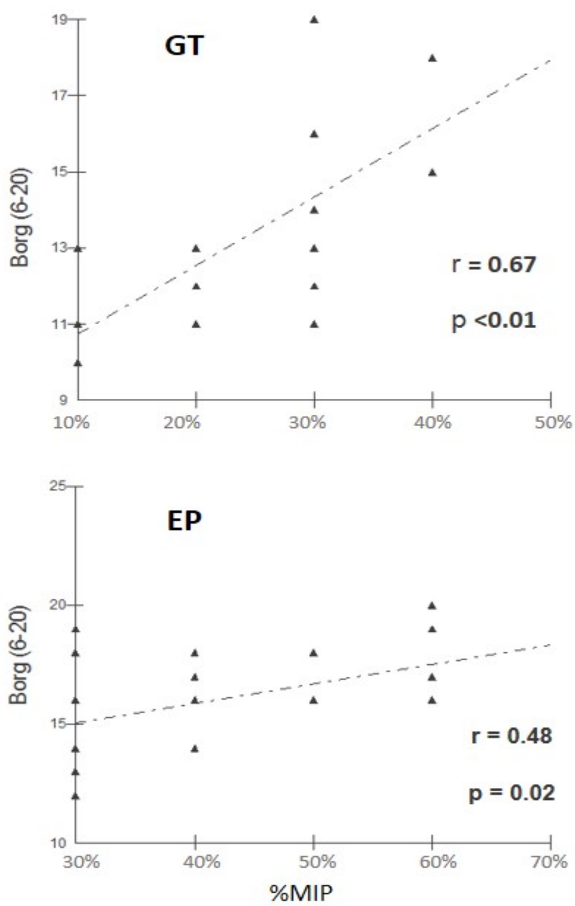

Figure 2. Correlation between Borg and relative load (%MIP), referring to the Glycemic Threshold (GT) and Exhaustion Point (EP).

observed in this young and irregularly active population that the subjective perception of Borg's effort is closely associated with work intensity (load), and therefore, this same analysis shows that it is also possible to estimate the relative PE load of the inspiratory muscles during an IIMT. After in-depth analysis, we found that, until then, these findings are unprecedented in the scientific literature.

The association between Borg and GT was due to the break in the linearity of cardiac work, whose main market is the increase in the double product, shown in Figure 1. This association is directly linked to the effort so that the work of the inspiratory muscles generated cardiorespiratory overload, which could be measured using the Borg scale. This scale grows linearly with effort, as we increase the relative (%MIP) and absolute (cmH2O) loads, leading to a gradual overload in the diaphragm muscle, which consequently increases the metabolic demand for glycemia[13]. The GT, therefore, corresponds to the lowest glycemic point of the curve and is accompanied by an increase, sometimes abrupt, generally linear of the blood glucose.

The understanding of dysanapsis[14] is another conditioning factor since the airflow in the lung is bidirectional and the increase in ventilatory overload generates an increase in tidal volume, a phenomenon called "dynamic hyperinflation". This mechanism causes the diaphragmatic fibers to be taken to the maximum stretch and shortening, thus increasing the activation of the muscle spindle[15]. The neural pathways involved in this mechanism include corollary discharge[16] from the cortical motor centers that trigger voluntary breathing; the central motor command activates the musculature and in the course of this increase occurs the activation of the muscle spindle, mediated by the types III and IV[17] afferent nerve fibers to the cerebral cortex, responsible for the subjective perception of effort[18]. This mechanism explains our main result, considering that, through IIMT, Borg was associated with GT and EP, showing its sensitivity in detecting metabolic and cardiorespiratory adaptations at the time of GT (light to moderate exercise) and maximum intensity.

The adjustments of the cardiovascular system during the IIMT may be associated with the beginning of the diaphragmatic metaborreflex[19], which is activated when the muscle contraction begins to generate an accumulation of H+ and CO2 ions in the intracellular environment, stimulating the afferent activity of the phrenic nerve[20]. This mechanism, already well described by Harms CA et al.[21], causes 16 to 20% of the cardiac output to be concentrated to the diaphragm muscle, mainly resulting from sympathetic nervous activation and peripheral vasoconstriction, intending to take more energy substrate and eliminate metabolic waste that intensifies the closer to the EP. Necessary in the EP, in our study, we observed that Borg was positively related to HR, confirming the idea that there was a diaphragmatic metaborreflex action that intensified the sympathetic cardiac chronotropic modulation. However, despite these adjustments, the analysis in table 1 shows that there was no statistically significant difference between them at the two cutoff points (GT and EP). This leads us to understand that these variables are little interfered with by the IMT and therefore do not serve as parameters for the analysis of the test, nor comparison between pure and post-training.

A point that needs to be demystified is that the greater the training load, the greater the gains, considering that one of the determining factors of muscle adaptations in strength training is the amplitude and quality of the movement performed[22]. In this sense, there is a theory that high loads decrease the tidal volume and the inspiratory reserve volume in the IMT, affecting the quality of the movement. Future studies are necessary to assess whether this factor interferes with the training results, however, in our research we observed that Borg was associated with EP, thus increasing its clinical applicability and leading to safety training.

One study[23] evaluated the acute effect of IMT at 30, 60, and 80% of MIP on heart rate variability in elderly men and found that the increased load produced significantly lower values of parasympathetic cardiac modulation. Another group of authors[24], evaluating the effect of IMT at 75% of MIP on sleep quality and cardiovascular function of patients with obstructive sleep apnea and found significant improvement in sleep and plasma noradrenaline levels compared to the placebo group that trained at 15% of MIP. These paradoxes point to the importance of assessing metabolic thresholds for better conclusions in different populations and diseases. In our study, using an IIMT, we showed that the GT of irregularly active young people happened close to 23% of MIP, this being the main application vary with Borg.

Sapata KB et al.[25], analyzed the effect of previous consumption of carbohydrates on glycemic response and physical performance and found that after consumption of maltodextrin and glucose drinks, there was a significant decrease in exercise glycemia compared to the placebo group, however, there was no change in sports performance. In our study, we used as an exclusion method individuals who used stimulants or anabolic steroids, however, it was not possible to control the amount of carbohydrate consumed in the last meal and the time between it and the test. Future studies are needed to ascertain whether this variable can interfere with the accuracy of the GT.

Although LT is called the "gold standard" in determining AT, its clinical application most of the time becomes infeasible, mainly due to the high financial cost. The possibility of substitution by GT increases the feasibility of the application, a fact that aroused our study group to analyze its association with Borg. This further extends the accessibility and clinical applicability, given the need for a specialized prescription at IMT.

As in all studies involving human beings, our research has limitations that must be considered for clinical practice. The first is that we evaluate only those young men, male and without any comorbidity, which limits the inference of our results in specific categories, such as those with metabolic and cardiovascular diseases. Also, for the application of the Borg scale, it is necessary to have a good knowledge of it, which limits its usefulness in individuals with low education or those cognitively compromised, even with previous anchoring.

Our study presents a precise and low-cost way to prescribe IMT, which is an accessible and non-invasive measure for determining GT. We observed that Borg had a good association with the inspiratory muscle GT, indicating that it can be used, especially in the young and irregularly active population to determine the ideal training load.

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