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ORIGINAL RESEARCH

Could peak oxygen uptake be estimated from proposed equations based on the six-minute walk test in chronic heart failure subjects?

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Maximal functional capacity;
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Abstract
Objectives: To evaluate the agreement between the measured peak oxygen uptake (VO_2peak) and the VO_2peak estimated by four prediction equations based on the six-minute walk test (6MWT) in chronic heart failure (CHF) patients. Q2
Method: Thirty-six CHF patients underwent cardiopulmonary exercise testing (CPET) and the 6MWT to assess their VO_2peak. Four previously published equations that include the variable six-minute walk distance (6MWD) were used to estimate the VO_2peak: Cahalin, 1996a (1); Cahalin, 1996b (2); Ross, 2010 (3); and Adedoyin, 2010 (4). The agreement between the VO_2peak in the CPET and the estimated values was assessed using the Bland–Altman method. A p-value of <0.05 was considered statistically significant.
Results: All estimated VO_2peak values presented moderate correlation (ranging from 0.55 to 0.70; $p < 0.001$) with measured VO_2peak values. Equations 2, 3, and 4 underestimated the VO_2peak by 30%, 15.2%, and 51.2%, respectively, showing significant differences from the actual VO_2peak measured in the CPET ($p < 0.0001$ for all), and the limits of agreement were elevated. The VO_2peak estimated by equation 1 was similar to that measured by the CPET, and despite the agreement, bias increased as VO_2peak increased.
Conclusions: Only equation 1 showed estimated VO_2peak similar to the measured VO_2peak; however, a large limits of agreement range (~3 METs) does not allow its use to estimate maximal VO_2peak.

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Introduction

Peak oxygen uptake (VO_2peak) is an important measurement of maximal functional capacity in patients with chronic heart failure (CHF). It is also a predictor of survival and an indicator for heart transplantation in these patients.[1–3] Although cardiopulmonary exercise testing (CPET) is considered the ideal process to evaluate oxygen consumption in subjects with CHF,[4] the high cost of the technique may limit access to it.

The six-minute walk test (6MWT) has been used as an alternative to the CPET to evaluate functional capacity in these individuals due to its feasibility and lower cost.[5,6] Prediction equations have been suggested to estimate VO_2peak in subjects with CHF[7–9] based on the six-minute walking distance (6MWD). These equations have demonstrated good correlation with anthropometric characteristics,[7,8] cardiac and lung function at rest,[7] 6MWD,[7–9] and VO_2peak, but the determination coefficient varies widely. In addition, the standard error of the estimate (SEE) reaches values close to 1 MET, which may represent a large percentage of the maximal functional capacity of patients with CHF. These results have led us to hypothesize that the VO_2peak estimated from the 6MWT does not indicate the real VO_2peak of these patients. Furthermore, no studies evaluated the agreement between measured and estimated VO_2peak values in a sample of individuals with CHF. The evaluation of agreement between two measurements allows for quantifying the differences between these measures and establishing limits of agreement and bias.[10]

Therefore, the present study aims to evaluate the agreement between the measured VO_2peak and the VO_2peak estimated by four prediction equations based on the 6MWD in subjects with CHF.

Method

The inclusion criteria were established to obtain a homogeneous sample of CHF patients that included patients clinically diagnosed with CHF (left ventricular ejection fraction <50%). Those who were stable for at least two months in optimal pharmacological treatment, aged between 25 and 59 years, with a body mass index <30 kg/m^2 and not practicing regular exercise were included in the study. Older adults, adolescents, or obese patients and those practicing regular exercise (because it affects disease severity and control) were not included in order to avoid other mechanisms potentially being involved in the pathophysiology of the disease. Patients were excluded if: they were classified as class IV according to the New York Heart Association (NYHA IV), with limiting disorders to physical exercise, recent history of pulmonary disease, unstable angina, uncontrolled arrhythmias or peripheral arterial disease, or if they did not reach a respiratory exchange ratio (RER) greater than or equal to 1.0 during CPET.[11] Table 1 shows the main characteristics of the samples in the different studies.

This study was approved by the ethics committee of the institution (protocol number 050/09, Comitê de Ética em Pesquisa, Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, MG, Brazil) in which the research was conducted in accordance with the Declaration of the World Medical Association. Volunteers signed a written informed consent form before participation.

Outcome measures

Cardiopulmonary exercise testing

Subjects underwent a CPET under medical supervision for assessing VO_2peak, using the gas analyzer (CPX Ultima Medical Graphics®, USA) and the breath-by-breath method. The ramp test protocol was performed on an electronic treadmill, as described by Pereira et al.[12] The oxygen saturation and electrocardiogram were continuously monitored, and blood pressure was checked every 2 min. Perceived exertion was measured on a Borg scale from 0 to 10.[13] The volunteers were instructed to maintain their usual medication, to refrain from cigarettes, food or drinks with caffeine for a period of 3 h, and to avoid exercise in the 12 h preceding the test.[14,15] The VO_2peak was defined as the highest 10-second average value obtained during the last 30 s of the CPET.[16]

Six-minute walk test

The 6MWT was carried out with a time interval of about one week after the CPET, in accordance with the standards of the American Thoracic Society.[17] Each patient was instructed to walk as quickly as possible without running in a 30-meter long corridor for 6 min. Two 6MWTs were performed with intervals of 30 min between them. If the difference between them exceeded 10%, a third test was applied. The test with the higher 6MWD was selected for analysis. Heart rate and oxygen saturation were continuously monitored during the test.

Estimation of peak oxygen uptake

Four previously published equations,[7–9] which included the variable 6MWD, were used in this study (Table 1): equation 1 (VO_2peak = 0.03 × distance in meters + 3.98),[7] equation 2 (VO_2peak = 0.02 × distance in meters − 0.191 × age in years − 0.07 × weight in kg + 0.09 × height in cm + 0.26 × RPP × 10^{-3} + 2.45),[7] equation 3 (VO_2peak = 4.948 + 0.023 × distance in meters)[9] and equation 4 (VO_2peak = 0.0105 × distance in meters + 0.0238 × age in years − 0.03085 × weight in kg + 5.598).[8] A weight scale with an attached stadiometer was used to measure the anthropometric data (Filizola™, Brazil).

Data analysis

Continuous variables were presented as mean ± standard deviation and the categorical variables as frequency values. The presence of normal distribution of the data was assessed using the Shapiro–Wilk test. The agreement between the VO_2peak measured in the CPET and the values estimated by the four equations was analyzed using the Bland–Altman method, which consists of a statistical and graphical approach for comparing two measurements of clinical variables. Using this method, it is possible to calculate the bias (difference between the measurements obtained by both methods), the mean and standard deviation of these differences, and the upper and lower limits of agreement (LoA) obtained per equation: bias ± 1.96 SD. The analysis is made by visually examining the graph, observing the data

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