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Association Between Physical Activity Measurements and Key Parameters of Cardiopulmonary Exercise Testing in Patients With Heart Failure

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ABSTRACT

Background: A hallmark characteristic of heart failure (HF) is reduced physical activity (PA) patterns. The relationship between key cardiopulmonary exercise testing (CPX) variables and PA patterns has not been investigated. Therefore, we evaluated PA patterns in patients with ischemic HF and its relationship to peak oxygen consumption (VO_2), the minute ventilation/carbon dioxide production (VE/VCO_2) slope, and the oxygen uptake efficiency slope (OUES).
Methods and Results: Sixteen patients with HF wore an accelerometer for six days to measure total steps/day as well as percentage of time at light, moderate, and vigorous PA. Symptom-limited CPX was performed on a treadmill using a ramping protocol. Total steps correlated with VO_2 ($r = 0.64$ $P < .05$), the VE/VCO_2 slope ($r = -0.72$; $P < .05$), and the OUES (0.63; $P < .05$). The percentage of time at light-intensity PA correlated with the VE/VCO_2 slope ($r = 0.58$; $P < .05$) and the OUES ($r = -0.51$; $P < .05$). The percentage of time at vigorous-intensity PA correlated with peak VO_2 ($r = 0.55$; $P < .05$) and the VE/VCO_2 slope ($r = -0.52$; $P < .05$).
Conclusions: PA assessed by accelerometer is significantly associated with key CPX variables in patients with HF. (*J Cardiac Fail 2013;19:635−640*)
Key Words: Heart failure, physical activity, exercise test.

Numerous studies demonstrate that patients with heart failure (HF) have lower levels of physical activity (PA).[1−3] Moreover, studies have demonstrated that self-reported physical activity levels are associated with hospital admissions, clinical status, and mortality in chronic disease cohorts.[4−6] Among the ways to assess PA patients with chronic disease, activity monitoring based on accelerometry has been reaffirmed as a very accurate method that may provide valuable information for quantifying activity of daily living patterns.[7]

Physiologically, the level of PA is extremely correlated with aerobic performance,[8] which has been described in different populations such as chronic obstructive pulmonary disease (COPD)[9] and implantable cardioverter defibrillator.[10]

Cardiopulmonary exercise testing (CPX) is a highly reliable and valid approach to assessing aerobic performance. It is a well accepted assessment technique in the HF population,[11] and American[12] and European associations endorse its use. CPX is most often performed on a treadmill or cycle ergometer using ramping protocols, and the addition of ventilatory expired gas analysis to the standard exercise test enables measurement of oxygen consumption (VO_2), carbon dioxide production (VCO_2), and minute ventilation (VE) over time.[13] Moreover, CPX provides a host of variables that are predictive of adverse events in HF patients, including peak VO_2, the VE/VCO_2 slope, and the oxygen uptake efficiency slope (OUES).[12]

However, there are potential patient difficulties associated with CPX,[12] such as trepidation with the test itself, mouthpiece/mask intolerance, and effort dependency. In

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truth, the application of CPX in the HF population is limited to a subset of patients who are being considered for more aggressive management (eg, left ventricular device implantation or heart transplantation). Therefore, measurements capturing PA patterns, and presumably CPX performance, which can be easily obtained in a broader proportion of the HF population, may be useful in reflecting disease severity and the level of functional limitation.

To our knowledge, the relationship between PA patterns and key CPX variables in HF patients has not been evaluated. Therefore, the primary aim of the present study was to evaluate PA patterns and its relationship to peak VO_2, the VE/VCO_2 slope, and the OUES in patients with ischemic HF.

Methods

Subject Characteristics

This cross-sectional study consisted of 16 male subjects diagnosed with ischemic HF. All subjects were on stable pharmacologic management before initiation of the study and were being treated by the same cardiologist. All study participants were recruited from Cardiology Institute of Distrito Federal, Brazil. Inclusion criteria consisted of a diagnosis of HF[14] and evidence of systolic left ventricular dysfunction (left ventricular ejection fraction [LVEF] ≤35%) by echocardiography.[15] Any subject with a previous diagnosis of moderate to severe chronic obstructive pulmonary disease based on absence of respiratory symptoms history and hospital admission related to respiratory disorder[16] or who were unable to walk without assistance were excluded from this study. All subjects provided informed written consent, and the study was approved by the Ethics Committee of the Heart Institute of Distrito Federal.

Measurements and Procedures

Cardiopulmonary Exercise Testing (CPX). Each patient performed a symptom-limited CPX on a treadmill (T2100; General Electric, Waukesha, Wisconsin), with an increase of 0.5 metabolic equivalents (METs)/min.[17] The aim was to achieve peak exercise in ≈10 minutes. If the test duration was >12 minutes or <8 minutes, the test was repeated the next day with an appropriate titration in progressive work rate. Ventilatory expired gas analysis was obtained with the use of a metabolic cart (K4; Cosmed, Milan, Italy). The oxygen and carbon dioxide sensors were calibrated before each test using gases with known oxygen, nitrogen, and carbon dioxide concentrations. The flow sensor was also calibrated before each test with the use of a 3-L syringe. Monitoring consisted of continuous 12-lead electrocardiography (Cardiosoft; General Electric, Waukesha, Wisconsin), manual blood pressure measurements (Tycos Welch Allyn, Skaneateles Falls, New York) at every stage, and heart rate recordings at every stage via the electrocardiogram. Test termination criteria consisted of patient request, ventricular tachycardia, ≥2 mm horizontal or down-sloping ST-segment depression or a drop in systolic blood pressure of ≥20 mm Hg during exercise. The same qualified physician conducted each test.

Oxygen consumption (L/min and mL kg^{-1} min^{-1}), VCO_2 (L/min), and VE (L/min) were collected continuously throughout the exercise test. Peak VO_2 was expressed as the highest 30-second average value obtained during the last stage of CPX. Peak respiratory exchange ratio[18] was the highest 30-second average value obtained during the last stage of the CPX. Ten-second averaged VE and VCO_2 data, obtained from the initiation of exercise to peak, were input into spreadsheet software (Excel; Microsoft Corp, Bellevue, Washington) to calculate the VE/VCO_2 slope via least-squares linear regression ($y = mx + b$; m = slope).[19] The OUES, which represents the relation between VO_2 and VE during the incremental exercise test, was calculated by logarithm expression of ventilation, in which OUES is defined as the regression slope a in $VO_2 = a \times \log VE + b$. A higher OUES represents greater efficiency of VO_2, whereas a low OUES represents a greater VE in relation to VO_2 and ventilatory inefficiency during exertion.[20]

Physical Activity Patterns. The subjects wore an accelerometer (GT3X; Actigraph, Pensacola, Florida) on a belt over their right hip for 7 days after CPX. This device is a triaxial accelerometer that measures vertical, anteroposterior, and mediolateral acceleration. The device also filters the data to detect only movements that occur within a given frequency (0.25–2.5 Hz) so as to detect human body movement and reject other forms of movement, such as vibration. The acceleration data is integrated over user-specified time intervals, called epochs, providing a number of counts. The more activity a person does, the greater the number of counts recorded by the device.

From the determination of counts, time spent time in sedentary or light-intensity (0–99 counts/min), moderate-intensity (100-2,220 count/min), and vigorous-intensity (>2,220 counts/min) for each individual can be estimated. The software package for the accelerometer also has provides information on total steps per day and percentage of time active.

Echocardiography. LVEF and LV mass were assessed by 2-dimensional echocardiography. Standard M-mode and 2-dimensional echocardiography as well as Doppler flow measurements were performed with the use of a Sonos 5500 device (Hewlett–Packard, Andover, Massachusetts) and after ≥15 minutes of rest, according to the recommendations of the American Society of Echocardiography.[21]

Statistical Analysis

An a priori analysis for this study revealed that 14 subjects were needed to achieve 80% power ($\alpha = 0.05$; $\beta = 0.20$). All analyses were carried out with a statistical software package (Graphpad Prism v 5; Graphpad Software, La Jolla, California). Values for continuous variables were represented as mean ± SD. Pearson correlation coefficient was used to evaluate the relationship between CPX and echocardiographic variables and PA patterns. A P value of <.05 was considered to be statistically significant for all correlations evaluated.

Results

Baseline and CPX characteristics are listed in Table 1. All subjects were in New York Heart Association functional class II or III and presented with a history of hypertension and dyslipidemia. Pharmacologic management was consistent with current clinical standards. Cardiopulmonary exercise testing results demonstrated functional limitations/abnormalities consistent with the HF population. Average daily physical activity data are presented in Table 2. The accelerometer recordings were available for a mean of 6 days, which is enough time for an accurate PA pattern characterization.[22] The subjects spent 67% of their time in low-intensity activities and the average time spent in vigorous intensity activities was very low (4.7%).