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Original article

Are first ventilatory threshold and 6-minute walk test heart rate interchangeable? A pilot study in healthy elderlies and cardiac patients

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ABSTRACT

Background: Heart rate (HR) at the ventilatory threshold (VT) is often used to prescribe exercise intensity in cardiac rehabilitation. Some studies have reported no significant difference between HR at VT and HR measured at the end of a 6-min walk test (6-MWT) in cardiac patients. The aim of this work was to assess the potential equivalence between those parameters at the individual level.

Method: Three groups of subjects performed a stress test and a 6-MWT: 22 healthy elderlies (GES, 77 ± 3.7 years), 10 stable coronary artery disease (CAD) patients (GMI, 50.9 ± 4.2 years) and 30 patients with chronic heart failure (GHF, 63.3 ± 10 years). We analyzed the correlation, mean bias, 95% confidence interval (95% CI) of the mean bias and the magnitude of the bias between 6-MWT-HR and VT-HR.

Results: There was a significant difference between 6-MWT and VT-HR in GHF (99.1 ± 8.8 vs 91.6 ± 18.6 bpm, $P = 0.016$) but not in GES and GMI. The correlation between those 2 parameters was high for GMI ($r = 0.78$, $P < 0.05$), and moderate for GES and GHF ($r = 0.48$ and 0.55, respectively, $P < 0.05$). The 95% CI of bias was large (> 30%) in GES and GHF and acceptable in GMI (8–12%).

Conclusion: 6-MWT-HR and VT-HR do not appear interchangeable at the individual level in healthy elderlies and CHF patients. In CAD patients, further larger studies and/or the development of other walk tests could help in confirming the interest of a training prescription based on walking performance, after an exhaustive study of their cardiometabolic requirements.

1. Introduction

Exercise training is one of the core components of cardiac rehabilitation (CR), with secondary prevention program [1,2]. However, the optimal method to personalize training intensity remains controversial, as recommendations vary considerably (ranging from 50 to 100% of the maximal exercise capacity) [1–3].

Cardiopulmonary exercise testing (CPET) is recommended in entering CR, firstly in order to screen for potential myocardial ischemia, for threatening arrhythmia or for effort-induced hypertension. CPET can also be used to help in estimating the prognosis of mortality [4], to evaluate the maximal and submaximal exercise capacity and prescribe tailored program for physical activity,[5] particularly during CR [6]. Training intensity is usually prescribed at a target heart rate (THR) [7], commonly set at the HR corresponding to the first ventilatory threshold (VT) [8–11]. Indeed, one of the main aims of CR is to improve submaximal aerobic capacity. However, no robust prospective studies clearly support the systematic use of the THR at the first VT in CAD patients. Moreover, considering the prevalence of cardiovascular disease, it is difficult to perform a CPET with VO_2 measurement for all these patients, as it requires a specialized infrastructure and expensive resources. In addition, a CPET could be contraindicated for debilitated patients because it exposes to musculoskeletal damage and to various cardiac events [12]. Finally, CPET may be perceived as an unpleasant experience, thus leading to a lack of motivation to reach maximal effort that can alter the results significance.

Other easier and faster testing modalities thus appear useful to evaluate patients at various submaximal levels that are more relevant to daily activities [13,14] Even if there are still no recommendations regarding potential alternatives to CPET,

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functional evaluations, such as walk tests are thus being more and more used. The 6-min walk test (6-MWT) is now widely proposed to assess functional exercise capacity and prognosis since it is reproducible, well tolerated and corresponds to submaximal moderate exercise. Some studies showed that its relative intensity corresponds approximately to the first VT in elderly and cardiac patients [13,15–18], whereas other authors found that HR or VO_2 recorded during the 6-MWT was higher than that observed at this first VT in elderlies [19], and chronic heart failure (CHF) patients [20,21].

In a recent pilot study, Gremeaux et al. showed that setting exercise intensity prescription at the HR measured at the end of the 6-MWT allowed to obtain a similar exercise capacity improvement than with a conventional protocol using a training HR derived from maximal HR of the CPET [18]. Another study showed that walking speed at self selected (comfortable) velocity could be used to personalize training intensity in CAD patients [22], with the advantage of being perceived as pleasant, which is a positive point for a really prolonged behavioral change [23].

The aim of this work was to assess the potential equivalence between the 6-MWT-HR and the first VT-HR at the individual level in 3 populations for whom exercise training is recommended in primary or secondary prevention: healthy elderly subjects, coronary artery disease patients, and CHF patients.

2. Methods

2.1. Participants

Participants were included if they had completed an exercise training program or a CR program. Patients were not included if they presented: significant cognitive disorders that hampered participation in the tests (Mini Mental State examination ≤ 24); atrial fibrillation; acute or chronic respiratory failure; or any associated disease that limited walking capacity apart from aging or cardiac disease. All data were collected on a personal form, included in the patient's medical file. This study was approved by the local ethic committee, and informed written consent was obtained for all participants after they had been informed of all of the risks, the discomfort and benefits involved in this study.

2.1.1. Elderly participants (GES group)

They were healthy community-dwelling older volunteers enrolled in a large prospective study investigating the effects of one-year exercise training program in healthy elderlies [24]. Twenty two participants completed this program combining aerobic and strength training, in line with recommendations [2]. Sessions were performed in the rehabilitation department of Dijon University Hospital twice a week and at home once a week [24].

2.1.2. Cardiac (coronary and CHF) patients (GMI and GHF groups)

Patients were included without distinction of gender, if they were aged between 35 and 80 years; they were at the end of an outpatient program of CR [1,25]; they had been referred for: myocardial infarction, coronary angioplasty (± stenting), coronary artery bypass surgery, stable angina, CHF. CHF was defined as left ventricular ejection fraction $< 45\%$ using the echocardiographic Simpson method. Patients were excluded if they presented: renal failure, exercise-induced arrhythmia, or residual myocardial ischemia; pacemaker; severe obstructive heart disease; moderate to severe aortic stenosis; intracavitary thrombosis; pulmonary hypertension > 70 mmgHg; modification of drugs affecting adaptation to effort within the 15 days preceding the tests (diuretics, angiotensin conversion enzyme inhibitor, angiotensin receptor antagonist 2, beta-blockers, anti-aldosterone, ivabradine). On the other hand, the drugs class, even influencing the HR (for example beta-blocker), was not an exclusion criterion. Sessions were performed in the rehabilitation department of Dijon University Hospital twice a week and at home once a week.

2.2. Protocol Design

2.2.1. Measurements

At baseline and after the training period, participants performed a symptom-limited CPET on a cycle ergometer and a 6-MWT. The walk test was performed 2 to 4 days after the CPET. We only analyzed the post-training data, in order to avoid the influence of potential medical treatment modifications, especially in the GMI and GHF groups.

2.2.2. Symptom-limited CPET

Each participant performed one symptom-limited incremental CPET on a cycloergometer (Lode, Groningen, Netherlands). After a 1-min warm-up period pedaling at 20 W, the work rate was increased by 10 W every minute. A 12-lead electrocardiogram (Cardiosystem Marquette Hellige, Milwaukee, Wisconsin, USA) was continuously monitored. Left arm blood pressure was measured every 2 min using a standard cuff mercury sphygmomanometer. Gas exchange was measured breath-by-breath by a computerized system (CPX, Medical Graphics, St. Paul, MN). The exercise was stopped when the subject was unable to maintain the imposed pedaling rhythm of 60 revolutions per minute, and the reason for stopping (dyspnea, exhaustion, leg fatigue) was noted. Before each test, the system was calibrated with a 3-L Rudolph syringe and a standard gas of known concentration. The inspiratory airflow and the fraction of expired oxygen and carbon dioxide were measured every second. Averages were then established every ten seconds for ventilation, oxygen uptake, carbon dioxide production, respiratory ratio and breathing frequency. Peak VO_2 and peak HR were defined as the mean oxygen uptake and heart rate values during the last 30 s of exercise. The first VT was determined by two blinded and independent investigators, using Wasserman's method [26]. HR value corresponding to the first VT was noted.

2.2.3. Walk tests

The 6-MWT walk test was administered by a therapist blinded to the CPET result. It was performed on a 50-m unobstructed path. The patients were instructed to walk at a self-selected pace from one end of the path to the other and back, in order to cover as much distance as they could during the allotted time. The test was monitored and the time was called out every 2 min. Standard encouragement at 30-s intervals was provided. Slowing down and stopping to rest were permitted. At the end of 6 min, the total distance walked in meters (m) was measured. These technical aspects are in line with the American Thoracic Society recommendations for the 6-MWTc (32). At first, the patients performed a familiarization test in order to avoid learning effects.

HR was monitored throughout the walk-test with a telemetric device (Teleguard, GE Medical Systems, Denmark) and the highest value was noted during the last 30 s of the test. These values allowed assessment of relative cardiac intensity of the 6-MWT with respect to the CPX maximal HR. Blood pressure was measured before and immediately after each test at the left arm using a standard cuff mercury sphygmomanometer. Any clinical symptoms such as angina were recorded.

2.3. Statistical analysis

Standard statistical methods were used for the calculation of means and standard deviations.

Normal Gaussian distribution of the data was verified by the Shapiro-Wilk test and homoscedasticity by a modified Levenne