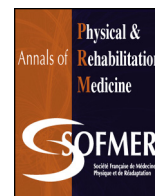




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Original article

Fixed-distance walk tests at comfortable and fast speed: Potential tools for the functional assessment of coronary patients?



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ABSTRACT

Objectives: There is ambiguity concerning the walk tests available for functional assessment of coronary patients, particularly for the walking speed. This study explores the psychometric properties of two walking tests, based on fixed-distance tests, at comfortable and fast velocity, in stabilized patients at the end of a cardiac rehabilitation program.

Methods: At a three-day interval 58 coronary patients (mean age of 64.85 ± 6.03 years, 50 men) performed three walk tests, the first two at a comfortable speed in a random order (6-minute walk test – 6MWT – and 400-metre comfortable walk test – 400mCWT) and the third at a brisk speed (200-metre fast walk test – 200mFWT). A modified Bruce treadmill test was associated at the end of the second phase. Monitored main parameters were: heart rate, walking velocity, VO_2 .

Results: Tolerance to the 3 tests was satisfactory. The reliability of the main parameters was good (intraclass correlation coefficient > 0.8). The VO_2 concerning 6MWT and 400mCWT were not significantly different ($P = 0.33$) and were lower to the first ventilatory threshold determined by the stress test ($P < 0.001$): 16.2 ± 3.0 vs. 16.5 ± 2.6 vs. 20.7 ± 5.1 mL·min⁻¹·kg⁻¹ respectively. The VO_2 of the 200mFWT (20.2 ± 3.7) was not different from the first ventilatory threshold.

Conclusions: 400mCWT and 200mFWT are feasible, well-tolerated and reliable. They explore two levels of effort intensity (lower and not different to the first ventilatory threshold respectively). 400mCWT is a possible alternative to 6MWT. Associated with 200mFWT it should allow a better measurement of physical capacities and better customization of exercise training.

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1. Introduction

In current practice, walk tests are used in patients with various chronic disabilities, particularly cardiovascular and respiratory diseases, to assess their adaptation to effort and the evolution of this under the effect of pharmacotherapies or non-pharmacotherapeutic interventions (such as exercise training programs). As they more specifically explore submaximal capacities, which is the intensity often required during daily activities, they complement data obtained from maximum cardiopulmonary exercise testing (CPET). Compared with the CPET, walk tests have the advantage of requiring limited human and technological resources, and can thus be repeated regularly. Consequently, walk tests have been

diversified and many different protocols are available: fixed-duration walking test (6-minute walk test, 2-minute walk test...), fixed-distance walking tests (6-metre walk test, 100-metre walk test, 200-metre walk test, 400-metre walk test...) and walking tests with incremental speed (10-metre shuttle walk test) [1]. Most of these tests explore aerobic capacities [2]. Indeed, recommended exercise programs in cardiovascular and respiratory diseases mainly seek to improve the aerobic performance [3].

Walking speed appears to be the key parameter, because it conditions the other physiological parameters such as metabolic parameters [4]. The comfortable walking speed (or self-velocity) is of great interest, because it represents the best bioenergetic efficiency of walking, in a steady state of aerobic metabolism [5]. It correlates with age and sex [6], it is associated with functional capacities and global health status [7], it represents an appropriate and well-tolerated stimulus for exercise training during cardiac rehabilitation [8] and it is a predictive factor of mortality [9,10].

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On the other hand, many usual activities involve anaerobic metabolism, and, high-intensity training programs, such as interval training, have also been validated [11], giving particular interest to brisk walk tests, which are designed to assess tolerance to higher levels of effort, beyond the strict aerobic limits. Finally, the comfortable and the fast walking speed appear to be highly complementary measurement, and for some authors the difference between the two is the best indicator of locomotor capacity [12].

Among current walk tests, the 6-minute walk test (6MWT) is the most commonly used as the main parameter to assess the impact of various therapeutic interventions in clinical practice and during experimental studies. However, there is some ambiguity in the instructions for the 6MWT concerning the required walking speed. Indeed, in its initial proposal, dedicated to heart failure patients, the 6MWT should be practiced at a self-selected velocity [13], though recommendations are different in other contexts. For example, for respiratory rehabilitation, the test is designed as “the distance that a patient can walk quickly” [14]. This leads to divergence regarding the modalities of the 6MWT, sometimes with conditions that must be strictly aerobic [2,12,15], and at other times with the aim to achieve an intensity close to maximum capacity [16]. This limitation and the heterogeneity in the available walk tests make them difficult to apply in clinical practice [17] and there are currently no recommendations regarding their indications.

This study is the first step in a project whose ultimate objective is to validate a new procedure dedicated to usual applications of walk tests. It is based on two preliminary observations: firstly, it seems justified to favor fixed-distance walking tests rather than fixed-duration walking tests (such as the 6MWT), because for planning motor activity, the use of spatial criteria has long been known to be more effective than time references [18,19]; secondly, it appears appropriate to specifically evaluate two levels of walking speed: comfortable walking speed (strictly aerobic) and fast walking speed (exceeding the limits of strict aerobic metabolism). For this purpose, the main objective of this study was to compare, in stabilized coronary patients, the metrological qualities of the 400-metre comfortable walk test (400mCWT), a fixed-distance walking test at a self-pace (comfortable speed), with the reference walk test, the 6MWT. The second objective was to compare these two self-pace walk tests with a CPET and a fast walk test, the 200-metre fast walk test (200mFWT), to clarify their respective characteristics.

2. Methods

2.1. Participants

Participants were included without distinction of sex, if they were aged between 55 and 80 years, at the end of an outpatient cardiac rehabilitation program and referred for either myocardial infarction, or coronary angioplasty (+ stenting), or coronary artery bypass surgery, or stabilised coronary artery disease. Enrolled subjects were excluded if they presented significant cognitive disorders that hampered participation in the tests (Mini Mental State examination < 24), any cardiac rhythm other than sinus rhythm (permanent or exercise-induced), acute or chronic respiratory failure, any associated disease that limited walking capacity or could stop an exercise test prematurely for a reason other than fatigue or dyspnoea, acute or chronic heart failure (left ventricular ejection fraction < 45% using the echocardiographic Simpson method), renal failure, residual myocardial ischaemia, pacemaker, severe obstructive heart disease, moderate to severe aortic stenosis, intracavitary thrombosis, pulmonary hypertension > 70mmHg, heart transplantation or any modification of

drugs affecting adaptation to effort (diuretics, angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, beta-blockers, anti-aldosterones, ivabradine) within the 15 days preceding the tests. Anthropometric measurements included height, weight, and body mass index.

Written informed consent, approved by the institutional ethics committee (Subjects Protection Committee, Dijon Est 1), was obtained for all participants, after they had been clearly informed about the protocol. This was a prospective single-centre study published in Clinical Trials Registration (reference NCT01904929).

2.2. Protocol

The whole protocol was carried out on a motricity analysis platform in a rehabilitation center of a university hospital.

2.2.1. Different phases of the protocol

The same experimental protocol was repeated at an interval of 72 hours to assess the reliability of the three walk tests (6MWT, 400mCWT, 200mFWT). A CPET, without pharmacologic wash-out, was carried out only at the end of the second phase of the protocol. Concerning the order of the walk tests, the two self-pace tests (6MWT, 400mCWT) were done first, in a random order, in order to subject the patients to an effort of increasing intensity, thus limiting the effects of fatigue for the brisk walk test and the CPET. All the walk tests were conducted on the same flat 50-metre-long indoor walking track at the same time of day. The same operator monitored the three successive tests, and the final CPET was supervised by a cardiologist specialised in cardiac rehabilitation. For all the tests, the occurrence of limitations or early termination (dizziness, chest pain, musculoskeletal pain...) was collected. The protocol was preceded by a 15-minute rest phase, and each test was separated by a new 15-minute rest period, or longer if the heart rate (HR) had not returned to the resting HR: Goal was to allow a sufficient recovery phase between each walking test (at least twice the duration of the test), with a return to resting levels of physiological parameters. The monitored parameters were HR assessed continuously by an HR monitor (POLAR FT1-Polar Electro Oy-90440 Kempele, Finland), blood pressure in the sitting position on the right arm before and after each test and continuous assessment of breath-by-breath gas exchange using a portable device (K4b2, Cosmed, Rome, Italy), VO_2 and VCO_2 being computed and extracted directly using the incorporated software.

2.2.2. The 6MWT

The patients were instructed to cover as much ground as they could during the allotted time, at their free-chosen walking speed (comfortable self-selected speed). Running was forbidden, but stopping and resting was allowed. No encouragement was given during the test, but patients were informed every 2 minutes of the time spent. The distance walked was recorded at the end of the test as an absolute value in metres.

2.2.3. The 400mCWT

The walking speed directives were the same as for the 6MWT, but on a fixed-distance of 400 m. The test result was expressed in seconds (time to cover the distance of 400 m).

2.2.4. The 200mFWT

The instruction was to cover a distance of 200 m as quickly as possible, without running. Standard encouragement was provided at mid-distance. Slowing down and stopping to rest were authorised. The results were also given in absolute values (time to complete the test in seconds).

2.2.5. The CPET

A modified Bruce treadmill test was performed with continuous 12-lead ECG monitoring (Marquette, GE Medical Systems, Milwaukee, USA) [20]. It was a symptom-limited maximum exercise test. Standard encouragement was provided at the mid time of every stage of the test to exercise patients to exhaustion. The use of handrail support was forbidden throughout the effort test, except in the case of a loss of balance or at the exhaustion phase at which time the test was stopped. Blood pressure was measured at the end of every stage of the test, at peak exercise and during recovery. The first ventilatory threshold was determined by the Wasserman method [21]. The CPET was terminated at exhaustion, defined as a final respiratory exchange ratio above 1.10. The VO_2 peak was defined as the highest value during the last 60 seconds of the stress test. The highest HR measured during the last minute of the treadmill test was used as the reference value for the maximal HR (HRmax).

2.3. Statistical analysis

To assess reliability, a test-retest was conducted with a single experimenter. The intraclass correlation coefficient (ICC) was computed in order to evaluate measurement agreement. An ICC higher than 0.7 was considered good, and over 0.9 excellent.

In order to evaluate the distribution of the difference of the means between walk tests, Bland and Altman plots were obtained by plotting the difference between sessions against the mean results for HR (bpm), VO_2 uptake ($\text{mL}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$) and the walking velocity ($\text{m}\cdot\text{s}^{-1}$). Bland and Altman representations make it possible to describe the percentage of subjects and their distribution within the 95% limits of agreement throughout the range of each walk test performance. The smallest detectable difference (SDD), which corresponds to the limits of agreement (mean change ± 1.96 SD) represents the smallest change that can be distinguished from the measurement error for each parameter.

The validity of the parameters was evaluated against the gold standard assessment of physical capacities (i.e. measures at the

CPET peak and first ventilatory threshold). A Pearson correlation coefficient was then used and the strength of the correlation was evaluated using Munro's classification system (very weak 0.15–0.24, weak 0.25–0.49, moderate 0.50–0.69, high 0.70–0.89 and very high 0.60–1).

The fact that we had more than 30 patients allowed us to analyse the data with parametric tests, in accordance with central limit theory. Differences between groups and tests were assessed respectively with independent and paired *t*-test. Means and 95% confidence intervals were calculated and are presented for both sessions of the test. Statistical analyses were done using statistica v10.0 (StatSoft, Tulsa, USA) and Matlab with statistical toolbox (MathWorks, Natick USA). An alpha value of 5% was chosen to determine the significance of the parameters.

3. Results

A total of 58 patients completed the protocol study (inclusions carried out from November 2013 to August 2015). The flow diagram of this study is presented in Fig. 1. The baseline characteristics of the patients are reported in Table 1.

Feasibility of the three walk tests was satisfactory, with no symptoms of intolerance. Concerning the reliability, there was no difference in any of the main values assessed (HR, walking velocity and VO_2 peak) for the three walk tests between the two sessions (Table 2). However, there was a difference due to the randomization in the first session between the 6MWT and 400mCWT. Indeed, walking speed was different between the two tests for the two sessions, only when the 6MWT was performed first (Fig. 2). This is consistent with a lower ICC for the 6MWT. Fig. 3 shows the Bland an Altman distribution of the three main parameters (HR, VO_2 and walking velocity) for the 6MWT, the 400mCWT and the 200mFWT.

For all values measured during the three walk tests, a difference was found for the 200FWT only, the distribution being identical between 6MWT and 400mCWT (see Fig. 4 for the VO_2 distribution).

The mean VO_2 measured during the 6MWT and 400mCWT, like the HR, was not different, but was lower than those corresponding

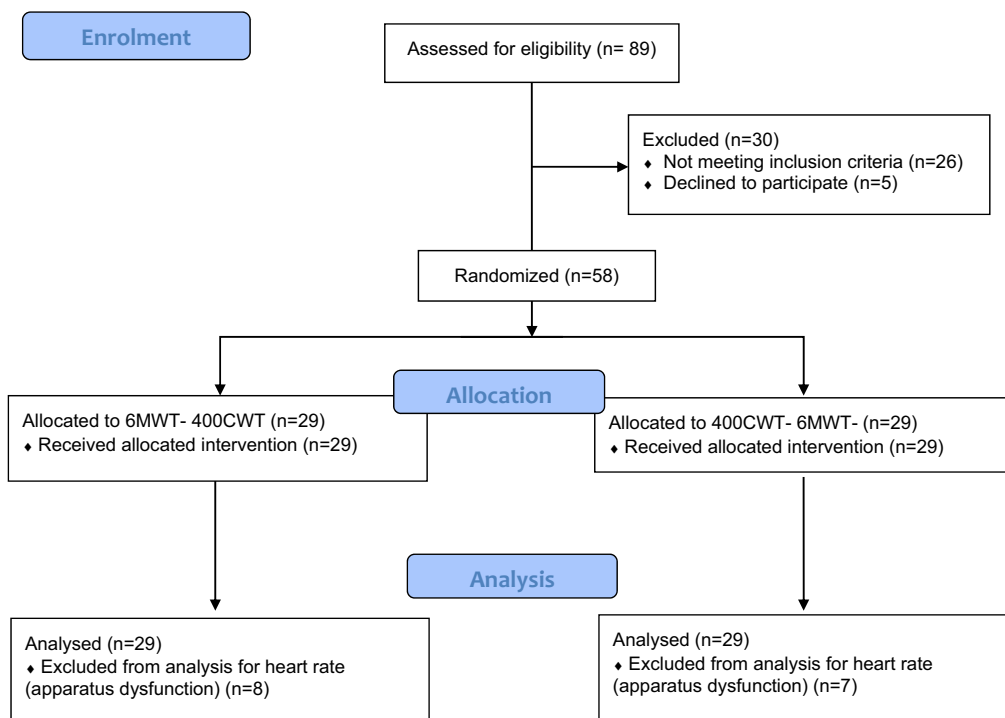


Fig. 1. Flow diagram (CONSORT 2010).

Table 1
Characteristics of patients included in the study.

Characteristics	Population (n = 58)
Sex (male/female)	(50/8)
Age (years)	64.85 ± 6.03
Height (m)	1.71 ± 0.07
Weight (kg)	76.92 ± 11.80
Body Mass Index (kg.m ⁻²)	26.28 ± 3.43
VO ₂ uptake at rest (mL.min ⁻¹ .kg ⁻¹)	4.3 ± 0.4
Heart rate at rest (bpm)	72 ± 3
Medications	
Beta-blockers	55
Angiotensin-converting enzyme inhibitors	48
Angiotensin receptor blockers	5
Antiplatelets	58
Statins	57
Anticoagulants	2
Calcium antagonists	9
Diuretics	5

to the first ventilatory threshold of the CPET (Fig. 5). In contrast, the VO₂ during the 200mFWT was not significantly different from that of the first ventilatory threshold, while the HR during the 200mFWT was higher than those corresponding to the first ventilatory threshold (Fig. 5).

4. Discussion

Though the CPET is always proposed as the gold standard for exercise prescription prior to a training program in cardiac rehabilitation [22], submaximal exercise testing is being increasingly developed as a complement, to better evaluate the physiological responses to situations encountered in daily life [23]. Among the available functional tests, the assessment of walking activities is of great interest, especially because of the commonly reported limitations of the compendium of physical activities [24]. Given the heterogeneity already highlighted regarding available walk tests and the ambiguity regarding the exact choice of walking speed, this study is part of a global project that attempts to validate a reasoned strategy, based on the use of fixed-distance walk tests at two speed levels: a comfortable speed, based on the 400mCWT, and a brisk speed based on the 200mFWT.

The distance of 400 metres was chosen for the comfortable speed test (400mCWT) because it is an average of the 6MWT distance assessed in patients with chronic disabilities, such as heart failure [25]. Furthermore, it includes the distance of 300 metres, which represents a threshold both functionally and in terms of predicted mortality [26,27]. A 400-metre walk test at a self-selected speed was first proposed as an alternative to the

Table 2
Means and 95% confident Interval (CI) of the heart rate, walking velocity and VO₂ uptake (means of the last 30s of the test) for the 6 minute, 400 m and 200 m walk tests during session 1 (S1) and 2 (S2). Inter-sessions Intraclass correlation coefficients (ICC) are presented with their 95% CI. Values higher than 0.7 indicate good reliability, and higher than 0.9, excellent reliability.

Parameters	Mean S1 (95% CI)	Mean S2 (95% CI)	ICC (95% CI)
Heart rate (bpm)			
6MWT	90.3 (86.4–94.1)	94.9 (90.3–99.5)	0.822 (0.66–0.9)
400mCWT	91.3 (87.3–95.3)	91.3 (86.9–95.7)	0.852 (0.72–0.92)
200mFWT	111.9 (106.6–117.3)	116.4 (110–122.9)	0.814 (0.67–0.89)
Walking velocity (m.min ⁻¹)			
6MWT	84.1 (81.8–86.4)	87.1 (84.7–89.6)	0.885 (0.81–0.93)
400mCWT	85.3 (83.1–87.5)	88.1 (85.7–90.4)	0.932 (0.89–0.96)
200mFWT	109.5 (106.7–112.4)	110.5 (107.5–113.4)	0.951 (0.92–0.97)
VO ₂ uptake (mL.min ⁻¹ .kg ⁻¹) (last 30 seconds of test)			
6MWT	15.2 (14.6–15.8)	16.3 (15.5–17.1)	0.824 (0.7–0.9)
400mCWT	15.5 (14.8–16.1)	16.5 (15.8–17.2)	0.826 (0.71–0.9)
200mFWT	20 (19–21)	20.3 (19.3–21.2)	0.859 (0.76–0.92)

6MWT: 6-minute walk test; 400mCWT: 400-metre comfortable walk test; 200mFWT: 200-metre fast walk test.

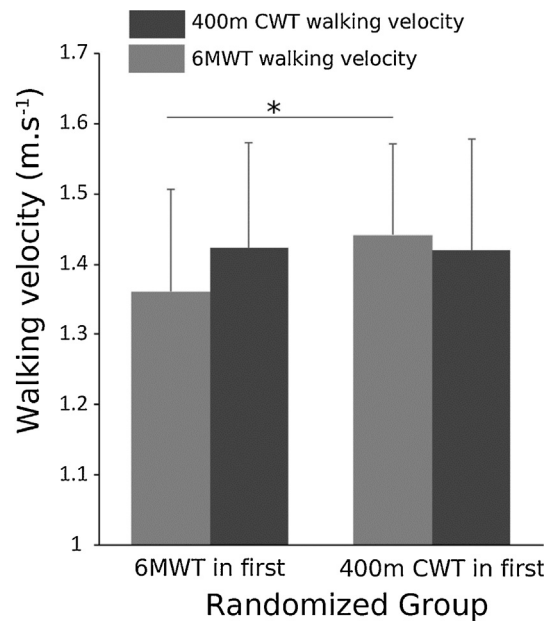


Fig. 2. Velocity histograms vs. randomization: mean walking velocity (m.s⁻¹) and standard deviation function of the randomized groups (either 6mWT in first or 400mCWT in first). This figure shows the interaction effect between the randomization order and the performance of the tests.

6MWT in healthy subjects, walking speed and HR being higher than for the 6MWT [28]. In contrast, in subsequent studies carried out in older adults, the same authors used the instructions to “walk as quickly as you can, without running” for this “long distance corridor walk”, the results (time to complete the test) being predictive of mobility limitation and of mortality [29] and being correlated with peak VO₂ [30]. The reliability of the 400-metre walk test at a brisk pace was shown to be excellent in healthy adult women [31]. To our knowledge, the 400-metre walk test “at a speed chosen by the patient himself” was only once implemented in patients with heart disease. In twenty patients with chronic heart failure, a good correlation was shown between distance covered during the 6MWT and time recorded during the 400-metre walk test [32].

The 200mFWT is derived from the 600-foot walking test, which was proposed as an alternative to a CPET in elderly coronary patients [33]. It was first designed to assess tolerance to high-intensity exercises in healthy elderly subjects [34]. The reliability, validity, sensitivity to change and efficiency to tailor high-intensity interval training have been found to be satisfactory in coronary patients [35,36], but a minimal clinically important difference has

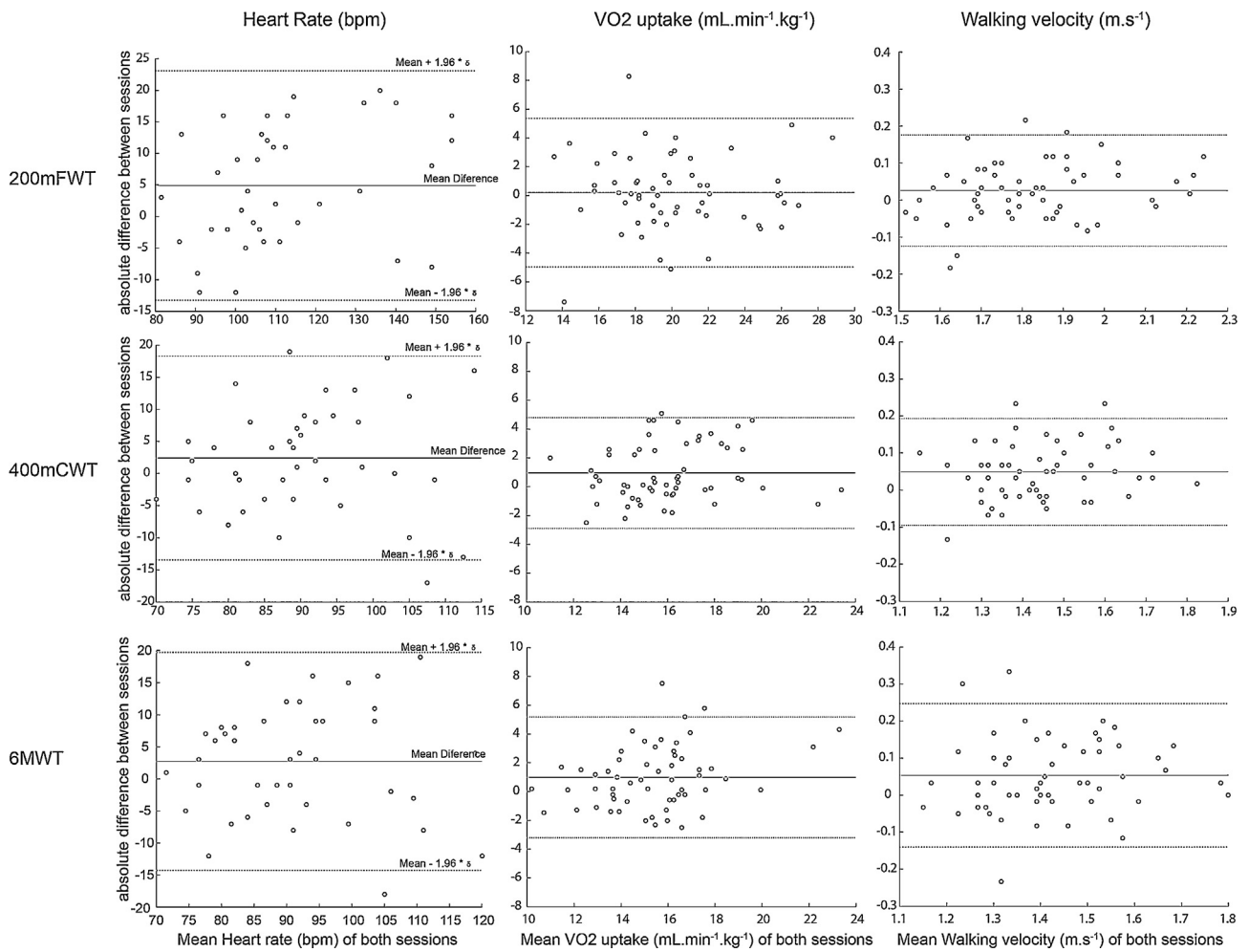


Fig. 3. Bland-Altman plots showing the absolute differences between sessions as a function of the mean of both sessions for the 6MWT (bottom panels), 400mCWT (middle panels) and 200mFWT (upper panels). The values of heart rate (bpm): left panels, VO₂ uptake (mL·min⁻¹·kg⁻¹): middle panels and walking velocity (m·s⁻¹): right panels are presented.

not yet been determined [37]. An equation involving the HR measured during this walk test and the patient’s age, proved to be more effective than the classic Fox formula (HR_{max} = 220 – age) to predict the HR_{max} of coronary patients: HR_{max} = 130 – 0.6 × age + 0.3 × HR_{200mFWT} [38].

In the present study, the reliability of these two tests, like that of the 6MWT, was satisfactory for the three main parameters, namely walking speed, VO₂ and HR. In addition, no significant difference was shown for these three factors between the 400mCWT and the 6MWT. These first results therefore suggest that the 400mCWT could be a possible alternative to the 6MWT, especially as randomization between the two tests showed additional interests for the 400mCWT. In this context of a comfortable speed, the comparison with the CPET data confirms, in agreement with previous studies [39], that aerobic capacities alone are explored by the 6MWT and the 400mCWT (VO₂ values below the first ventilatory threshold). In contrast, the 200mFWT effectively corresponds to a more intense effort, the same intensity level as the first ventilatory threshold, which is a transition zone between a strictly aerobic metabolism and a mixed metabolism (aerobic and anaerobic). A low difference between the 200mFWT speed and the 400mCWT speed is probably linked to a premature recourse to the anaerobic metabolism, corresponding maybe to a deficiency of the strictly aerobic capacities. The assessment of the evolution of the ratio of these two speeds, depending on an exercise training program, will be of particular interest to answer this question.

There is an apparent paradox concerning the 200mFWT results, with a not different VO₂ value but a higher HR than for the first ventilatory threshold determined during the CPET. This can be explained by the difference in the effort type (treadmill for CPET, flat walking track for 200mFWT) that causes different changes in

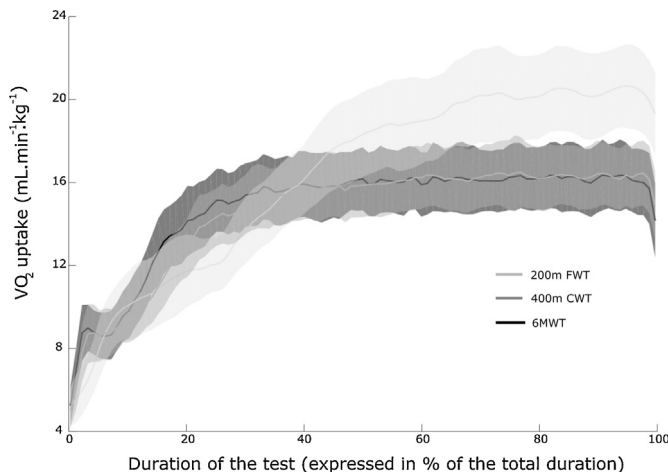


Fig. 4. VO₂ uptake curves: mean VO₂ and 95% confident interval for the 6MWT, 400mCWT and 200mFWT, expressed as the percentage duration of each test.

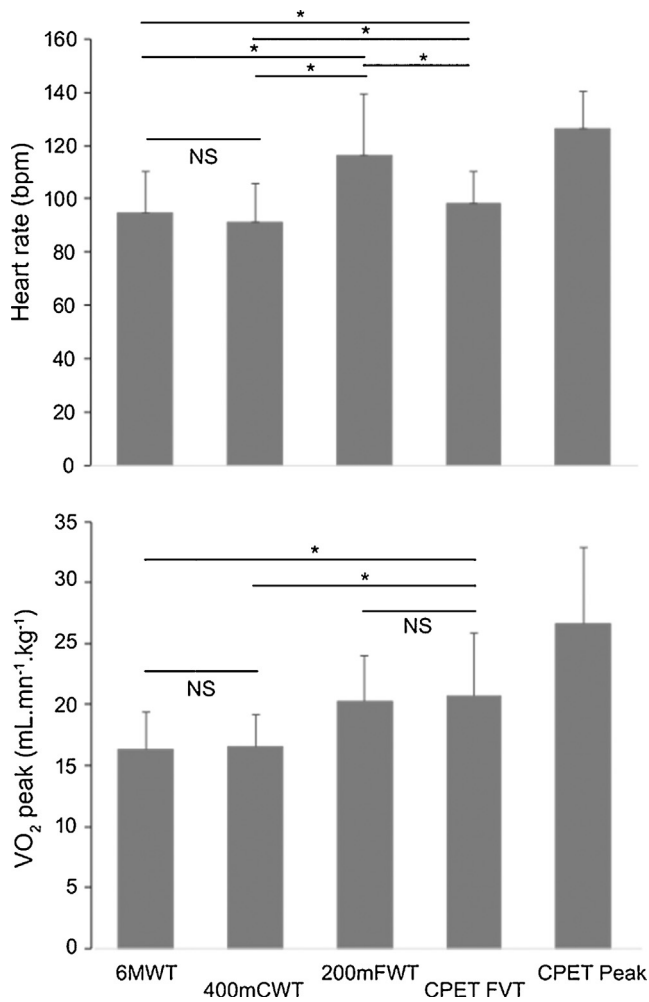


Fig. 5. Mean values and standard deviation of VO₂ uptake (mL·min⁻¹·kg⁻¹) (bottom) and the heart rate (upper) for the 6MWT, 400mCWT, 200mFWT, CPET first anaerobic threshold (AT1) and CPET peak.

the various parameters of the Fick formula, in particular for the relationship between cardiac output and peripheral oxygen utilization in coronary patients. Pathophysiological studies are currently lacking in this area.

The main limitation of this study is that it did not allow us to draw any definitive conclusions about the superiority of the 400mCWT compared with the 6MWT for the functional assessment of coronary patients in current practice. To meet this objective, this study will now continue in order to evaluate, firstly the sensitivity to change of the 400mCW (e.g. after cardiac rehabilitation), and secondly, in the real world of the cardiac rehabilitation, the simplification truly provided by the preferential use of fixed-distance walk tests. Indeed, the challenge is to show that the 400mCWT is more appropriate than the 6MWT to determine the comfortable walking speed in everyday practice (outside the strict conditions of an experimental protocol).

5. Conclusion

The functional assessment of stabilized coronary patients by fixed-distance walk tests at two different speeds (comfortable and fast) is feasible, well-tolerated, and reliable. It represents a simple and cheap procedure to assess exercise capacity at two intensity levels. If the results of complementary studies are favorable, in the future, it should be possible to clarify the current ambiguity regarding the selection of the walking speed, in order to better

assess the physical capacities regularly implemented in everyday activities and to better customize training programs.

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Disclosure of interest

The authors declare that they have no competing interest.

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