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Research paper

Clinical outcomes vary between the Shuttle Walk Test and Stress Test in patients with coronary artery disease

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ABSTRACT

Purpose: The purpose of this study was to determine if the Incremental Shuttle Walk Test (ISWT) can elicit similar patient responses as a treadmill stress test in patients with coronary artery disease (CAD).
Methods: Both the stress test and the ISWT were performed by 172 participants, aged 60.67±10.23 years. We screened participants for unstable angina, severe aortic stenosis, uncontrolled hypertension, and excluded if unable to walk on a treadmill. Outcome measures (signs and symptoms) included: i) patient-reported chest pain; ii) patient-reported breathlessness/exhaustion and not being able to keep up with test protocol; and iii) able to reach target HR_{max}. Additionally, EKG changes during the stress test were monitored for ST changes or arrhythmias.
Results: During the stress test, 15 participants reported chest pain, 23 participants reached target HR_{max}. No participants reported chest pain and 2 participants reached target HR_{max} during the ISWT. Participants reporting chest pain had a higher mean BMI and significant difference in METS ($p < 0.001$) during the stress test and walking distance ($p = 0.03$) when compared with patients who did not report chest pain during the stress test. Breathlessness and not being able to keep up with protocol were the most commonly reported in both tests. Changes in EKG were observed in 38 participants in the stress test.
Conclusion: A maximal effort stress test is better at eliciting ischemic signs and symptoms and a superior tool for diagnosis of progression or severity of CAD than the ISWT. Appropriate selection of exercise tests is important in the clinical setting.

1. Introduction

Functional evaluation of patients with complaints of chest pain is an important aspect of the diagnosis of coronary artery diseases (CAD). The gold standard in functional assessment remains the maximal effort test also referred to as the Cardiopulmonary exercise test (CPX) to determine maximal oxygen uptake ($VO_{2\ max}$) and maximal heart rate (HR_{max}) [1]. In the clinical setting, peak oxygen uptake ($VO_{2\ peak}$) is often used as a surrogate for $VO_{2\ max}$ [2]. The test is generally conducted using a treadmill or a bicycle ergometer with an incremental increase in workload till voluntary exhaustion is reached. The maximal effort test is well accepted in the cardiovascular population [3] and a treadmill maximal effort stress test (Bruce stress test) [4] is commonly used to determine the severity, progression and diagnosis of CAD. Oxygen consumption is typically not measured during a stress test and the focus is on evaluating signs and symptoms of coronary ischemia. A positive stress test is determined by the patient reporting chest pain, and/or electrocardiogram changes (EKG) changes to indicate coronary artery

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stenosis or an underlying arrhythmia [5–7]. Cardiac rehabilitation (CR) programs also use the CPX test to determine functional capacity and determining exercise intensity for exercise programs. It is advised that a stress test in patients with CAD be conducted in a laboratory setting supervised by trained medical personnel [8].

In the absence of a facility with adequate resources and trained personnel to conduct a maximal effort test, alternate forms of submaximal or maximal tests are often used to determine functional capacity. Unlike a stress test, cardiac rhythm may not be monitored during these tests. The 6-Minute Walk Test (6MWT) and the Incremental Shuttle Walk Test (ISWT) are examples of such tests. The 6MWT is a submaximal effort where the patient is allowed to self-regulate their walking pace with the instruction to cover the maximal distance over 6 min when walking in a hallway or corridor [9]. However, its results may not correlate with a $VO_{2\ max}$ test [2]. This is largely because patients may not be exerting themselves maximally and without an increase in workload, an aerobic steady-state may be reached during the 6 min [3,10]. The ISWT is different from the 6MWT fundamentally with the pace being set externally and the workload increased in each stage [11]. As such, it may be comparable to the stress test. In their scientific statement, the American Heart Association advised against the use of alternate forms of testing, including the 6MWT, for developing exercise prescriptions and programs for cardiac rehabilitation [2]. However, the ISWT was not included in the list of alternate forms of functional tests that were reviewed. In reviewing the literature, we found that no study has evaluated the ISWT and maximal stress test in patients with CAD. As such, the purpose of this study was to determine if the ISWT can elicit similar patient responses (signs and symptoms) as a maximal effort stress test in patients with CAD.

2. Methods

2.1. Design

This was a single group design with study participants performing both the 6MWT and the ISWT. The study protocol was approved by the Human Research Ethics Committee and all procedures were carried out following the Declaration of Helsinki. All participants signed informed consent before enrollment. Data was collected between January 2103 and December 2015.

2.2. Sample

All participants enrolled in the study had complaints of chest pain that was determined as stable angina by a cardiologist and were referred for a stress test for further evaluation. Participants who previously were diagnosed with CAD were on standard medical treatment for at least 4 weeks. Participants with unstable angina, severe aortic stenosis, uncontrolled hypertension, and unable to walk on a treadmill were excluded from the study. Participants were recruited from an outpatient clinic of a University Hospital in Valencia, Spain, and a cardiologist clearance was obtained prior to participation in the study.

3. Outcome variables and measures

The outcome responses for signs and symptoms we specifically monitored included: i) patient-reported chest pain; ii) patient-reported breathlessness/exhaustion and not being able to keep up with test protocol; and iii) patients HR reaching their target HR_{max} defined as reaching 85% of age-predicted maximal HR (220-age). Additionally, EKG changes during the maximal effort stress test were also monitored for ST changes or arrhythmias. We recorded any other reasons patients may not have completed the tests.

1) **Maximal Effort Stress Test:** The Bruce protocol [12] was used for the maximal effort test and recommendations for exercise testing were followed [13]. Participants were asked to walk on a treadmill and the workload was increased every 3 min by increasing the pace and grade. Theoretically, the test can last a maximum of 21 min with a maximum pace of 5.5 mph and 22% grade. Participants took their beta-blocker as usual but were asked to not eat, drink or smoke for 3 h prior to the test to enable the patient to achieve a higher workload. A resting EKG was obtained prior to starting the test and blood pressure was monitored at the end of each stage. The test was stopped if any of the above-mentioned outcomes were noticed.
2) **The Incremental Shuttle Walking Test (ISWT):** The test required patients to walk between two cones 10 m apart at a pace to reach each cone before a bleep. Following standard protocol, at each level, the time duration between the bleeps was reduced every minute to increase the pace [11]. The test has a total of 12 levels. The test was stopped if: i) above-mentioned outcomes were met; and ii) was more than 0.5 m away from the cones when bleep sounded [11]. Blood pressure was obtained before and after the test.

4. Procedure

Research staff screened participants for inclusion and exclusion during their regular clinic visits. Details of the study, including procedures involved in both the stress test and the ISWT were provided and informed consent was obtained. Two appointments were set up for participants to complete both tests. Participants were asked to be adequately hydrated and not perform any exercise on the day of the test. The maximal effort stress test was completed on day 1 and within the next 7 days returned to complete the ISWT. The physiotherapist demonstrated the ISWT to the participants and the participants performed the test for 1–2 min for familiarization. Adequate rest was provided after the trial and determined by the physiotherapist by HR lowering to resting levels and the participant reported a rating of perceived exertion (RPE) of <10 on the Borg scale [14]. Data was collected by the same staff on all participants. Demographic and clinical characteristics of the consented participants were obtained from participants' medical records.

5. Data analysis

Descriptive statistics including mean, standard deviation, and percentage were used for describing demographic characteristics, clinical characteristics, and outcome measures. An independent *t*-test was used to test for any significant group-based differences in outcomes. Statistical analysis was performed with SPSS V. 25 (IBM SPSS, Inc., Chicago, IL, USA).

6. Results

A total of 172 participants completed both the ISWT and the stress test. The demographic and clinical characteristics of the participants are provided in Table 1.

The mean walking duration during the stress test was 6.41 ± 2.39 min. The mean metabolic equivalent (METS) was 7.9 ± 2.2 METS (range: 4–13 METS). The mean distance walked during the ISWT was 231.6 m $\pm$112.37 m. The total number of participants who completed the different levels of the stress test are shown in Table 2. No significant differences were found in BMI, METS, and distances walked in ISWT between men and women.

The patient-reported and observed outcomes during the ISWT and the stress test are highlighted in Fig. 1.

During the stress test, 38 patients developed EKG changes (37 with ST changes and 1 arrhythmia). Leg pain that included knee pain, ankle pain, or claudication type pain was reported by 8 participants during the stress test and 7 participants during the ISWT. Three participants were not comfortable walking on the treadmill when the pace and grade were increased during the stress test and 1 participant reported feeling

Table 1
Sociodemographic and clinical characteristics.

	Total (N = 172)
Age (years±SD)	60.67 ± 10.23
Sex	
Male	135 (78.49)
Female	37 (21.51)
Height (cms ± SD)	165.4 ± 7.77
Weight (kg ± SD)	79.71 ± 12.21
BMI (kg/m^2)	29.03 ± 3.8
Diagnosis	
Acute myocardial infarction	132 (76.75)
Stable angina	40 (23.25)
Therapeutic action	
PCI	77 (44.77)
CABG	18 (10.46)
Drugs	
Antiplatelets	169 (98.25)
Beta-blockers	146 (84.88)
ACE Inhibitors	76 (44.18)
ARBs	20 (11.63)
CCB	16 (9.3)
Diuretics	9 (6.40)
Statins	156 (90.70)
CVRF	
Hypertension	114 (66.27)
Dyslipidemia	156 (90.70)
Diabetes	38 (22.09)
Current smoker	18 (10.47)
Previous Smoker	123 (71.51)

BMI: Body Mass Index; PCI: Percutaneous Coronary Intervention; CABG: Coronary Artery Bypass Grafting; ACE: Angiotensin Converting Enzyme; ARB: Angiotensin Receptor Blocker; CCB: Calcium Channel Blocker; CVRF: Cardiovascular Risk Factors.

Table 2
Incremental Shuttle Walk Test levels completed.

Level	Number of participants completing the level
Level 1	172
Level 2	170
Level 3	158
Level 4	142
Level 5	111
Level 6	76
Level 7	37
Level 8	11

dizziness. During the ISWT, the vast majority of participants (n = 163) reported either feeling breathless or exhausted and not being able to keep up with the test protocol. Twenty-three participants during the stress test and two participants during the ISWT reached their theoretical HR max.

During the stress test, 15 participants reported chest pain while no participants reported chest pain during the ISWT. We tested the equality of variance assumptions between the 15 participants who reported chest pain versus did not report chest pain. These two groups were compared using two independent sample *t*-test for BMI, distance walked during the ISWT, and METS during the stress test. The mean BMI of these 15 participants who reported chest pain, although not significant, was higher than other participants. The mean METS score for patients reporting chest pain (6.1 ± 1.9) vs not reporting chest pain (8.1 ± 2.2) was significantly different ($p < 0.001$). A significant difference ($p = 0.03$) was also seen in the mean distance walked in ISWT between the 15 participants who experienced chest pain during the stress test and those that did not (Table 3).

7. Discussion

To our knowledge, no other study has compared the clinical responses between a maximal effort stress test and the ISWT. Our study shows that when performing both the ISWT and a maximal effort stress test, breathlessness, exhaustion and not being able to keep up with the test protocol was the most commonly patient-reported symptom in patients with CAD. We also found similar patient-reported pain (knee, ankle, claudication type) in both the test which is in line with studies done in patients with intermittent claudication [15]. However, the most important outcome was the ability of the stress test to elicit a response of chest pain in 15 participants which was not reported during the ISWT. This observation can be attributed to the difference in the structure and protocol used in the two tests. Whereas the ISWT requires participants to progressively walk faster on a flat surface, the Bruce protocol combines an increase in pace and grade on a treadmill. The cardiac workload can be higher during the stress test than during the ISWT with the recruitment of additional muscle while walking incline [16]. Incline treadmill walking impacts gait [17], and gait pattern (step width, arm swing, knee flexion, etc.) has been shown to influence the metabolic cost and oxygen demand [18–20]. In our study, these factors may have influenced the cardiac workload during treadmill walking during the stress test versus walking on a flat surface during the ISWT. Also, in the ISWT the stages are changed every minute, while in the stress test each stage is 3 min long. The 3-min stages potentially can allow the participant to adapt after the workload is increased. A quicker increase in workload in shorter durations can leave one breathless which was the most common patient-reported symptom in the ISWT. Our interpretation can be supported by the results of a previous study where a lower level of cardiovascular response was observed in treadmill vs ISWT in older adults with cardiovascular diseases (n = 9) [21] and intermittent claudication (n = 19) [15]. The slowing of gait speed, cadence, and stride length is associated with increasing age [22,23]. The difference in the report of chest pain can also be attributed to the number of participants achieving theoretical target HR_{max}. Only 2 participants during the ISWT compared to 23 participants in the stress test reached target HR_{max}. Our sample also consisted of adults with a mean age of 60 years who may have preferred to walk slower at an incline than quicker on a flat surface [24]. We found that participants reporting chest pain had a higher mean BMI and significant difference in METS ($p < 0.001$) during the stress test and walking distance ($p = 0.03$) when compared with patients who did not report chest pain during the stress test. Obesity and METs during a stress test have been established as significant cardiovascular risk factors for CAD [25–27]. Finally, in this group that consisted of mostly older adults, anxiety associated with performing a maximal effort treadmill test and mental stress associated with the outcome of the test may also influence respiration and metabolic demand [28,29].

Objective changes in EKG were also noticed during the stress test which is essential for a clinical diagnosis of CAD. Although we did not monitor EKG changes during the ISWT, these changes during the ISWT may not be prominent as reported in another study [30]. The ISWT has been tested for its validity and reliability in measuring functional capacity in patients with CAD [31–33], stroke [34], asthma [35], and other pulmonary diseases [36,37]. Only forty-eight (27.9%) participants in our study were able to complete level 7 in the ISWT while no participant completed all 12 stages. However, similar observations have been reported in other studies. One study on post-coronary artery bypass patients (n = 34; mean age 61.2 years; all males) also reported a similar observation of patients not being able to complete all 12 stages [33]. Another study in patients with cardiovascular diseases reported 7 (n = 8) participants to have completed level 7 [21]. Our study included a significantly larger sample size than these studies which strengths our results. It may also be cautioned that without a maximal effort test, prescription of exercise intensity may not provide optimal benefit to the patient [38]. From our study results, we would like to add that an underlying cardiac condition can go undiagnosed and masked as exhaustion/shortness of breath with the use of the ISWT with both subjective measures (chest pain) being underreported and objective measures (EKG) generally not being measured or not reliable.

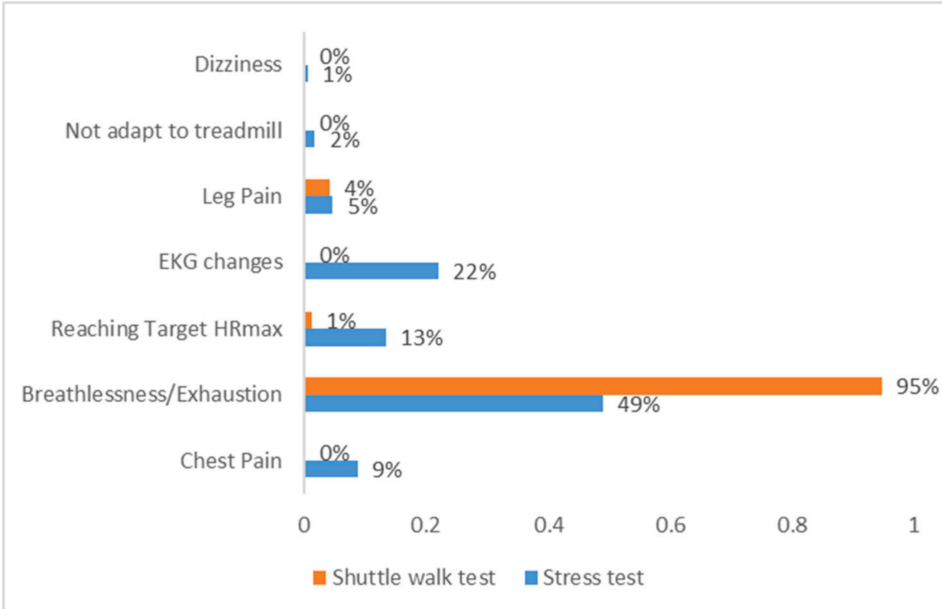

Fig. 1. Outcomes during the stress test and the ISWT.

Table 3
Description of participants reporting chest pain during the stress test.

Description	n = 15
BMI (kg/m^2)	30.7 ± 3.5
METS during the stress test	6.1 ± 1.9
ISWT levels completed	
Level 3	15 (100)
Level 4	14 (93)
Level 5	8 (53)
Level 6	3 (20)
ISWT distance walked (m)	195.3 ± 57

Abbreviations: BMI = Body mass Index; METS = Metabolic equivalent; ISWT = Incremental shuttle walk test; *Data are expressed as mean ± SD or frequency(percentage), as appropriate.*

The study had a few limitations. The design was cross-sectional and both the tests were conducted only once. The majority of our participants were males which did not allow evaluation of sex-related differences. Participants were mostly Caucasian and a gross generalization of our results should be avoided. Another limitation of our study was not measure EKG during the ISWT which did not allow for detecting any EKG changes during the test. Future studies should consider addressing this limitation in designing their study.

8. Conclusions and implications

In conclusion, our study found a maximal effort stress test to be superior and better at diagnosis of progression or severity of CAD. The results of our study highlight two important findings: 1) the fact that even in externally controlled graded exercise testing such as the ISWT, the instances of patients reporting chest pain is lower than a stress test; and 2) an underlying CAD that may have been found with a stress test from an EKG can be masked as shortness of breath during the ISWT. Older adults with multiple comorbidities including obesity reporting of unusual shortness of breath during the ISWT should be recommended for the stress test. As such, we reinforce the fact that the appropriate selection of exercise test is important in the clinical setting. The ISWT may be used for non-diagnostic purposes such as determine functional capacity in patients in whom CAD is not suspected or are stable.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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