ramr
American Review of Respiratory Medicine
Revista Americana de Medicina Respiratoria

PERSPECTIVES

ISSN 1852-236X

Shuttle Test, or Incremental Shuttle Walking Test. Thirty Years Later: So Useful and Yet So Rarely Used

Shuttle test o prueba de caminata de carga progresiva treinta años después: tan útil y tan poco usada

Sívori, Martín L.

Received: 02/18/2023
Accepted: 11/02/2023

Correspondence
sivorimartin@yahoo.com

The objective measurement of disability or difficulty in mobilizing due to chronic lung diseases, particularly Chronic Obstructive Pulmonary Disease (COPD), is a crucial assessment in the management of patients with this condition.[1-3] However, cardiopulmonary exercise testing isn't widely available in our country due to the expensive equipment required. Therefore, field exercise tests represent an attractive alternative. Since Cooper popularized the first field exercise test (the 12-minute test) in 1968, much research has been conducted on the topic.[4] Today, the most commonly used field test is the 6-minute walk test, which is a submaximal test.[1-3] Its use and indication were standardized by the American Thoracic Society (ATS) in 2002 and more recently in 2014 by several intersocietal documents of the ATS and the European Respiratory Society (ERS).[1-3,5] Other maximal field exercise tests include the stair climbing test and the shuttle test or "Incremental Shuttle Walking Test" (ISWT).[1-3] The ISWT was developed by Léger and Lambert in 1982 for the evaluation of healthy individuals. The same authors adapted it for athletes between 1984 and 1988, using a 20-meter circuit.[6,7] The test consisted of 12 steps of progressive intensity.[6-7] Singh et al finally adapted it for patients with moderate to severe COPD thirty years ago, studying 35 patients with two types of protocols: one with 10 levels and another modified protocol with 12 levels, each lasting one minute.[8] The initial speed is 0.5 m/s, increasing by 0.17 m/s until reaching a maximum of 2.37 m/s on the last level.[8] Two cones, separated by 9 meters, delimit the circuit with 0.5 meters at each end for turning. In summary, a simple audible signal tells the patient that they should be at one end, and a triple signal every completed minute indicates an increase in walking speed. In the first minute or level, the patient completes the circuit three times (3 x 10 m = 30 meters); in the second level, four times (4 x 10 m = 40 meters), and so on. The test is considered complete when the patient informs that they cannot maintain the walking pace for two consecutive sections, being more than 0.5 meters away from the cone, not completing two consecutive sections being more than one meter away from the cone.[1-2]

Rev Am Med Resp 2023;23:293-298
https://doi.org./10.56538/ramr.WZQ3579

Pulmonology and Tisiology Unit, Hospital "Dr. J. M. Ramos Mejia". Autonomous City of Buenos Aires
Pulmonology University Center, "Dr. J. M. Ramos Mejia", Faculty of Medicine, University of Buenos Aires

WHY IS IT SO USEFUL?

The operational characteristics (reproducibility and correlation with other physiological parameters) make it ideal for multiple indications (Table 1). It shows good correlation with the 6-minute walk test (r=0.68), but, more importantly for its everyday clinical application, it has moderate to high correlation with the patient's aerobic capacity (peak oxygen uptake [VO_2p]) (r=0.68-0.88).[8-12] Singh et al studied the correlation between the ISWT and VO_2p in 19 patients with different degrees of COPD (FEV_1 [forced expiratory volume in the first second] of 0.5 to 3.1 L), also observing a high correlation between the two tests (r=0.88).[11] Elias Hernandez et al correlated the ISWT with the VO_2 determined in a maximal test with a cycle ergometer, resulting in a slightly lower correlation (VO_2 in L/min of r=0.71 and VO_2 in ml/kg/min of r=0.68).[12] In our group of 21 patients with severe obstruction, the correlation was high (R^2 = 0.8135, p<0.001).[13] In places where cardiopulmonary tests are not available to assess aerobic capacity, either due to a lack of equipment or high costs, applying the prediction formula basing on the maximum distance walked in the ISWT can predict the patient's VO_2p with high accuracy. The formula we developed is:

$$VO_2 \text{ peak mL/kg/min} = 0.0438 \times \text{ISWT meters} + 0.8569.[13]$$

For distances above 300 meters walked in the ISWT, a VO_2 peak greater than 13 mL/kg/min was always observed. This could be used as a parameter for predicting success in lung resection surgeries of patients with uncertain predictions based on FEV_1 (at the functional resectability limit) and limited access to a cardiopulmonary test for measuring the VO_2 peak.[14]

Another important characteristic is its simplicity in terms of the resources required and the speed at which results can be obtained: it only requires an audio signal, a 10-meter hallway, an oximeter, and a chart for evaluating dyspnea/muscular fatigue on the Borg scale. In addition to heart rate, the variables measured include blood pressure at the beginning and end, and the distance walked when completing the last section before the study is considered complete. The criteria for ending the test were highly variable until standardized by the ATS/ERS, as defined above.[1-2]. There is also a medical criterion, according to which the test may be stopped if oxygen saturation is less than 80 %.[1-2] However, the recommendation does not specify other situations such as angina, loss of stability, altered consciousness, or intermittent claudication, which should also be considered as reasons for stopping the test according to the opinion of this author.[1-2] The reproducibility of the test is very good, and two studies should be conducted, separated by 20 to 30 minutes, with the one covering the greater distance being considered for evaluation.[1-2]

The ISWT predicts the risk of hospitalizations and even mortality in COPD.[1-3] Elías Hernández et al demonstrated high correlation between the meters walked, dyspnea, and heart rate in patients with severe COPD, with high reproducibility.[12] We did not find a significant correlation between the ISWT and different spirometric indices, although there was a trend showing that more meters walked = lower degrees of bronchial obstruction.[13] No significant correlation was observed, either, in the quality of life scale used for chronic respiratory diseases, similar to other authors.[11,13] However, Elías Hernández et al found a significant moderate correlation between the ISWT and parameters of lung function and dyspnea, but not with quality of life.[12]

It has been suggested that the clinically significant minimum difference was 4 sections or 40 meters, and more recently, 35-36 meters.[15-16] Our group has investigated the response of the ISWT to different non-pharmacological interventions (respiratory rehabilitation and non-invasive ventilation).[17-18]

Table 1 highlights its indications, and Table 2 outlines its contraindications. Figure 1 shows a report model from our Hospital Ramos Mejía in CABA.

Revill et al have introduced a variant of the ISWT, known as the Endurance Shuttle Walk

TABLE 1. Indications for the incremental shuttle walking test*

• Assessment of lung resection
• Assessment of surgical emphysema
• Assessment after heart and lung transplant
• Determination of incapacity
• Disproportionate dyspnea and other functional tests
• Indication of training intensity

*Adapted from quotations[1, 2]

TABLE 2. Contraindications to the incremental shuttle walking test*

Absolute	Relative
Acute myocardial infarction (<5 days)	Left coronary artery disease
Unstable angina	Moderate aortic stenosis
Uncontrolled arrhythmia	Systolic arterial hypertension > 200 mmHg
Syncope	Diastolic arterial hypertension > 120 mmHg
Active endocarditis	Tachy-bradyarrhythmias
Acute myocarditis or pericarditis	High-grade atrioventricular block
Severe symptomatic aortic stenosis	Hypertrophic cardiomyopathy
Acute heart failure	Significant pulmonary hypertension
Acute pulmonary embolism	Advanced or complicated pregnancy
Acute thrombosis of lower limbs	Abnormality of the internal environment
Uncontrolled asthma	Orthopedic problems preventing ambulation
Suspected aortic dissection aneurysm	
Acute respiratory failure	
Resting arterial oxygen saturation < 85%	
Thyrotoxicosis	
Acute infection	
Severe acute or chronic renal failure	
Psychiatric illness that does not allow cooperation	

*Adapted from quotations[1,2]

ramosMejía

Laboratorio Pulmonar
Unidad Neumotisiología
Hospital Gral. De Agudos "Dr.J.M.Ramos Mejía"
Prueba de Caminata de Carga Progresiva ("*Shuttle Test*")

Apellido y Nombre: …… N°Historia Clínica: ……..
Sexo: …… Edad: ….. años Peso: ……kg Altura: .cm
BMI: ……..
Fecha: /…/….

Motivo del pedido: ……

Metodología usada

- Task Force of European Respiratory Society (ERS) and American Thoracic Society (ATS) Report: Technical Standard: field walking tests in chronic respiratory disease. *Eur Respir J* 2014; 44:1428-46.
- Probst VS, Hernandes NA, Teixeira DC, et al. Reference values for the incremental shuttle walking test. Respir Med 2012; 106: 243–248

	Borg Disnea	Borg Fatiga	Tensión Arterial	F.Cardíaca	%Saturac. O_2
Reposo					
Final de la Prueba					

Tiempo total de prueba: ……
Recuperación de FC (min): ……
Recuperación de Sat.O2 (min):……..
Recuperación de TA (min): ……..

Niveles completos:……
Metros finales caminados (m):…….. (…….% predicho)
VO_2 predicho (ml/min/kg)……
Informe Final

Figure 1. Test report template.

Test, as an assessment of exercise endurance capacity (a submaximal test at 75 to 95 % of the initial ISWT maximum speed), comparing it with a treadmill.[19] They evaluated 10 patients with severe COPD and found no differences in heart rate and dyspnea responses between both tests.[19] This type of test should be carried out only once.[2] It is a highly reproducible test, very sensitive to changes with therapeutic interventions. Jolly et al assessed COPD patients after an outpatient respiratory rehabilitation program (hospital-based vs home-based), and found greater sensitivity to post-training changes.[17] Martínez Fraga el al also determined significant changes in COPD patients receiving non-invasive ventilatory assistance with pressure support during exercise.[18]

WHY ISN'T IT USED?

With regard to the ISWT, one of the main reasons why the test is not widely used is the lack of training among physicians. Physicians are the ones who should perform this field test, given that it is a maximal exercise test for legal reasons, and therefore may lead to acute cardiovascular or cerebrovascular events, but this is not clarified in the latest regulations.[1-3] Another reason is that the test isn't widely disseminated. It should be proposed on a local and intersocietal level with cardiologists and thoracic surgeons, including local dissemination guides, as it happened with the six-minute walk test.[20-21]

As for the test itself, the circuit is very short for patients who are not functionally incapacitated, and the turn in the same direction can cause dizziness, as minutes pass by. It is essential to always insist on providing adequate training and information before the patient's study, as many patients find it difficult to understand the test's methodology regarding the synchronicity of the pace in reaching each end of the circuit and the different meanings of the audio. In the past, the provision of audio signals was one of the main limiting factors, but nowadays, through the Internet and various applications, it is easier.

Another issue with the test is that it narrowly evaluates physiological variables of exercise and its changes, and it does not evaluate its metabolic response. Therefore, unlike the cardiopulmonary test with expired gas measurement, it does not allow the differentiation of concomitant diseases and their relationship with exercise intolerance.

Another problem is the safety of the test, in the opinion of the author, which is not adequately declared in international regulations. It is stated that "it shows rare complications, and no adverse events have been reported in clinical studies".[2] I suggest doing it with cardiac telemetry to have readings of cardiac electrophysiological changes as the test progresses, as it is a maximal test as would be done in any cardiac ergometry or maximal cardiopulmonary test. Certainly, since it is not properly standardized in the international guideline, if telemetry is not available, it is possible to request prior cardiovascular risk assessment to rule out the occurrence of arrhythmias or unknown coronary artery disease.

Another area that needs to be developed is the investigation of the minimum clinically important difference (MCID), which should be explored in other diseases apart from COPD.[22-29] The ISWT has been studied to assess patients with advanced cancer, pacemakers, chronic heart failure, asthma, cystic fibrosis in adults, interstitial lung diseases, and even in the pediatric population.[22-29] In cardiac patients, this test would be of great value due to its close estimate of the predicted VO_2 max in the context of pre-cardiac transplant evaluation, especially in areas where cardiopulmonary tests aren't easily available.

Another issue is the limited number of tables with normal predictive values. Besides the small number, there is the restricted age range and enrolled ethnicity. There are four tables of Latin subjects (three from Brazil) and one from the United Kingdom.[30-34] And there are two pediatric tables.[30-31] In adults, Probst et al estimated predictive values in 242 subjects between 30 and 60 years from Southern Brazil.[32] The determining factors affecting the prediction of normality are age, gender, and body mass index (BMI), which explain 71 % of the prediction.[32] The other table from Brazil is from the state of São Paulo, which establishes reference values in 131 subjects between 40 and 84 years .[33] The determining factors were age, gender, height, and weight, explaining 50.3 % of the prediction.[33] From the group of Singh in Leicester, United Kingdom, reference values have been determined in 114 subjects aged 40 to 90 years.[34] Age, FEV_1, BMI, maximum voluntary contraction of the quadriceps, and a physical activ-

ity scale explain 50.4 % of the prediction.[34] This author suggests that, until we have more studies with tables of normal values, we should use the predictive table of Probst et al for adults under 40 years, both the Probst et al and the Jürgensen et al tables for individuals between 40 and 60 years, and also the Probst et al and Jürgensen et al tables for subjects above 60 years, as the subjects in these tables are probably closer to the ethnic mix of our country.[32-33]

Regarding the endurance shuttle walk test, it is only used in clinical studies because it is very time-consuming as it requires a prior incremental test, and it is validated in patients with COPD and has very high sensitivity to therapeutic intervention responses.[19] The MCID for this test has been established at 65 to 85 seconds after bronchodilation and 180 seconds post-respiratory rehabilitation.[2]

THE FUTURE OF ISWT

The ISWT is a maximal field exercise test: simple, standardized, and potentially more available in our country than the oxygen consumption test. It allows for the high-reliability assessment of the aerobic capacity of patients with COPD. Further research should be conducted in other diseases. Despite the fact that it has been developed specifically for COPD patients thirty years ago, its daily clinical use is still limited. Areas of research should include having predictive value tables more representative of our population, validating it in other chronic respiratory diseases, and thoroughly studying the safety of the test. In the meantime, it is necessary to disseminate its utility through related Medical Societies, generating documents and dissemination and training activities for the medical community. In a country with limited availability of equipment and high costs of cardiopulmonary tests (oxygen consumption), the ISWT is an ideal tool for evaluating the functional capacity of patients with COPD and other diseases.

Conflict of interest
The author declares having no conflict of interest regarding the writing of this manuscript.

Acknowledgement
The author thanks Dr. Javier Brea Folco for his incentive to write this critical review.

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