



Original Article

Fixed-Altitude Stair-Climbing Test Replacing the Conventional Symptom-Limited Test. A Pilot Study[☆]Nuria M. Novoa,^{*} María Rodríguez, M. Teresa Gómez, Marcelo F. Jiménez, Gonzalo Varela

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ARTICLE INFO

Article history:

Received 14 July 2014

Accepted 15 September 2014

Available online 3 March 2015

Keywords:

Preoperative evaluation

Stair-climbing test

Lung resection

Exercise capacity

ABSTRACT

Introduction: The objective of this study was to investigate whether a patient's maximum capacity is comparable in 2 different stair-climbing tests, allowing the simplest to be used in clinical practice.

Method: Prospective, observational study of repeated measures on 33 consecutive patients scheduled for lung resection. Stair-climbing tests were: the standard test (climb to 27 m) and the alternative fixed-altitude test (climb to 12 m). In both cases, heart rate and oxygen saturation were monitored before and after the test. The power output of stair-climbing for each test (Watt1 for the standard and Watt2 for the fixed-altitude test) was calculated using the following equation: Power (W)=weight (kg)*9.8*height (m)/time (s). Concordance between tests was evaluated using a regression model and the residuals were plotted against Watt1. Finally, power output values were analyzed using a Bland–Altman plot.

Results: Twenty-one male and 12 female patients (mean age 63.2±11.2) completed both tests. Only 12 patients finished the standard test, while all finished the fixed-altitude test. Mean power output values were Watt1: 184.1±65 and Watt2: 214.5±75.1. The coefficient of determination (R^2) in the linear regression was 0.67. No fixed bias was detected after plotting the residuals. The Bland–Altman plot showed that 32 out of 33 values were within 2 standard deviations of the differences between methods.

Conclusions: The results of this study show a reasonable level of concordance between both stair-climbing tests. The standard test can be replaced by the fixed-altitude test up to 12 m.

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La prueba de escaleras limitada por altura podría sustituir a la prueba estándar en la evaluación funcional previa a la resección pulmonar. Estudio piloto

RESUMEN

Introducción: El objetivo de este estudio es conocer si en una prueba de subir escaleras en la que solo se asciende una altura fija de 12 m se desarrolla una potencia similar a la de la prueba estándar, lo que significaría que ambas son equivalentes.

Método: Estudio prospectivo, observacional de medidas repetidas en 33 pacientes consecutivos valorados para resección pulmonar. Prueba estándar: límite de 27 m de altura; prueba altura fija: 12 m. Se monitorizaron saturación de oxígeno y frecuencia cardíaca al inicio y al final del ejercicio y se midió el tiempo de esfuerzo. La potencia desarrollada en cada prueba se calculó (Watt1: estándar y Watt2: altura fija) mediante: Potencia (Watt) = peso (kg)*9.8*altura (m)/tiempo(seg). Para evaluar la equivalencia entre potencias, se construyó un modelo de regresión lineal y se contrastaron gráficamente los residuos. Los valores de las potencias se analizaron mediante el método de Bland y Altman.

Palabras clave:

Evaluación preoperatoria

Prueba de subir escaleras

Resección pulmonar

Capacidad de ejercicio

[☆] Please cite this article as: Novoa NM, Rodríguez M, Gómez MT, Jiménez MF, Varela G. La prueba de escaleras limitada por altura podría sustituir a la prueba estándar en la evaluación funcional previa a la resección pulmonar. Estudio piloto. Arch Bronconeumol. 2015;51:268–272.

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Resultados: Veintiún varones y 12 mujeres realizaron ambas pruebas. Edad media $63,2 \pm 11,2$. Solo 12 pacientes terminaron la prueba estándar. Todos acabaron la prueba de 12 m. Los valores de potencia alcanzados fueron Watt1: $184,1 \pm 65$ y Watt2: $214,5 \pm 75,1$. En la regresión lineal, R^2 fue 0,67. No se encontró ningún sesgo en la distribución gráfica de los residuos. El análisis de Bland y Altman mostró que 32 de los 33 valores de potencia estaban dentro de las 2 desviaciones estándar de las diferencias entre métodos.

Conclusión: Los resultados muestran un nivel razonable de concordancia entre ambas pruebas de subir escaleras por lo que la prueba corta podría sustituir a la estándar.

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Introduction

Predictive models allow patients to be classified according to their surgical risk in lung resection. If the risk is considered excessive, non-surgical treatment of the neoplasm is recommended. According to general consensus, the cardiopulmonary exercise test (CPET) with measurement of oxygen consumption (VO_2), performed in the lung function laboratory, is the most sensitive and specific method for predicting this risk.¹ However, this test is not available in all hospitals, and in those where it is used, a considerable number of candidates may have to forego it due to limited availability and other circumstances.²

The European Respiratory Society and European Society of Thoracic Surgeons (ERS/ESTS) clinical practice guidelines published in 2009³ recommend that patients undergo a low technology screening test prior to prescribing a CPET.^{1,3} This enables clinicians to identify patients with a high VO_2 level despite abnormal lung function tests. The symptom-limited stair-climbing test is one of 2 recommended.^{1,3} This test, however, has its drawbacks, suggesting that a low cost, low technology (compared with CPET) test that is easier to standardize and safer for the patient than the 22 m climb test would be an interesting alternative.

Patients who cannot reach 22 m in the standard stair-climbing test⁴ have been shown to have a higher probability of post-operative cardiopulmonary complications (CPC), as these are patients with deconditioned cardiopulmonary, vascular and muscular systems.⁵

In recent years, 2 groups of investigators have published a variation of the symptom-limited stair-climbing test.^{6–8} Ambrozin et al.⁸ named their variation the *fixed altitude stair-climbing test*. Both groups encouraged the patient to climb to a fixed altitude (12.6 m or 20 m), less than in the symptom-limited test, as fast as they could. The variation lies in that it is the time taken^{6,8} or speed.^{7,9} at which the patient climbs to this altitude that is measured. Both groups found a significant association between the parameters measured and CPC,⁸ and also with the patient's VO_2 .^{7,9} However, none of these studies analyzed the possible relationship between these variations of the stair-climbing test and the test described by Brunelli et al.⁴ and recommended in the latest 2 clinical guidelines published.^{1,3}

The aim of this study was to determine whether a variant of the symptom-limited stair-climbing test, in which the patient is invited to climb to a fixed altitude of 12 m as quickly as possible, generates a power output similar to that of the symptom-limited stair-climbing test (to at least 22 m). This would suggest that both tests are equivalent. If this is the case, the short test could replace the standard test accepted in clinical practice guidelines.

Methods

This was a prospective, repeated-measures observational study conducted in March 2014.

Study Population

We included 33 consecutive patients with any diagnosis who were referred to the thoracic surgery clinic for lung resection assessment. All patients met the minimum operability criteria published previously,¹⁰ agreed to undergo the proposed lung surgery, and had no limitations for climbing stairs due to joint problems or unstable comorbidities. The inclusion of patients with ischemic heart disease in the study was conditional upon previous coronary revascularization or evidence of good functional capacity evidenced by ergometry or an equivalent examination.

All patients signed an informed consent form and the study was authorized by the local ethics committee.

Exercise Tests

All patients performed the 2 stair-climbing tests in the hospital, on the same stairs and accompanied by the same team of doctors. The 2 doctors who accompanied the patient monitored their vital signs and took the appropriate measurements. They were prepared to halt the test if the patient's condition so advised, and to provide medical assistance if required.

The height of the stairs was measured at various levels to determine the real altitude of each flight of stairs, and to accurately determine the altitude reached by the patient in the long test and the point at which the patient had climbed 12 m from a fixed starting point.

Both tests were carried out within 3 weeks of each other. As a rule, the symptom-limited stair-climbing test was done on the day of the assessment in outpatients, while the fixed-altitude test was done on the day of admission prior to the procedure. All patients were weighed before performing the second test to confirm that there had been no changes in their weight between both tests.

Before climbing the stairs, the patient did a 3–5 min leg warm-up on an unloaded cycle ergometer.

Both types of tests ended when the patient stopped at any point on the flight of stairs, the doctor accompanying the patient suspended the test due to the onset of warning signs, or when the stipulated altitude of 12 m or 27 m was reached.

The standard test⁴ consisted of climbing up to 27 m (8 floors), at a steady pace as far as possible, without holding on to the banister except in the case of instability. In the fixed-altitude test, the patient was asked to climb 12 m as quickly as possible. In both tests, the patients were encouraged by the staff accompanying them to keep going.

Variables Collected

Patient demographic variables were recorded: age, sex, weight, height and lung function studies (FVC%, FEV1%, FEV1%/FVC and DLCO%).

The following parameters were recorded during the exercise tests: heart rate and oxygen saturation immediately before

Table 1
Demographic Data for the Patient Population.

Variables	Mean (SD)
Age	63.2 (11.2)
BMI	27.2 (5.8)
FEV1	86.2 (4.5)
FEV1%/FVC	0.68 (0.12)
DLCO adjusted for Hg	77.6 (3.9)

BMI: body mass index.

beginning the ascent and on finishing the test; exact altitude climbed; time taken and reason for not completing the test: dyspnea, claudication of the lower extremities, angina, dizziness, joint pain or other problems.

Using these data, the speed of ascent and power output in each exercise were calculated. The following formula was used for the latter: Power (W)=weight (kg)*9.8* altitude ascended (m)/time taken (s).

Statistical Analysis

First, a linear regression model was developed to determine whether a linear relationship existed between the power output reached in each test. In this model, the power output reached during the 12 m stair-climbing test (Watt2) was considered the dependent variable and the power output reached in the 27 m test (Watt1) the independent variable. In order to detect any possible fixed bias in the measurement of the power outputs, the residuals of this regression were plotted against the Watt1 value in a graph. Finally, a Bland–Altman plot was constructed,¹¹ and Pitman's test was performed to calculate the probability that the differences between the variances of the mean power output values and the values of the 2 power outputs (Watt1 and Watt2) were due to chance. The calculations were performed using Stata 13.

Results

Twenty-one male and 12 female patients completed both tests. Mean patient age was 63.2 years (Table 1).

In the symptom-limited stair-climbing test, 21 patients did not reach the altitude of 27 m; of these, 17 did not reach 22 m, recognized as the limit for classifying the patient as low risk and excluding the need for CPET. Nine patients stopped the test due to dyspnea, 9 due to claudication of the lower extremities, 2 due to joint pain, and 1 due to dizziness and unsteadiness. All patients reached 12 m in the second test. On comparing the data obtained in the 2 tests (Table 2), the heart rate and saturation on finishing the

Table 2
Average Data Obtained From the 2 Stair-climbing Tests.

Variables	27 test mean (SD)	12 m test mean (SD)	Paired t-Test ^a
SpO ₂ at start	93.3 (1.9)	95.5 (1.9)	
SpO ₂ at end	92 (5)	92.6 (4)	0.28
HR at start	86 (15.9)	91.4 (15.4)	
HR at end	127.4 (29.3)	126.3 (24.9)	0.86
% of MHR reached ^b	81.5 (18.4)	80.1 (16.9)	0.8
Altitude ascended (m)	19.8 (5.65)	12	
Time (s)	80.2 (26.5)	43.2 (12.7)	
Speed of ascent (m/s)	0.25 (0.07)	0.29 (0.07)	P<.001
Power (Watt)	184.1 (65)	214.5 (75.1)	

HR: heart rate.

^a All the variables showed a normal distribution.

^b %MHR: percentage of the estimated maximum heart rate reached according to the patient's age.

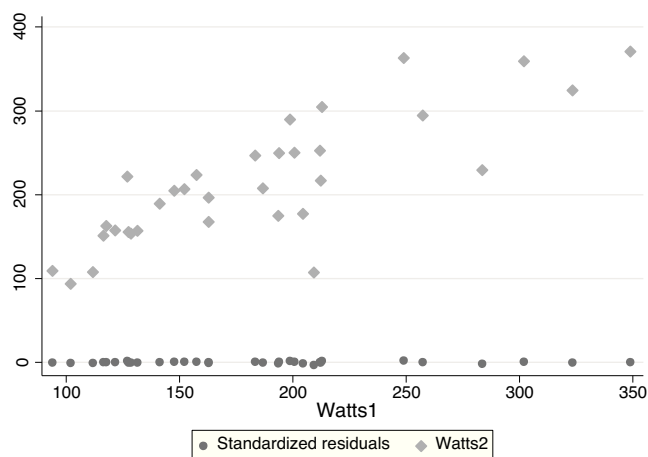


Fig. 1. Scatter plot of power output values calculated in both exercise tests (Watt1: standard 27 m test; Watt 2: short 12 m test; $R^2=0.67$) and standardized residuals plot.

exercise and the percentage increase in the heart rate with respect to the maximum heart rate calculated according to the patient's age were similar.

Fig. 1 shows the graph of the relationship between the 2 power outputs calculated. There is a linear relationship between both variables ($P>.001$) and the model explains to a large extent the variability found in power outputs ($R^2=0.67$). Residual analysis did not detect any specific bias in the measurements (Fig. 1). Finally, the Bland–Altman plot (Fig. 2) showed that 32 out of 33 values were within 2 standard deviations of the difference of the power output values obtained with both tests ($P=.173$).

Discussion

Our results suggest that both tests are reasonably equivalent. This is not only shown by the specific study of power outputs, but by similarities in heart rate on finishing the exercise, percentage variation in heart rate with respect to age during the exercise, and saturation on finishing both types of exercise (Table 2). However, a substantial number of patients were unable to complete the standard test, while all were able to reach 12 m with relative ease.

Despite having been accepted in the latest 2 clinical practice guidelines,^{1,3} the symptom-limited stair-climbing test⁴ as a low technology screening test has been highly criticized, particularly

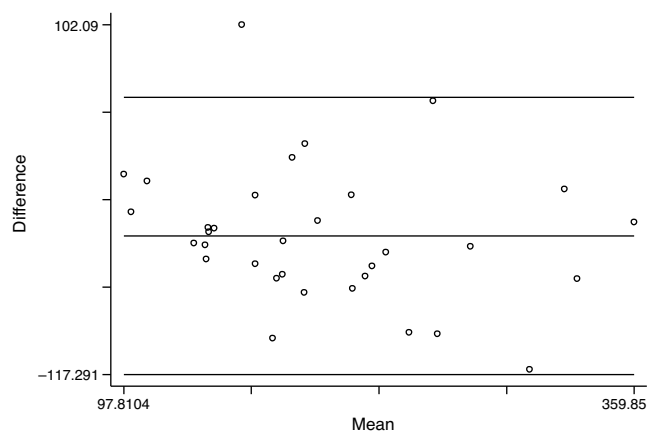


Fig. 2. Bland–Altman plot showing the distribution of the values obtained with this method within 2SD of the differences between the power output values obtained with the 2 methods (Pitman's test $P=.173$).

for its lack of standardization and patient safety. Increasing patient safety during the exercise is difficult, as the test takes place outside a controlled environment. To improve standardization, it must be carried out on a single stairway where the height of the stairs has been carefully measured, and the point at which each key event occurs can be accurately determined: the altitude at which the exercise ends, and the altitude of 22 m, considered as a cutoff point for classification of the patient's surgical risk. These 22 m correspond to approximately 7 floors, although they can vary according to the architectural characteristics of the building.

The physiological rationale for the stair-climbing test is based on the need for the patient to reach a certain level of metabolic stress that somehow mirrors the stress to which they will be subjected during the perioperative period. The level of activity in preoperative studies has been found to be greater than the level required for the intervention.¹² It is estimated that in order to maintain a perioperative VO_2 demand of 5 ml/kg/min, the patient's anaerobic threshold should be above 11 ml/kg/min in normal conditions.¹² In the low technology tests, the degree of activity, or more accurately, the power output reached during the test, gives an estimation of the patient's aerobic capacity, as power output is one of the main factors in the VO_2 calculation.¹³

The recent introduction of alternative stair-climbing tests, published by Brunelli et al.⁴ and accepted in the most recent guidelines, is innovative because of the different relationships between established and analyzed variables. Various groups have studied other versions of the stair-climbing test, reporting that all were able to detect patients with a very high risk of complications,^{14–16} or correlating the altitude reached by the patient with their lung function.^{17,18} Pollock et al.¹⁸ were the first to correlate the climbing test with the patient's VO_2 . In their test, however, patients climbed at their own pace, without being encouraged to keep up the effort. Brunelli et al. modified that aspect by inviting patients to climb at a faster, less comfortable pace than they would have used in a normal situation, and to maintain this speed. This meant that patients climbed to a much higher altitude than that recorded in previous studies. Developing a shorter test but encouraging the patient as they climbed, Cataneo and Cataneo found that the time taken to climb to 12.16 m maintained a good correlation ($R^2=0.7$) with the patient's VO_2 measured in the standardized laboratory test.⁶ In a later study, Ambrozin et al.⁸ found significant differences between mean time and mean power output reached by patients with CPC with respect patients with no CPC in the postoperative period following lung resection. This study showed that the prevalence of CPC was directly proportional to the time needed to make the ascent: they recorded 14% CPC in those who took less than 30 s and 60% in those who needed more than 50 s. The South African group, meanwhile, found speed of ascent to be the parameter that predicted CPC.^{7,9} This speed had a high correlation with the VO_2 measured in the laboratory test ($R^2=0.67$), and they concluded that a patient capable of climbing at a speed of 15 m/min had an estimated VO_2 of at least 20 ml/kg/min and could therefore even tolerate a pneumonectomy without the need for further studies.⁷

A stair-climb of only 12 m is consistent with the findings of various investigators^{4,6,15} that have shown that ascending to an altitude of 12–14 m (approximately 3 floors) was sufficient to identify patients with a low risk of suffering postoperative complications despite having abnormal lung function tests. Furthermore, this altitude of 3 floors is very tolerable when compared with the altitude used in the standard test (at least 7 floors). It also enables patients who are least fit but with an acceptable VO_2 level to climb without stopping. Our experience with the standard test has shown that a significant number of

patients sent for CPET because they did not reach the critical altitude of 22 m have a good VO_2 level, but performed poorly because they were unused to physical exercise (unpublished data).

This study has some limitations. Firstly, it is a pilot study, so the results have yet to be confirmed in a larger population and validated by other investigators. Additionally, all the patients included had already been selected for surgery in other centers in accordance with some consensual criteria. This limitation is very difficult to overcome, and is inherent to all surgical departments. Finally, it is important to note that during the first visit, patients learn breathing exercises and are encouraged to increase their daily of physical exercise.¹⁹ This could suggest that the 2 tests were performed in different conditions.

In conclusion, the data suggest that the 2 stair-climbing tests are reasonably equivalent, and therefore the 12 m fixed-altitude test can be used instead of the symptom-limited stair-climbing test in the preoperative evaluation of patients referred for lung resection assessment. The cutoff point for evaluating the surgical risk has yet to be determined.

Conflict of Interests

The authors declare that they do not have any conflict of interests that could cause any bias in this study.

References

- Brunelli A, Kim AW, Berger KI, Addrizzo-Harris DJ. Physiologic evaluation of the patient with lung cancer being considered for resectional surgery: diagnosis and management of lung cancer, 3rd ed.: American College of Chest Physicians evidence-based clinical practice guidelines. *Chest*. 2013;143:e166S–90S.
- Novoa NM, Ramos J, Jiménez MF, Gonzalez-Ruiz JM, Varela G. Primera fase de validación del algoritmo europeo de evaluación funcional previa a la resección pulmonar, cuantificación del cumplimiento de las recomendaciones en la práctica clínica real. *Arch Bronconeumol*. 2012;48:229–33.
- Brunelli A, Charloux A, Bolliger CT, Rocco G, Sculier JP, Varela G, et al., European Respiratory Society and European Society of Thoracic Surgeons Joint Task Force on Fitness for Radical Therapy. ERS/ESTS clinical guidelines on fitness for radical therapy in lung cancer patients (surgery and chemo-radiotherapy). *Eur Respir J*. 2009;34:17–41.
- Brunelli A, Al Refai M, Monteverde M, Borri A, Salati M, Fianchini A. Stair climbing test predicts cardiopulmonary complications after lung resection. *Chest*. 2002;12:1106–10.
- Brunelli A, Sabbatini A, Xiumé F, Borri A, Salati M, Marasco RD, et al. Inability to perform maximal stair climbing test before lung resection: a propensity score analysis on early outcome. *Eur J Cardiothorac Surg*. 2005;27:367–72.
- Cataneo DC, Cataneo AJM. Accuracy of the stair-climbing test using maximal oxygen uptake as the gold standard. *J Bras Pneumol*. 2007;33:128–33.
- Koegelenberg CFN, Diacon AH, Irani S, Bolliger CT. Stair climbing in the functional assessment of lung resection candidates. *Respiration*. 2008;75:374–9.
- Ambrozin ARP, Cataneo DC, Arruda KA, Cataneo AJM. Time in the stair-climbing test as a predictor of thoracotomy postoperative complications. *J Thorac Cardiovasc Surg*. 2013;145:1093–7.
- Bernasconi M, Koegelenberg CFN, von Groote-Bidlingmaier F, Maree D, Barnard J, Diacon AH, et al. Speed of ascent during stair climbing identifies operable lung resection candidates. *Respiration*. 2012;84:117–22.
- Varela G, Cordovilla R, Jimenez MF, Novoa N. Utility of standardized exercise oximetry to predict cardiopulmonary morbidity after lung resection. *Eur J Cardiothorac Surg*. 2001;19:351–4.
- Bland JM, Altman DG. Comparing methods of measurement: why plotting difference against standard method is misleading. *Lancet*. 1995;346:1085–7.
- Biccard BM. Relationship between the inability to climb two flights of stairs and outcome after major non-cardiac surgery: implications for the preoperative assessment of functional capacity. *Anaesthesia*. 2005;60:588–93.
- Olsen GN. The evolving role of exercise testing prior to lung resection. *Chest*. 1989;95:218–25.
- Gaensler EA, Cugell DW, Lindgren I, Verstraeten JM, Smith SS, Strieder JW. The role of pulmonary insufficiency in mortality and invalidism following surgery for pulmonary tuberculosis. *J Thorac Surg*. 1955;29:163–87.
- Olsen GN, Bolton JW, Weiman DS, horning CA. Stair climbing as an exercise test to predict the postoperative complications of lung resection: two years experience. *Chest*. 1991;99:587–90.

16. Pate P, Tenholder MF, Griffin JP, Eastridge CE, Weiman DS. Preoperative assessment of the high-risk patient for lung resection. *Ann Thorac Surg.* 1996;61:1494–500.
17. Bolton JW, Weiman DS, Haynes JL, Hornung CA, Olsen GN, Almond CH. Stair climbing as an indicator of pulmonary function. *Chest.* 1987;92:783–8.
18. Pollock M, Roa J, Benditt J, Celli B. Estimation of ventilatory reserve by stair climbing: a study in patients with chronic airflow obstruction. *Chest.* 1993;104:1378–83.
19. Varela G, Novoa NM, Agostini P, Ballesteros E. Chest physiotherapy in lung resection patients: state of the art. *Semin Thorac Surg.* 2011;23:297–306.