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# Six-minute stepper test to assess effort intolerance in interstitial lung diseases

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**Abstract.** The six-minute stepper test (6MST) is a new test for evaluating exercise tolerance. Unlike the six-minute walk test (6MWT) it can be carried out in a limited space. The aim of this study was to compare the 6MST and the 6MWT in patients with various diffuse interstitial lung disease (ILD). 6MWT and 6MST were performed the same day in 84 patients with various ILD. The covered distance during 6MWT was compared to the number of steps during the 6MST. We also compared heart rate, oxygen saturation, dyspnoea and leg tiredness on a Borg scale. All the patients successfully completed the tests, and tolerance was considered good. The number of steps completed in the 6MST was strongly correlated with the distance walked in the 6MWT ($r^2$=0.5; p<0.0001). Oxygen desaturation was less frequent and less severe (p<0.0001), heart rate was higher (p<0.0001) and dyspnoea and leg tiredness were more marked (p<0.0001) in the 6MST than in the 6MWT. The 6MST is feasible for patients with ILD. It is a simple, safe, mobile test that is cheap and easy to carry out in all structures. *(Sarcoidosis Vasc Diffuse Lung Dis 2012; 29: 107-112)*

**Key words:** diffuse interstitial lung disease, walk test, exercise, pulmonary fibrosis

## Introduction

Interstitial lung diseases (ILD) include a series of chronic diseases characterized by thickening of conjunctive structures of the lung associated with possible damage to the alveolar and bronchiolar spaces, which are heterogeneous in their aetiology (1).

Pulmonary function tests provide precise information about the impact of ILD at rest. However, the severity of gaseous exchange abnormalities is best evaluated during exercise. Exercise tests have been validated to evaluate the functional consequences of ILD (2-4). In particular, the six-minute walk test (6MWT), updated in 2002 (5), is a well characterized, easy to use, and validated test in the field. However, the 6MWT frequently demonstrates oxygen desaturation on exercise in patients with ILD (4, 3).

The 6MWT is easy to use, but some studies performed in healthy subjects have observed differences in the covered distance. Speed of usual walking and cultural aspects related to lifestyle, mood, attitude and motivation of the subject are possible reasons for these variations (6). In addition, 6MWT, to be performed in optimal conditions, has the drawback of requiring a corridor at least 30 m long. Smaller length may result in misleading results due to a high number of turns. Indeed, increasing the number of turns results in a loss of energy, leading to a decrease

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in the covered distance (5). The stepper is an exercise device simple of use, that takes up little space. It is designed to reproduce the physical effort of climbing stairs. This test can be carried out on the spot, and has no spatial constraints. The reproducibility and sensitivity of the six-minute stepper test (6MST) have recently been demonstrated in patients with chronic obstructive pulmonary disease (COPD) (7). Recently, Dal Corso et al reported that a 6-min step test provided reliable and reproductible estimates of exercise capacity in ILD but did not compare this test with 6MWT (8). Therefore the aim of this study was to compare the 6MST and the 6MWT in a large cohort of patients with various ILD.

## Materials and methods

In this prospective study, 84 consecutive patients with various ILD were recruited from the ILD outpatient unit of the hospital.

Clinical and functional stability was confirmed by the absence of change in medication dosage and forced vital capacity (FVC) values (±5%) in the preceding 3 months. Inclusion criteria were as follows: 1) presence of diffuse interstitial infiltrate on high-resolution computed tomography; 2) decreased single-breath diffusing capacity of the lung for carbon monoxide ($D_{L,CO}$); 3) resting arterial oxygen saturation measured by pulse oximetry ($S_{p,O2}$; (Novametrix®) ≥90% in room air and 4) 6MWT and 6MST in the normal atmospheric air, carried out on the same day. None of the subjects were receiving long-term oxygen therapy. Patients with severe and/or uncontrolled arterial hypertension, recent coronary disease or stroke, severe arteritis of the legs, orthopaedic disease with functional impairment limiting exercise were excluded.

A written document explaining the principle and aim of the 6MST was given to the patients, and written informed consent was obtained. The Research Protocol Evaluation Committee of the Society of French-Speaking Pneumology approved this study (CEPR 2008-004).

### Study design

We first studied respiratory function at rest. Dyspnea during daily life activities was assessed at the time of evaluation with the modified MRC (Medical Research Council) dyspnoea scale self-administered questionnaire consisting of 6 questions about perceived breathlessness from 0 (no dyspnea) to 5 (very severe dyspnea: too breathless to leave the house or breathless when dressing or undressing). After a resting period (1 h), patients performed either 6MWT or 6MST and after 1 h, the other test was performed.

### Measurements

*Pulmonary function tests*

Forced expiratory volume in 1 second ($FEV_1$), FVC, $FEV_1$ to FVC ratio, total lung capacity (TLC), and functional residual capacity (FRC) were measured by plethysmography with a Jaeger-Masterlab® cabin. Diffusing capacity of the lung for carbon monoxide (DLCO: $mlCO.min^{-1}.mmHg^{-1}$), after adjusting for hemoglobin concentration in $g.dl^{-1}$, according to Cotes' equation: corrected (Hb) DLCO = DLCO x (10.2 + Hb)/(1.7 x Hb). Predicted normal values were derived from standard equations (9).

*Six-minute walk test*

The 6MWT was carried out, under the supervision of trained nurses, in the ILD unit, in a 30 m-long corridor with distance markers at regular 5 m intervals. This test was systematically carried out in normal atmospheric air after five minutes of rest in a sitting position. We measured transcutaneous oxygen saturation ($S_{p,O2}$) and heart rate continuously, with a pulse oximeter (Novametrix®). The patient was not given encouragement during the test. At the end of the exercise, the nurse noted the total distance covered in metres, dyspnoea and leg tiredness according to the Borg scale [6]. The data were then analysed with Novacard® software and presented as saturation curves and heart rates, with minima, maxima and means. Desaturation was defined as an oxygen saturation during exercise at least 4% lower than that at rest.

*Six-minute stepper test*

We used a stair-stepper apparatus (Go Sport ®) for this test. The Stepper is an exercise apparatus

(commonly used in exercise gymnasiums) with a uniform stepping height and uniform resistance to stepping. It mimics stair-climbing while exercising. This stepper is equipped with two articulated foot plates. The movement is synchronised by a central gear lever. The effort developed is triggered by a jack under each foot plate. A sensor was used to determine the number of steps taken by the patient. The test was supervised by the same observer in each case, in a calm area. The stepper was positioned to face the wall, at a distance adapted for each patient. After five minutes of rest, the patients mounted the stepper in a standing position, supporting themselves by light pressure of the fingertips against the wall at shoulder height. One of the foot plates was at its highest position, the other at its lowest. A preliminary test was carried out over a period of two minutes, to allow the patient to become familiar with the apparatus. During the stepper test, arterial oxygen saturation and heart rate were continuously measured with the aid of a pulse oximeter. The data were analysed with a computer and saturation curves and heart rate curves were obtained, with minimal, maximal and mean values. At the end of the exercise test, we recorded the number of steps completed by the patient in six minutes, dyspnoea and leg tiredness on the Borg scale (10).

The patients were given the same instructions for the two tests, and these instructions were read to the patients in a standardised manner (7).

### Statistical analysis

The data were analysed with SAS (SAS Institute, Cary, N.C. 25513; version 9.1) and Statview version 4 software. Values of $p<0.05$ were considered statistically significant. The results are expressed as means ± standard error (SEM) for quantitative variables and as percentages for qualitative variables. We used the MacNeymar test to compare qualitative variables (occurrence of desaturation during the stepper and walk tests). Quantitative variables were compared in Student's t tests. Correlations between quantitative variables were evaluated with Pearson's correlation test. Saturation was compared between groups of patients for each test, with the aid of non-parametric Kruskall-Wallis and Mann-Whitney tests.

## Results

In this study, 84 patients with various ILD were recruited: 21 patients with idiopathic pulmonary fibrosis (IPF) according to the criteria from the American Thoracic Society/European Respiratory Society (11); 19 with idiopathic non specific interstitial pneumonia (NSIP) and 15 with biopsy-proven pulmonary sarcoidosis. The remaining 29 patients presented various ILD as shown in table 1. The clinical characteristics of these patients are summarised in table 2. There were 56 men and 28 women, aged 56±1.5 years, mostly of Caucasian origin (85%). Twenty-one of the patients were on heart rate-lowering treatment.

The patients presented mild restrictive ventilation problems, with major DLCO abnormalities (table II). The patients did not display hypoxaemia at rest ($PaO_2$: 87±2 mmHg) and their haemoglobin levels were normal (14.7±2 g/dl).

### *The six-minute stepper test*

All the patients successfully completed the 6MST, with 47 patients (56%) presenting oxygen desaturation at the end of the test. Six patients stopped at least once during the test, due to strong dyspnoea (n=6) associated with leg pain (n=4). The mean number of steps taken in six minutes was 543±15 [302-984]. The mean lowest oxygen saturation level during the 6MST was 91±0.5% [75-97]. Maximum heart rate was 130±2 beats per minute

**Table 1.** Etiologies of interstitial lung disease

| Etiology of ILD | Number of patients |
|---|---|
| Idiopathic pulmonary fibrosis | 21 |
| Idiopathic Non-specific interstitial pneumonia | 19 |
| Sarcoidosis | 15 |
| ILD associated with connective tissue disease | 7 |
| Hypersensitivity pneumonitis | 5 |
| Langerhans' cell histiocytosis | 4 |
| Alveolar proteinosis | 2 |
| Silicosis | 3 |
| Drug-induced ILD | 2 |
| Desquamating ILD | 2 |
| Lymphangioleiomyomatosis | 1 |
| AL amyloidosis | 1 |
| Diffuse alveolar haemorrhage | 1 |
| ILD of undetermined origin | 1 |

ILD: insterstitial lung disease

**Table 2.** Clinical and functional characteristics of the 84 patients

| Clinical and functional characteristics | |
|---|---|
| Sex (M/F) | 56/28 |
| Age (years) | 56±1.5 |
| BMI (Kg/m²) | 27.6±0.6 |
| Smoking status | |
| Non-smoker | 28 (33%) |
| Former smoker | 50 (60%) |
| Current smoker | 6 (7%) |
| Dyspnoea (MRC dyspnoea scale) | |
| MRC 1-2 | 58 (69%) |
| MRC 3-4 | 22 (26%) |
| MRC 5 | 4 (5%) |
| Resting pulmonary function | |
| TLC * | 84±2 |
| DLCO * | 51±2 |
| FEV1 * | 77±2 |
| FVC * | 82±2 |
| FEV1/FVC (%) | 76±0.7 |

BMI: body mass index; MRC: Medical Research Council dyspnoea scale; TLC: total lung capacity; DLCO: diffusion capacity of carbon monoxide; $FEV_1$: forced expiratory volume in one second; FVC: forced vital capacity.
* Values expressed as a percentage of predicted values.

[78-169]. Mean dypsnoea and leg tiredness values were 4.5±0.2 [0.5-10] and 3.7±0.3 [0-10], respectively, on the Borg scale. Results in 3 groups of patients did not show significant difference (Tab. 3).

*The six-minute walk test*

The 84 patients studied carried out the 6MWT. One patient stopped during the test, due to pain in the legs. Sixty patients (76%) presented oxygen desaturation during the 6MWT. We were unable to evaluate the data for one patient, due to a loss of the saturation signal at the end of the test. The mean distance covered in six minutes was 440±9 meters [260-610], corresponding to 79% of the predicted value (12) Mean lowest saturation during the 6MWT was 89±0.6% [72-97]. Mean maximum heart rate was 116±2 beats per minute [76-154]. Dyspnoea and leg tiredness at the end of the 6MWT were 3±0.2 [0-10] and 1±0.2 [0-10], respectively, on the Borg scale. There was no significant difference in the covered distance in 3 groups of patients (Tab. 3)

**Table 3.** Results of 6MWT (expressed in meters) and 6MST (expressed in steps) in patients with idiopathic pulmonary fibrosis (IPF), non specific idiopathic pneumonitis (NSIP) and sarcoidosis

| | 6MWT (distance) | 6MST (steps) |
|---|---|---|
| IPF | 450 ± 76 | 543 ± 122 |
| NSIP | 435 ± 72 | 544 ± 119 |
| Sarcoidosis | 460 ± 89 | 587 ± 179 |

*Correlations between the results of the 6MWT and the 6MST*

The number of steps achieved in the 6MST was strongly correlated with the distance covered in the 6MWT (r=0.7; $r^2$=0.5; p<0.0001; figure 1). The correlation between the distance and the number of steps was also observed in the groups of patient with IPF ($r^2$=0.5; p=0.0006), NSIP ($r^2$=0.3; p=0.0085) and sarcoidosis ($r^2$= 0.6; p=0.0015). Oxygen desaturation was less frequent and less severe (p<0.0001), heart rate was higher (p<0.0001) and dyspnoea and leg tiredness were more marked (p<0.0001) in the 6MST than in the 6MWT. The number of steps was correlated with age ($r^2$=0.1; p=0.0061), height ($r^2$=0.2; p=0.0001), $PaO_2$ ($r^2$=0.25; p=0.0002) and DLCO ($r^2$=0.1 p=0.0065). By contrast, the number of steps was not correlated with the patient's weight ($r^2$=0,001; p=0.74) or BMI ($r^2$=0.04; p=0,07).

*Changes in heart rate and oxygen saturation during the tests*

Oxygen desaturation generally occurred during the first two minutes of exercise. It was significantly more marked during the 6MWT than during the

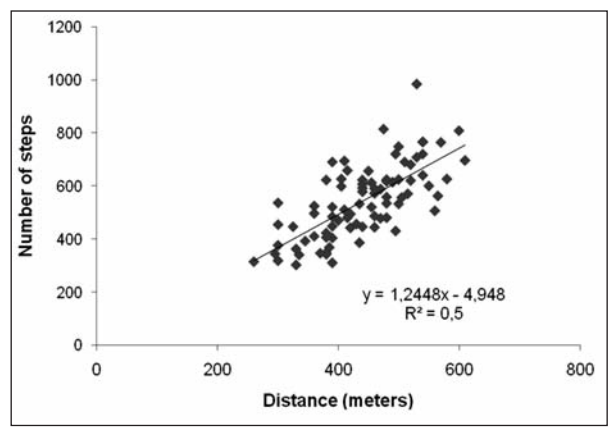


**Fig. 1.** Correlation between distance covered in the 6MWT and number of steps completed in the 6MST ($r^2$=0.5 ; p<0.0001)

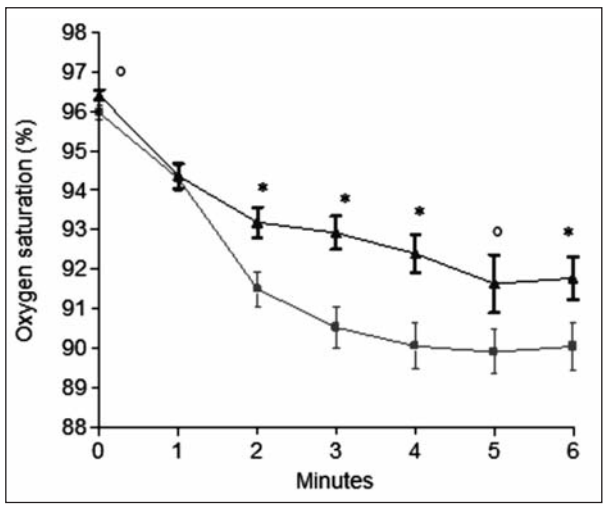


**Fig. 2.** Changes in oxygen saturation during the 6MWT and the 6MST. ● six-minute walk test; ▲ six-minute stepper test; * p<0.0001; ○ p<0.01

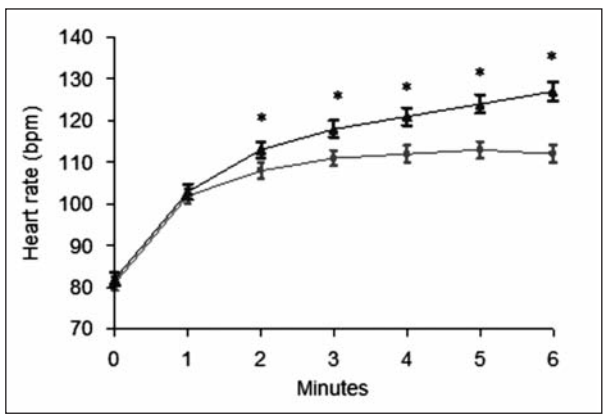


**Fig. 3.** Changes in heart rate during the 6MWT and the 6MST. ● six-minute walk test; ▲ six-minute stepper test; * p<0.001

6MST (Fig. 2). Sixteen patients (19%) presented desaturation only during the 6MWT. Heart rate was significantly higher during the 6MST, beginning to increase from the second minute of exercise. During the 6MWT, heart rate stabilised towards the third minute, whereas heart rate continued to increase steadily throughout the 6MST (Fig. 3).

## Discussion

This prospective study demonstrates the feasibility of the 6MST for patients with ILD and the close correlation between the distance covered in the 6MWT and the number of steps in the 6MST. Desaturation was less frequent and less severe in the 6MST than in the 6MWT, whereas heart rate, dyspnoea and leg tiredness were greater in the 6MST than in the 6MWT.

The 6MWT is a non-invasive, inexpensive and simple test to carry out, understand and interpret. Despite these advantages, some variability in the results obtained may be observed. A questionnaire-based analysis of 71 respiratory rehabilitation programmes highlighted a lack of standardisation in walk tests (13). The factors identified as associated with variability in the results obtained were environment (inappropriate corridor), a learning effect and encouragement from the examiner or the examiner's behaviour (14).

The stepper is a small piece of equipment, taking up little space and easily obtainable from sports shops, at a price of 29 to 100 Euros, according to the model chosen (the model used in this study costs €45). It is portable (it weighs only 7.5 kg). The necessary configuration of the site for carrying out the 6MST is less complex than that for the 6MWT: the stepper is positioned face to a wall. The test could, for example, be carried out in the patient's hospital room, in a doctor's surgery or consultation rooms.

Few studies have evaluated the 6MST. Ninan et al. showed that this test could be used to predict morbidity and mortality in patients due to undergo thoracic surgery of the pneumectomy type (15). The occurrence of desaturation in this previous study was found to be predictive of a longer stay in intensive care and higher rates of morbidity. Borel et al. showed that the 6MST was a simple and reproducible tool for evaluating exercise tolerance in COPD patients (7). They also demonstrated the sensitivity of this test, through comparisons of the performances of a healthy population and a population of patients with COPD. A "step test" has been previously assessed in patients with ILD (8). Thirty-one patients with idiopathic pulmonary fibrosis or chronic forms of lung hypersensitivity took part in two six-minute step tests and a cardiorespiratory test on an exercise bicycle. The authors concluded that this step test was reproducible and reliable for this population. The results of this previous study are not directly comparable with the results reported here for the 6MST. Indeed, the effort developed during the step test is different from that developed in the

6MST, involving a greater displacement of the muscle mass and possible balance problems.

More than half the patients presented desaturation during both the 6MWT and the 6MST, but this desaturation was significantly less marked during the 6MST. Oxygen desaturation was also less frequent during the 6MST. The 6MWT therefore appears to be more sensitive than the 6MST for the detection of oxygen desaturation on exercise. Similar findings have also been reported by Poulain et al. comparing exercise desaturation during a 6MWT and during an exercise test on an exercise bicycle in 80 patients with COPD (16). These authors found that 23 patients (28%) presented desaturation only during the 6MWT. This phenomenon was reproducible, but the underlying mechanisms remain unknown. One hypothesis was that COPD patients exhibited higher ventilatory responses during cycle exercise, responsible for higher PAO2minimizing the decrease in SpO2 (17).

Along this line, in our series, the increase in heart rate was greater during the 6MST. Indeed 8 patients reached their theoretical maximum heart rate during the 6MST. Therefore one can rise the hypothesis that VO2 was higher during 6MST responsible for higher vevntilatory response, higher PAO2, and thus higher $S_{p,}O2$. In other words, oxygen consumption and hyperventilation may be greater during the 6MST than during the 6MWT. A study including measurements of gaseous exchange during the 6MST and the 6MWT would be required to confirm this hypothesis.

We did not assess the sensitivity and reproducibility of the 6MST, and this may be considered a limitation of our study. The sensitivity and reproducibility of the 6MST were demonstrated by Borel et al., for a population of patients with COPD (7) and reproducibility of step test has been demonstrated by Dal Corso for patients with ILD (8) .

## Conclusion

This prospective study demonstrates the feasibility of the 6MST in patients with ILD. The 6MST is a safe test that can be used in routine practice, is simple to understand and to carry out, portable and inexpensive. It can easily be carried out in all structures, especially for patient evaluation in primary care. The 6MST also constitutes a suitable alternative to the 6MWT to assess effort intolerance when the 6MWT cannot be carried out in appropriate conditions. Lastly 6MST might useful to evaluate the beneficial effects of home-based respiratory rehabilitation (18).

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