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Six minute walking distance in healthy elderly subjects

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ABSTRACT: The six minute walking distance (6MWD) test is a commonly used test to estimate functional exercise capacity in patients with chronic diseases including chronic obstructive lung disease. Surprisingly, no attempt has been made to establish normal values for the 6MWD. The aim of this study, therefore, was to evaluate the 6MWD in healthy elderly volunteers and to evaluate its determining factors.

Fifty-one healthy subjects aged 50–85 yrs volunteered to participate in the trial. All subjects were free of diseases that could interfere with performance in a walking test. Tests were performed in a quiet 50-m long hospital corridor. Patients were encouraged every 30 s to continue walking as quickly as possible.

Walking distance averaged 631±93 m and was 84 m greater in the male compared to female subjects (p<0.001). The 6MWD showed significant correlations with age (r=-0.51, p<0.01) and height (r=0.54, p<0.01). Stepwise multiple regression analysis showed that age, height, sex and weight were independent contributors to the 6MWD in healthy subjects, thus explaining 66% of the variability.

It is concluded that the six minute walking distance can be predicted adequately using a clinically useful model in healthy elderly subjects. Its variability is explained largely by age, sex, height and weight. Results of the six minute walking distance may be interpreted more adequately if expressed as a percentage of the predicted value.
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Assessment of functional exercise capacity has gained importance in the evaluation of patients in various diseased states. Timed walking tests are widely used to evaluate functional exercise performance, as they are likely to measure the ability to undertake the activities of day-to-day life [1]. In patients with chronic obstructive pulmonary disease (COPD), the 12 minute walking test was introduced by McGavin *et al.* [2] in 1976 to evaluate disability. Subsequently, the six minute walking distance (6MWD) test was proposed and has been accepted as a reliable test to measure functional exercise capacity [3]. It has been used extensively in research into heart and lung diseases. Guyatt *et al.* [4] described the 6MWD test as a simple, inexpensive and safe test. A literature search using the Medline database revealed 72 papers in which the 6MWD was used in various diseases, either to estimate functional performance and exercise capacity or to evaluate treatment efficacy.

Surprisingly, until now, no attempt has been made to relate the 6MWD to the performance of healthy subjects, which complicates data interpretation. On an empirical basis, Redelmeier *et al.* [5] suggested 700 m to be a normal 6MWD, but they did not specify whether this applies for all ages. Neither is there any information on which factors may account for variability in healthy elderly subjects.

The aim of the present study was to investigate whether variables known to affect exercise capacity such as age and sex, as well as anthropometric variables influence performance in a 6MWD test in healthy elderly subjects. Furthermore, it was the intention to predict walking distance in such subjects in order to improve the interpretation of the data obtained from the 6MWD test for an individual patient.

Methods

Healthy subjects

Fifty-three healthy subjects who volunteered to participate were recruited by the investigators from relatives of students at their faculty. Subjects were aged 50–85 yrs, were free from injury and had no history of hospitalization or chronic disease influencing their exercise capacity. Subjects were sedentary and not involved in any competitive sport. All gave written informed consent. Tests were performed between 09:00 and 13:00 h. All participants were screened by an investigator with whom the subjects were not familiar.

Screening

After obtaining informed consent, a health status questionnaire was completed by all subjects to ensure good health; medication, smoking habits and physical activities of the subjects were also recorded. Height and body weight were recorded, and the body mass index (BMI) was calculated as BMI=weight/height^2 (expressed in kg·m^{-2}). Spirometry was performed using a heated pneumotachograph (Partn′ air Medisoft, Dinant, Belgium) to determine forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) following the European Respiratory Society guidelines for spirometry [6]. The results were referred to the predicted values as reported by QUANJER *et al.* [6]. If the FEV_1 or FVC was <80% of the predicted value, patients were excluded from further study and eventually referred to a pulmonologist. Peripheral and respiratory muscle strength were measured. Knee extension torque was assessed by the best of three maximal isometric voluntary contractions (Cybex II; Lumex, Bay Shore, NY, USA) and related to normal values obtained previously in the authors′ laboratory [7]. Results of handgrip strength were related to the normal values of MATTHIOWETZ *et al.* [8]. Respiratory muscle strength was measured using the technique described by BLACK and HYATT [9]. Inspiratory muscle pressure ($P_{I,max}$) was measured from residual volume, and expiratory muscle pressure ($P_{E,max}$) was measured from total lung capacity. The results obtained in both tests were referred to the normal values of ROCHESTER and ARORA [10]. The techniques to measure respiratory and peripheral muscle strength have been described in detail elsewhere [7].

Functional exercise test

A 6MWD test was performed twice with ~2.5 h between the two tests. Subjects were asked to walk at their own maximal pace along a 50-m long hospital corridor. Subjects were asked to walk from end to end, covering as much ground as they could during the allotted time, without running. Encouragement was standardized [4]. Every 30 s, subjects were given feedback on time progression and were encouraged to keep on walking as fast as possible. During the test, oxygen saturation and heart rate were measured by transcutaneous pulse oximetry (Nonin 8500; Nonin Medical, Inc., Minneapolis, MN, USA). The protocol stated that the testing was to be interrupted if threatening symptoms appeared. The subjects were told that they could rest if they were too exhausted to continue the test. No test had to be interrupted. The distance covered in 6 min and the heart rate at the end of the test were recorded for analysis. The maximum predicted heart rate for each patient was calculated as 220 minus the patients′ age. The test was repeated with equal encouragement, and the best of the two tests was used for further analysis. GUYATT *et al.* [4] showed that when encouragement was unaltered, the 6MWD did not improve significantly after the second walking test. Using a similar encouragement strategy, the authors have previously shown in 27 patients with COPD (unpublished data) that a third walk after two practice walks did not result in further improvement (10±41 m, p=0.22). Hence, the use of only one practice walk in well motivated subjects was believed to be valid.

Statistical analysis

All statistical analyses were performed using the SAS package (SAS Institute, Cary, NC, USA). Data were checked for distribution, and the means±SD were calculated. Differences between males and females were analysed using a two tailed t-test. Pearson single correlation coefficients were calculated and a stepwise multiple regression analysis was used to evaluate independent variables explaining the variance in the 6MWD.

Results

Twenty-three female and 30 male subjects were screened. Two subjects were withdrawn, one male because of obvious obstructive pulmonary disease (FEV_1 50% pred, FEV_1/FVC ratio of 57%, with a smoking history of 15 pack-yrs and a clinical history of bronchial hyperresponsiveness), and one female patient because of morbid obesity (BMI >35 $kg \cdot m^{-2}$). Patient characteristics are summarized in table 1. The age of the subjects ranged 50–85 yrs. Muscle strength and pulmonary function were well within normal limits for all subjects. Twenty-nine subjects had never smoked, the average number of pack-years for all subjects was 13. All data, except smoking history expressed in pack-yrs, were found to be distributed normally.

On average, subjects walked 631±93 m. Substantial variability in the 6MWD was present in these healthy subjects, with a range 383–820 m. The 6MWD was 84 m greater in male subjects when compared to female subjects (fig. 1). The second test was on average 8±5% better than the first test (p<0.001). Heart rate obtained during this second test was 8±16 $beats \cdot min^{-1}$ higher than during the first test (p<0.01). The mean walking distances of the first and second tests were, respectively, 574±97 and 621±86 m. The first test was the better in eight (15%) patients. During the better test, patients reached 77±15% of their maximal predicted heart rate. Oxygen saturation remained unaltered throughout both tests. Single correlation coefficients with 6MWD are presented in table 2. Significant correlations with height, quadriceps strength and age were observed. The 6MWD was not related to the scores on the daily activities questionnaire nor to the subjects′ smoking habits. In the stepwise multiple regression analysis, age, height, weight and sex were retained, and the model explained 66% of the variability in 6MWD. Parameter estimates, partial r^2 and significance of the model are shown in table 3. Figure 2 shows the relationship (r=0.81, p<0.001) between the actual walking distance and the predicted walking distance.

Table 1. – Characteristics of the study subjects

	Mean±SD
Sex M/F	29/22
Age yrs	65±10
Height cm	167±8
Weight kg	73±14
BMI $kg \cdot m^{-2}$	26±5
FEV_1 % pred	109±16
FVC % pred	117±16
QF % pred	118±32
$P_{I,max}$ % pred	115±24
6MWD m	631±93

M: male; F: female; BMI: body mass index; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; QF: quadriceps force; $P_{I,max}$: maximum inspiratory pressure; 6MWD: 6 minute walking distance.

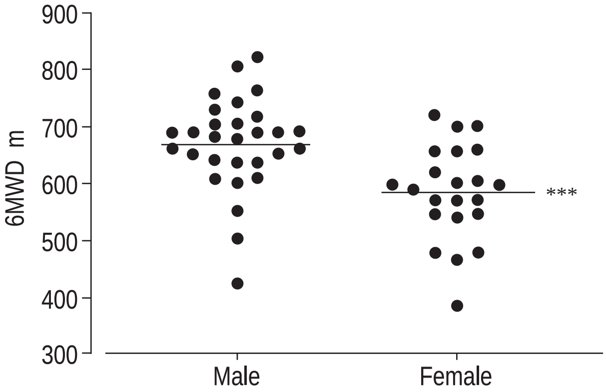

Fig. 1. – Six minute walking distance (6MWD) of elderly male and female subjects. ***: p<0.01.

Discussion

The present study showed considerable variability in the 6MWD of healthy subjects aged 50–85 yrs, ranging 383–820 m. On average, the 6MWD was 631±93 m. An important part of the variability in 6MWD was explained by height, sex, age and weight as dependent variables.

Some caution is warranted when interpreting the results of this study. Firstly, the study was a cross-sectional study in volunteers, and hence may overestimate walking distance in the oldest subjects because of a possible selection bias [11]. Secondly, the study population was not large enough to determine normal values, since the sample may not represent the population characteristics. However, figure 3 shows the anthropometric data of the present subject sample compared to a large epidemiological study conducted in Belgium [12]. The data in the present study show marked similarity, indicating that the relatively small sample represented a good estimate of the general Belgian population in the studied age group. A further criticism is that the measured anthropometric variables may not cover all the important anthropometric information that may be required to explain variability in exercise capacity. For example, lean body mass was not measured. This variable is known to be a predictor of exercise capacity in healthy control subjects [13]. It is possible that other factors, not under investigation in the present trial could further improve the model and therefore explain more variability. It could be speculated that walking efficiency may be such a factor.

Although these criticisms may be valid to some extent, the available evidence supports the validity of the results. The significant contribution of age and weight is in agreement with the findings of PEARCE *et al.* [14], reporting an interaction of walking speed with age and weight in a population of healthy male subjects.

Table 2. – Univariate correlation coefficients between the six minute walking distance (6MWD) and patient variables

	Age yrs	Height cm	Weight kg	BMI $kg \cdot m^{-2}$	QF Nm
6MWD m	-0.51	0.54	0.04	-0.26	0.62
p-value	0.001	0.001	NS	0.06	0.001

BMI: body mass index; QF: quadriceps force.

Table 3. – Multiple stepwise regression analysis with six minute walking distance (6MWD) as the dependent variable to determine the significance of the model proposed

	Cumulative r^2	Partial r^2	p-value
Height cm	0.30	0.47	0.0001
Age yrs	0.56	0.44	0.0001
Weight kg	0.62	0.15	0.005
Sex$^+$	0.66	0.09	0.05

$^+$: one male, no females. The model predicts 6MWD as: $6MWD_{pred} = 218 + (5.14 \times height - 5.32 \times age) - (1.80 \times weight + 51.31 \times sex)$. Residual standard deviation=56 m.

The reported intersubject variability in walking distance, and consequently walking speed, is in agreement with the findings of BOHANNON [15] who found a maximal walking speed over a very short distance (7.62 m) of 1.74–2.53 $m \cdot s^{-1}$. Although the walking speed in the latter trial [15] was considerably higher, it showed the same intersubject variability. Determinants of maximal walking speed were height, age and peripheral muscle strength. In the present study, peripheral muscle strength played no independent role after correcting for height, weight, age and sex. This contrasts with the previously reported relationship of peripheral muscle strength to the 6MWD in patients with moderate to severe chronic obstructive lung disease [7]. Although contradictory at first sight, it should be noted that peripheral muscle strength was normal in all the current subjects, whereas patients with COPD presented with significant muscle weakness.

These results show remarkable similarity to these reported by LIPKIN *et al.* [16] in healthy control subjects. When the regression analysis was applied to the 10 slightly younger healthy control subjects reported in this study, these individuals had a mean walking distance of 94% pred. The somewhat lower walking distance may be due to the considerably shorter corridor (20 m) in which the test was performed. Consequently, the patients lost more time as they had to turn twice as much as in the present trial. This probably caused some reduction in walking distance. A more important factor is that, in the

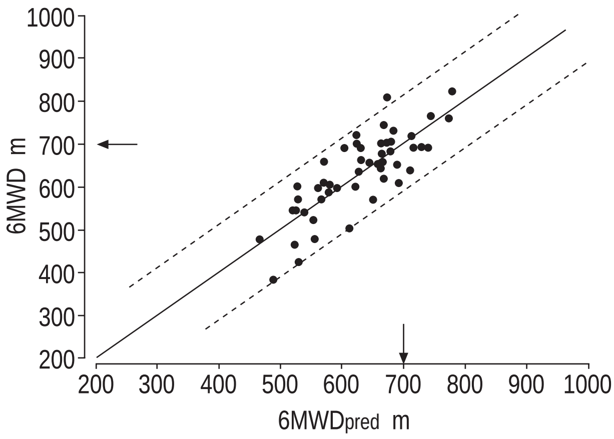

Fig. 2. – Predicted six minute walking distance ($6MWD_{pred}$) based on the proposed model and actual six minute walking distance (6MWD). The arrows represent the normal walking distance as suggested by REDELMEIER *et al.* [5]. The line of identity (——) and the 95% confidence interval (- - -) are plotted.

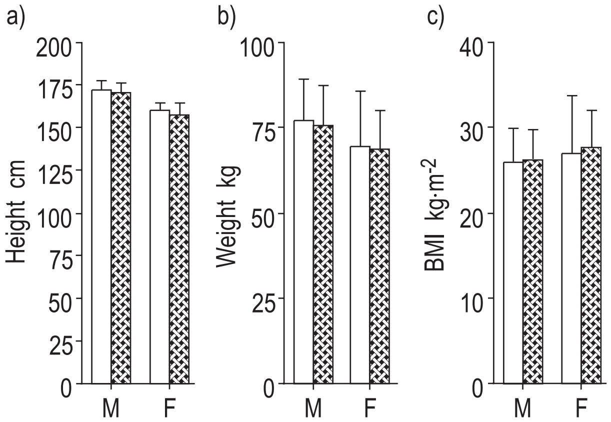

Fig. 3. – Comparison of subjects from the present study (□) with subjects from a large epidemiological study conducted in Belgium (▩) [12] for height, b) weight and c) body mass index (BMI). M: male; F: female.

study by LIPKIN *et al.* [16], there was no practice walk. This may underestimate walking distance in healthy subjects. In the present study, patients reached only 91% of the predicted walking distance in the practice walk. It can be argued that further improvement in walking distance may be achieved by allowing more than one practice walk [17]. However, the authors' unpublished data in 27 patients with moderate to severe COPD, as well as that of others [4], suggest that the 6MWD performance does not improve significantly after one practice walk. The regression equation was therefore applied prospectively in a further 22 subjects meeting the inclusion criteria of the present trial. The mean walking distance in these 22 subjects was 102±6% pred with a minimum performance of 507 m or 92% pred and a maximum performance of 818 m or 113% pred. As can be seen in figure 4, the variability in walking distance in these healthy control subjects was substantially reduced when the results were corrected for age, height, sex and weight.

The present study confirms the common appreciation that the 6MWD test is a submaximal test. The maximal heart rate achieved was on average 77±15% pred. This may not be the case in patient populations. BAARENDS *et al.* [18] reported near maximal oxygen consumption ($V'O_2$)

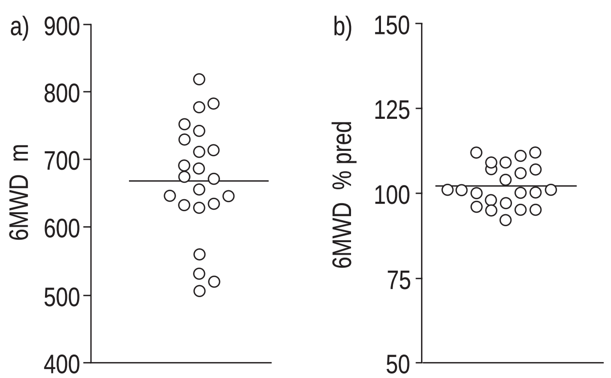

Fig. 4. – The prospective use of the presented regression equation (see footnote to table 3) in 22 healthy control subjects (18 males) undergoing the six minute walking distance (6MWD) test. a) The actual distance walked; b) the % predicted distance walked.

and ventilation after a 12-min self paced treadmill walk compared to an incremental exercise test in moderate to severe COPD patients.

The most important outcome of this study is that a normal 6MWD should not be fixed at 600 or 700 m as has been previously suggested [5]. The predicted and actual measured walking distances ranged 468–782 m and 383–820 m, respectively. When the regression equation is used, a walking distance <82% pred can be considered abnormal. Using 700 m as the predicted walking distance would, in this population of healthy elderly patients, result in a walking distance of 90±13% pred on average. An abnormal walking distance (outside the 95% confidence interval) would be 64% pred or 518 m in the studied population sample. In future, 6MWD obtained in patients can be related to height, weight, sex and age in order to interpret the results with more accuracy. Caution, however, has to be taken over how the test is performed. At least one practice walk should be performed. The corridor should be long enough and free of obstacles to prevent multiple turns during the test. The testing area should be indoors and flat, with controlled temperature and humidity. Encouragement can influence the 6MWD. To ensure maximal motivation and performance, encouragement should be given regularly, *i.e.* every 30 s, and standardized. Since the 6MWD test only gives an estimate of the patient's functional capacity, it cannot replace an incremental maximal exercise test. The latter gives the investigator more direct information on exercise physiology and points more directly towards the causes of the exercise limitation [19].

It is concluded that performance on the six minute walk test is variable in healthy persons over the age of 50 yrs. Variability, however, can be explained by using height, weight, age and sex. Although there is evidence for the accuracy of the presented regression equation, it should be confirmed in larger populations.

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