Respiratory Medicine (2006) 100, 1573–1578

ELSEVIER

respiratoryMEDICINE

Reference values for the 6-min walk test in healthy subjects 20–50 years old☆

Alfredo Chetta[a,*], Andrea Zanini[b], Giovanna Pisi[c], Marina Aiello[a], Panagiota Tzani[a], Margherita Neri[b], Dario Olivieri[a]

[a]Department of Clinical Sciences, Section of Respiratory Diseases, University of Parma, Italy
[b]Salvatore Maugeri Foundation, Division of Pneumology, IRCCS Rehabilitation Institute of Tradate, Italy
[c]Department of Pediatrics, Cystic Fibrosis Unit, University of Parma, Italy

Received 3 November 2005; accepted 1 January 2006

KEYWORDS
Exercise capacity;
6MWD;
Exercise test

Summary In 102 healthy Caucasians, 20–50 years old, we investigated the effect of anthropometrics on the 6-min walk test (6MWT), in order to provide reference values for walk distance (6MWD), oxygen saturation (SpO_2), pulse rate (PR), respiratory rate (RR), breathlessness perception (VAS) and for the walking distance and body weight product (*DW*).

The mean 6MWD and *DW* values were 593±57 and 638±44 m ($P<0.01$) and 35,030±5306 and 48,882±6555 kg m ($P<0.01$), respectively for women and for men. While walking, SpO_2 remained unaltered and subjects reached 67±10% of their maximal predicted heart rate and a RR mean value of 19±4 bpm. VAS ratings were significantly higher in females as compared to males (24±15 vs. 18±5 mm, $P<0.05$), however, when corrected for PR change while walking, they were not different. The equation by stepwise multiple regression analysis included height, age and gender for the 6MWD and accounted for 42% of the total variance.

This study confirms the relevant effect of anthropometrics on walking capacity and suggests that when rating dyspnea, the change in heart rate during walking should be considered.

Introduction

In the last decade, the 6-min walk test (6MWT) has been increasingly used to assess functional exercise performance across various patient populations.[1–8] The 6MWT is self-paced, and involves measuring the distance a patient can walk on a level course in

☆The study was supported by the Ministry of University and of Scientific and Technological Research.
*Corresponding author. Tel.: +39 0521 703 475; fax: +39 0521 292 615.
E-mail address: chetta@unipr.it (A. Chetta).

0954-6111/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rmed.2006.01.001

6 min.[9] The increasing acceptance of this test is due its simplicity and that it does not require sophisticated equipment and can be easily performed by even the most severely debilitated patients. Moreover, the 6MWT better reflects activities of daily living than other walk tests.[10] Recently, the American Thoracic Society developed guidelines for the 6MWT in clinical settings.[11]

In healthy subjects, the 6-min walk distance (6MWD) ranges from 400 to 700 m, the main predictor variables being gender, age and height.[12–14] However, the few published studies have all used different methods, and the predicted distances differ by up to 30%.[15] Furthermore, although 6MWT performance has been assessed even in patients at relatively young age, such as those with interstitial lung disease,[3] cystic fibrosis,[4] obesity,[6] or HIV-associated wasting,[8] only one study [14] published reference values for the 6MWD for subjects 20–40 years old.

Accordingly, the aim of the present study was to investigate in healthy subjects, 20–50 years old, the effect of demographics and anthropometrics on the 6MWT, performed according to the standardized approach provided by the ATS guidelines.[11] Furthermore, we aimed to provide reference values in such subjects for the 6MWD and other primary variables measured in the 6MWT, such as oxygen saturation (SpO_2), pulse rate (PR), respiratory rate (RR), and breathlessness perception. In this study, we also considered a derived variable of the 6MWT, the product of walking distance and body weight (*DW*), which is considered to mimic the work of walking.[16]

Methods

Subjects

We studied a sample of 102 healthy subjects (54 females) from all decades of age between 20 and 50 years (mean $\pm$ standard deviation (SD) age: 34 ± 9 years). They were volunteers recruited from the University campus and from the surrounding community. All subjects were free from injury and had no history of hospitalization or chronic disease influencing their exercise capacity. Moreover, they were not involved in any competitive sport and they were lifetime non-smokers. All subjects gave informed consent to participate in the study.

Lung function test

Lung function was measured by a flow-sensing spirometer and a body plethysmograph connected to a computer for data analysis (Vmax 22 and 6200, Sensor Medics, Yorba Linda, USA). Baseline total lung capacity (TLC), forced expiratory volume in 1 s (FEV_1), vital capacity (VC), and FEV_1/VC ratio were recorded. Carbon monoxide transfer capacity (TL_{CO}) was measured by the single breath method and considered valid only if the inspiratory volume was at least 90% of VC. At least three measurements were made for each lung function variable to ensure reproducibility. Predicted values of lung volumes and expiratory flows as well as TL_{CO} were obtained from regression equations by Quanjer et al.[17] and Cotes et al., [18] respectively.

Six-min walk test

After lung function testing, all subjects performed two 6MWTs according to a standard protocol.[11] All subjects received the same instructions before the walk and were encouraged by the investigator who repeated set phrases every 30 s during the walk. Each subject underwent the 6MWT in an undisturbed 30-m indoor, level, hospital corridor. The second 6MWT was performed in the same manner as the first, following a rest of at least 60 min. The 6MWD covered during the test was recorded in meters. Results from the second walk were only used for analysis to allow for any learning effect.[19]

Before and immediately after the 6MWT, all subjects rated the magnitude of their perceived breathlessness on an interval scale, which was a 100-mm horizontal visual analogue scale (VAS).[20] The VAS consisted of a horizontal ruler without any mark on the subject's side with the words "not at all breathless" and "extremely breathless" on the left and right end, respectively. The subject had to indicate his breathlessness perception at the moment of the assessment, by moving a marker along the ruler. Breathlessness perception ratings were expressed in mm from 0 to 100 and corresponded to the distance of the marker from the left end of the VAS. In each subject, resting and after-walk RR (bpm) were also recorded before and immediately after the 6MWT.

The SpO_2 (%) and PR (bpm) were continuously monitored from 5 min before the walk until test completion, as well as 5 min after completion, or until recovery of the baseline value by using a lightweight (0.3 kg) portable pulse oximeter (Healthdyne, Model 920M, Marietta, GA, USA). This device was carried by each subject with a shoulder strap and a finger probe and was applied to the non-dominant hand. The oxygen saturation and heart rate readings were recorded in the oximeter memory every 10 s. For each subject, the resting

SpO_2 values (resting SpO_2, %), such as the average of the SpO_2 readings taken before the walk, and the mean saturation recorded during the walk (walking SpO_2, %) were noted. The resting PR values (resting PR, bpm) which were the average of the PR readings taken before the walk, the mean PR recorded during the walk (walking PR, bpm) and the maximum PR sustained for more than 10 s (maximum PR, bpm) during the walk were also noted. The predicted maximum PR was calculated by the following equation: 210–0.66 × age.[21]

Statistical analysis

All pulmonary function test results are expressed as percent of predicted value or as absolute value. Data are reported as mean ± SD and differences in numerical data between groups were determined by the unpaired *t*-test. Furthermore, relationships were estimated by the Pearson correlation coefficient (r). Stepwise multiple regression analysis was used to determine the best predictor variables for the 6MWT dependent variables. Percentage of total variance in the dependent variable, accounted for by the predictor variables, is expressed as the adjusted square of the multiple correlation coefficient (r^2). A P-value of less than 0.05 was taken as significant.

Results

Lung function values of healthy subjects are summarized in Table 1. The *DW* was calculated as the product of the walk distance (in m) × body weight (in kg).

The mean 6MWD was 614 ± 56 m, ranging from 459 to 738 m, and the mean *DW* was 41,548 ± 9112 kg m, ranging from 26,100 to 66,976 kg m. Oxygen saturation remained unaltered throughout the walk. Mean resting and walking SpO_2 values were, respectively, 98 ± 0.9% and 97 ± 1.3%. The mean change in SpO_2 was 1.0 ± 1.1%.

PR and RR were significantly affected by the walk. Mean resting, walking and maximum PR values were, respectively, 78 ± 11, 108 ± 19 ($P<0.001$ vs. resting values), and 126 ± 19 bpm ($P<0.001$ vs. resting values). Moreover, during the walk, subjects reached 67 ± 10% of their maximal predicted heart rate. Resting and after-walk RR were, respectively, 14 ± 3 and 19 ± 4 bpm ($P<0.001$). In all subjects, the mean value of ratings on the VAS after the walk was 21 ± 15 mm.

Table 1 Lung function values of the 102 study subjects.

TLC, % pred	110 ± 10
FEV_1, % pred	112 ± 14
FEV_1/VC, %	82 ± 6
TL_{CO}, % pred	98 ± 14

Values are expressed as mean ± SD.

Table 2 Personal details and 6-MWT measures of the study subjects.

	Women ($n=54$)	Men ($n=48$)
Age, years	33 ± 9	36 ± 8
Height, cm	164 ± 7	176 ± 7**
Weight, kg	59 ± 8	77 ± 9**
BMI, kg/m^2	22 ± 3	25 ± 2**
6MWD, m	593 ± 57	638 ± 44**
DW, kg m	35,030 ± 5306	48,882 ± 6555**
PR base, bpm	81 ± 10	75 ± 10**
PR mean, bpm	115 ± 18	101 ± 17**
PR maximal, bpm	132 ± 18	119 ± 18**
VAS, mm	24 ± 15	18 ± 15*
VAS/PR_{change}	0.65 ± 0.41	0.53 ± 0.48

Values are expressed as mean ± SD; ** $P<0.01$, * $P<0.05$.

Gender significantly affected the 6MWD (Table 2). On average, the 6MWD and the *DW* values were 45 m and 13,582 kg m greater in male subjects, when compared to female subjects. Mean resting, walking and maximum PR values were significantly higher in female subjects, as compared to male subjects. Moreover, ratings on the VAS were significantly higher in females as compared to males, however, when corrected for the maximum PR percentage change of resting PR (VAS/PR_{change}), there was no difference between females and males.

In all subjects, the 6MWD was inversely and directly related, respectively, to age ($r=-0.42$; $P<0.001$) and height ($r=0.46$; $P<0.001$) (Fig. 1). After-walk VAS was directly related to after-walk RR ($r_s=0.27$, $P<0.01$) and to PR max ($r_s=0.24$, $P<0.05$).

The regression equation generated by stepwise multiple regression analysis for the 6MWD included height, age and gender. This model accounted for 42% of the total variance for the 6MWD (Table 3). Moreover, multiple regression analysis for the ratings on the VAS after walking could not account for more than 10% of the total variance, the main predictor variable being RR after walking.

Discussion

The present study provides reference values for the primary variables measured in the 6MWT in healthy subjects between 20 and 50 years of age. The reference values may be useful to interpret 6MWT performance in patients with significant respiratory or cardiac dysfunction at a relatively young age, such as those with cystic fibrosis, obesity, interstitial lung disease, or dilatative cardiomyopathy. Moreover, the reference values provided by this study apply to the 6MWT protocol proposed by the American Thoracic Society guidelines.[11] In these guidelines, some recommendations and suggestions concerning technical aspects and quality assurance of the 6MWT are present. Specifically, the recommended length of the corridor is 30 m so as to avoid too many turns during the test, one practice walk should be considered to allow for the learning effect and encouragement should be given regularly to ensure maximal motivation and performance. In this regard, previous studies did not take into account some of these methodological aspects of the 6MWT. For example, in the study by Gibbons and colleagues,[14] a 20-m corridor was used, while in the study by Enright and Sherrill,[12] a practice test was not performed.

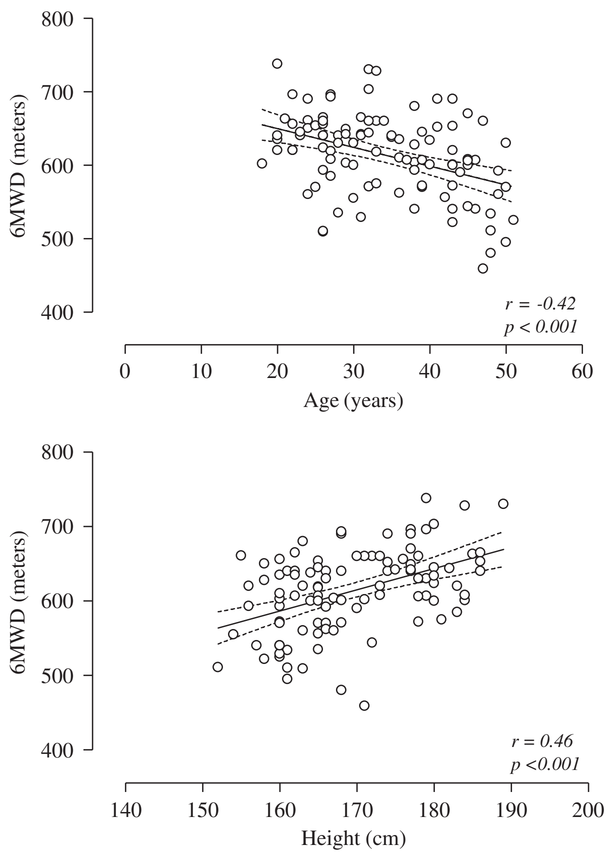

Figure 1 Relationship between 6MWD and age (upper panel) and height (lower panel) in 102 healthy subjects 20–50 years old. The linear regression line is superimposed, surrounded with the 95% confidence interval lines for the regression line. r = Pearson correlation coefficient.

As expected, the present study confirmed that several demographic and anthropometric factors can influence the 6MWT performance in healthy subjects. In our model, gender, height and age can reliably predict the 6MWD. Intuitively, a taller height is associated with a longer stride, which probably results in a longer distance walked by taller subjects. Moreover, the shorter distance walked by the older participants in our study may be explained by changes in skeletal muscles, as compared to the younger subjects. A gradual reduction of skeletal muscle mass and strength has been demonstrated in the elderly,[22,23] however our findings suggest that the decline in skeletal muscle function could be earlier. Our model can explain only 40% of the variance in the 6MWD, which is in agreement with previous reports.[12,14] Potential sources of variance other than age, gender or height should be considered. One potential source of variance may be the different attitudes, beliefs as well as the mood of the participants. Indeed, it has been demonstrated that psychological status is related to exercise capacity both in healthy subjects [24] and in patients with chronic bronchitis.[25] Another potential source of variance may be the different peripheral muscle conditioning of the participants, since we included in this study both habitually active and sedentary healthy subjects.

The *DW* is a simplification of the equation proposed by Cavagna and Margaria [26] to determine the horizontal work on a treadmill and was proposed by Chuang et al.[16] as a measure for assessing the functional capacity during a 6MWT. In COPD patients, *DW* was superior to the 6MWD, when correlated with oxyhemoglobin saturation

Table 3 Predicting model for walk distance (6MWD, m).

	Coefficient	Standard error	P	95% confidence intervals	
$r^2 = 0.42$					
Height	1.250	0.641	0.05	−0.006	2.506
Age	−2.816	0.497	0.000	−3.790	−1.842
Gender	−39.07 (1 = females, 0 = males)	11.592	0.001	−61.789	−16.349
Constant	518.853	118.114	0.000	287.350	750.356

changes during walk and with anaerobic threshold and maximal oxygen uptake.[16] In addition, in a large group of COPD patients, the *DW* could discriminate better than the 6MWD, patients with low work capacity from those with high work capacity as assessed by bike ergometry.[27] Therefore, *DW* is considered to be a measure that reflects the work of walking better than the 6MWD and is suggested to evaluate exercise tolerance, if a cardiopulmonary exercise test is unavailable.[16] As expected, in our study, *DW* was higher in males than in females, since males were heavier and covered a longer 6MWD than females.

In this study, we found that both resting and walking PR values were significantly higher in females as compared to males. Previous studies showed gender related differences in heart rate and reported an increase in resting heart rate in women.[28,29] Additionally, Jones [21] reported higher heart rates in women following submaximal exercise when compared to those of men.Baroreflex heart rate regulation may be different between women and men [30,31] and the effects of estrogen on baroreflex regulation can also occur in humans.[32] Lastly, the present study confirms the common appreciation that in healthy subjects the 6MWT is a submaximal test, since the maximal heart rate achieved was an average 68%.

In this study, we found that the walking-induced breathlessness was weakly related to after-walking RR and maximum PR, but was not reliably predicted by any demographic and anthropometric variables of the subjects. We also observed a slight gender difference in breathlessness perception, which lacked statistical significance when corrected for heart rate change while walking. Our results mainly support the view that the underlying mechanisms of exertion dyspnea are quite elusive, and that subjectivity is inherently involved in the symptom. However, they also suggest that in healthy subjects, walk-induced dyspnea could be linked to the perception of both walk-induced tachycardia and tachypnea.

In summary, this study provides reference values for the 6MWT variables for Caucasian subjects 20–50 years old. Our results confirm the relevant effect of anthropometric characteristics on walking capacity and suggest that, when rating dyspnea, the change in heart rate while walking should be considered.

Acknowledgment

We gratefully acknowledge the help of Prof. Francesco Donato from the Department of Experimental and Applied Medicine, University of Brescia, Italy, in analysing the data.

References

1. Kotloff RM, Tino G, Palevsky HI, Hansen-Flaschen J, Wahl PM, Kaiser LR, et al. Comparison of short-term functional outcomes following unilateral and bilateral lung volume reduction surgery. *Chest* 1998;**113**:890–5.
2. Oga T, Nishimura K, Tsukino M, Hajiro T, Ikeda A, Izumi T. The effects of oxitropium bromide on exercise performance in patients with stable chronic obstructive pulmonary disease. A comparison of three different exercise tests. *Am J Respir Crit Care Med* 2000;**161**:1897–901.
3. Chetta A, Aiello M, Foresi A, Marangio E, D'Ippolito R, Castagnaro A, et al. Relationship between outcome measures of six-minute walk test and baseline lung function in patients with interstitial lung disease. *Sarcoidosis Vasc Diffuse Lung Dis* 2001;**18**:170–5.
4. Chetta A, Pisi G, Zanini A, Foresi A, Grzincich GL, Aiello M, et al. Six-minute walking test in cystic fibrosis adults with mild to moderate lung disease: comparison to healthy subjects. *Respir Med* 2001;**95**:986–91.
5. Eng JJ, Chu KS, Dawson AS, Kim CM, Hepburn KE. Functional walk tests in individuals with stroke: relation to perceived exertion and myocardial exertion. *Stroke* 2002;**33**:756–61.
6. Hulens M, Vansant G, Claessens AL, Lysens R, Muls E. Predictors of 6-minute walk test results in lean, obese and morbidly obese women. *Scand J Med Sci Sports* 2003;**13**:98–105.
7. Olsson LG, Swedberg K, Clark AL, Witte KK, Cleland JG. Six minute corridor walk test as an outcome measure for the assessment of treatment in randomized, blinded intervention trials of chronic heart failure: a systematic review. *Eur Heart J* 2005;**26**:778–93.
8. Esposito JG, Thomas SG, Kingdon L, Ezzat S. Anabolic growth hormone action improves submaximal measures of physical performance in patients with HIV-associated wasting. *Am J Physiol Endocrinol Metab* 2005;**289**:E494–503.
9. Guyatt GH, Sullivan MJ, Thompson PJ, Fallen EL, Pugsley SO, Taylor DW, et al. The six-minute walk: a new measure of exercise capacity in patients with chronic heart failure. *Can Med Assoc J* 1985;**132**:919–23.
10. Solway S, Brooks D, Lacasse Y, Thomas S. A qualitative systematic overview of the measurement properties of functional walk tests used in the cardiorespiratory domain. *Chest* 2001;**119**:256–70.
11. American Thoracic Society Statement. Guidelines for the six-minute walk test. *Am J Respir Crit Care Med* 2002;**166**:111–7.
12. Enright PL, Sherrill DL. Reference equations for the six-minute walk in healthy adults. *Am J Respir Crit Care Med* 1998;**158**:1384–7.
13. Troosters T, Gosselink R, Decramer M. Six minute walking distance in healthy elderly subjects. *Eur Respir J* 1999;**14**:270–4.
14. Gibbons WJ, Fruchter N, Sloan S, Levy RD. Reference values for a multiple repetition 6-minute walk test in healthy adults older than 20 years. *J Cardpulm Rehabil* 1995;**15**:394–405.
15. Enright PL. The six-minute walk test. *Respir Care* 2003;**48**:783–5.
16. Chuang M- L, Lin I- F, Wasserman K. The body weight-walking distance product as related to lung function, anaerobic

threshold and peak V'O2 in COPD patients. *Respir Med* 2001;**95**:618–26.
17. Quanjer PhH, Tammeling GJ, Cotes JE, et al. Lung volumes and forced ventilatory flows. *Eur Respir J* 1993;**6**:5–40.
18. Cotes JE, Chinn DJ, Quanjer PhH, et al. Standardization of the measurement of transfer factor (diffusing capacity). *Eur Respir J* 1993;**6**:41–52.
19. Knox AJ, Morrison JFJ, Muers MF. Reproducibility of walking test results in chronic obstructive airways disease. *Thorax* 1988;**43**:388–92.
20. Mahler DA, Guyatt GH, Jones PW. Clinical measurement of dyspnea. In: Mahler DA, editor. *Dyspnea*. New York: Marcel Dekker; 1988. p. 149–98.
21. Jones NL. *Clinical exercise testing*, 4th ed. Philadelphia: WB Saunders Company; 1997. p. 243–7.
22. Evans WJ, Campbell WW. Sarcopenia and age-related changes in body composition and functional capacity. *J Nutr* 1993;**123**(2 Suppl):465–8.
23. Bemben MG. Age-related physiological alterations to muscles and joints and potential exercise interventions for their improvement. *J Okla State Med Assoc* 1999;**92**:13–20.
24. King B, Cotes JE. Relation of lung function and exercise capacity to mood and attitudes to health. *Thorax* 1989;**44**:402–9.
25. Morgan AD, Peck DF, Buchanan DR, McHardy GJR. Effect of attitudes & belief on exercise tolerance in chronic bronchitis. *Br Med J* 1983;**286**:171–3.
26. Cavagna GA, Margaria R. External work in walking. *J Appl Physiol* 1963;**18**:1–9.
27. Carter R, Holiday DB, Nwasuruba C, Stocks J, Grothues C, Tiep B. 6-minute walk work for assessment of functional capacity in patients with COPD. *Chest* 2003;**123**: 1408–15.
28. Gillum RF. The epidemiology of resting heart rate in a national sample of men and women: associations with hypertension, coronary heart disease, blood pressure, and other cardiovascular risk factors. *Am Heart J* 1988;**116**: 163–74.
29. Sheila RB, Raymond JM, Dan KK, Margaret G, Gohar A, Eric LK, et al. Effects of age and gender on autonomic control of blood pressure dynamics. *Hypertension* 1999;**33**: 1195–200.
30. Abdel-Rahman AR, Merrill RH, Wooles WR. Gender-related differences in the baroreceptor reflex control of heart rate in normotensive humans. *J Appl Physiol* 1994;**77**: 606–13.
31. Beske SD, Alvarez GE, Ballard TP, Davy KP. Gender difference in cardiovagal baroreflex gain in humans. *J Appl Physiol* 2001;**91**:2088–92.
32. Minson CT, Halliwill JR, Young TM, Joyner MJ. Influence of the menstrual cycle on sympathetic activity, baroreflex sensitivity, and vascular transduction in young women. *Circulation* 2000;**101**:862–8.