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The six-minute walk test and body weight-walk distance product in healthy Brazilian subjects

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Abstract

We assessed the 6-min walk distance (6MWD) and body weight x distance product (6MWw) in healthy Brazilian subjects and compared measured 6MWD with values predicted in five reference equations developed for other populations. Anthropometry, spirometry, reported physical activity, and two walk tests in a 30-m corridor were evaluated in 134 subjects (73 females, 13-84 years). Mean 6MWD and 6MWw were significantly greater in males than in females (622 ± 80 m, 46,322 ± 10,539 kg·m *vs* 551 ± 71 m, 36,356 ± 8,289 kg·m, P < 0.05). Four equations significantly overestimated measured 6MWD (range, 32 ± 71 to 137 ± 74 m; P < 0.001), and one significantly underestimated it (-36 ± 86 m; P < 0.001). 6MWD significantly correlated with age (r = -0.39), height (r = 0.44), body mass index (r = -0.24), and reported physical activity (r = 0.25). 6MWw significantly correlated with age (r = -0.21), height (r = 0.66) and reported physical activity (r = 0.25). The reference equation devised for walk distance was $6MWD_m = 622.461 - (1.846 \times Age_{years}) + (61.503 \times Gender_{males = 1; females = 0})$; $r^2 = 0.300$. In an additional group of 85 subjects prospectively studied, the difference between measured and the 6MWD predicted with the equation proposed here was not significant (-3 ± 68 m; P = 0.938). The measured 6MWD represented 99.6 ± 11.9% of the predicted value. We conclude that 6MWD and 6MWw variances were adequately explained by demographic and anthropometric attributes. This reference equation is probably most appropriate for evaluating the exercise capacity of Brazilian patients with chronic diseases.

Key words: Walking; Exercise; Rehabilitation; 6MWD; 6MWw

Introduction

The 6-min walk test (6MWT) is a simple tool for the evaluation of functional exercise capacity, which reflects the capacity of the individual to perform activities of daily living (1,2). Demographic, anthropometric, clinical, and physiological characteristics can affect the test performance in healthy elderly subjects and in patients with cardiopulmonary diseases (3,4). Since the 6MWT is a self-paced test, the results are influenced by external factors such as energy expenditure, operator encouragement and subject motivation. Accordingly, the 6-min walk distance (6MWD) varies widely, even among healthy subjects (1,5). Therefore, the instructions and the level of verbal encouragement given must be carefully standardized (3). The American Thoracic Society (ATS) recommends that researchers establish specific reference values for each population (3). Recent studies have defined 6MWT reference values for various populations (6-10). However, previous studies have shown that equations used in other populations are not necessarily applicable to Brazilian subjects (11,12).

It has been suggested that 6-min walk work (6MWw), which is the product of 6MWD and body weight, can be used as an alternative means of measuring functional walking capacity (13). In patients with lung disease, the 6MWw rate has demonstrated better sensitivity and specificity in identifying exercise intolerance than has 6MWD (14). Recently, Hill et al. (15) described 6MWw as an appropriate variable for estimating maximal exercise capacity in patients with chronic obstructive pulmonary disease during an incremental cycle

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ergometer test. Thus, the 6MWw should be considered for a widespread evaluation of walking ability.

To our knowledge, there are no reference equations for predicting 6MWD in Brazilian subjects. Although the 6MWT has been validated for use in young Brazilian patients with chronic diseases, it is necessary to expand the evaluation of reference values to other populations and age brackets (16-19). In the present study, we assessed 6MWD and 6MWw in a population-based sample of healthy subjects aged 13-84 years and established a reference equation to predict 6MWD and prospectively assess its reliability. We also compared the 6MWD values measured with those predicted by five reference equations devised for use with other populations.

Material and Methods

Screening

We studied 134 healthy subjects over 13 years of age. Volunteers were recruited from students and employees of the Federal University of São Paulo and from employees of the Santa Casa Hospital, both located in Santos, SP, Brazil, as well as from residents of the surrounding community. Reported physical activity (RPA) scores were collected from the subjects by means of the Baecke questionnaire (20), and subjects were classified as sedentary (score <8) or physically more active but still untrained (score ≥8). The volunteers were stratified into the following categories, based on body mass index (BMI): underweight (<18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2), and obese (>30 kg/m^2) (21). All subjects selected for study presented clinical stability, defined as the absence of any acute disease during the 6 weeks preceding the study. Subjects with abnormal post-bronchodilator lung function, i.e., forced expiratory volume in one second (FEV_1) <80% of the predicted value or forced vital capacity (FVC)/FEV_1 ratio <70%, were excluded, as were those with a current diagnosis of cardiovascular/respiratory disease, those with any health problem that might interfere with the ability to perform physical exercises (e.g., impaired cognition, metabolic, neuromuscular or musculoskeletal diseases, or use of walking aids), and those regularly using medications for chronic diseases. However, those with controlled arterial hypertension, as well as former smokers without tobacco-related diseases, were included in the study. To verify the reliability of our 6MWD reference equation, we prospectively measured 6MWD in a second group of 85 additional healthy adults (45 women) at another center located in the Botucatu Medical School (UNESP, São Paulo State University), Botucatu, Brazil. As done in Santos, these volunteers were recruited among students and employees from the University and the surrounding community. They met the study inclusion criteria and had not participated in the first part of the study. Total body mass (kg) and body height (cm) were measured according to standard techniques, with the subjects wearing light clothing and no shoes (22). Measurements were made with a calibrated Filizola scale (0.1 kg of precision) and with a stadiometer (0.5 cm of precision) and the BMI (body $mass_{kg}$ body $height_m^2$) was calculated. Subsequently, the volunteers completed the physical activity readiness questionnaire (23). The risk for cardiovascular events during exercise was assessed according to the recommendations of the American College of Sports Medicine (24). On the basis of age, health status, symptoms, and cardiovascular risk factors, the volunteers were stratified into two risk levels, i.e., low and moderate. Subjects presenting high risk were excluded.

Pulmonary function and reversibility tests were performed using a spirometer (Spirodoc; Medical International Research, Rome, Italy), according to the criteria established by the ATS (25). FEV_1 values are reported as percentages of reference values (26).

The study design was approved by the Human Research Ethics Committee of the Federal University of São Paulo, and all subjects gave written informed consent to participate.

Six-minute walk test

Each subject was instructed to walk as far as possible during a 6-min period over a 30-m course in an indoor hospital corridor. Following a rest of at least 30 min, each subject performed a second 6MWT in the same manner as the first. The course was identified by two traffic cones, and the corridor was marked every 3 m according to ATS standards (3). Instructions and verbal encouragement given to the subjects were standardized. Encouragement was given every minute during the test until subject exhaustion. The end of the test was determined either by the subject, for any reason, or by the physical therapist conducting the test. Chest pain, intolerable dyspnea, dizziness, leg cramps, diaphoresis, and pallor were additional criteria for immediately stopping the test. The results of the second test were recorded for analysis. Before and after each test, the following data were obtained: pulse rate; respiratory rate; blood pressure, and dyspnea/leg effort, using the Borg scale (27). Measured 6MWD values were compared with predicted values using five reference equations devised for use in other populations (1,5,6,28,29).

Statistical analysis

Statistical analysis was performed using the statistical package SigmaStat 2.03 (SPSS, Chicago, IL, USA). Data are reported as mean ± standard deviation (SD) or as median (interquartile range). The following tests were performed: Kolmogorov-Smirnov, for descriptive data analysis; calculation of variation (Δ) in the absolute values for the variables studied, Pearson or Spearman coefficient to evaluate the correlations between the studied variables, unpaired Student *t*-test or Mann-Whitney test for comparisons between means, and multiple linear regression (dependent variable: 6MWD; independent variables: demographic and anthropometric attributes). The reliability of our 6MWD reference equation was evaluated in the second group of 85 healthy adults. We compared the measured 6MWD with the predicted distance derived from our equation. The predicted maximal heart rate (HRmax) was calculated using the following equation: 220 - age_{years}.

Results

Of the 134 subjects evaluated, 73 (54.4%) were females. The mean age of the sample was 36 ± 15 years. All individuals studied presented normal lung function (FEV_1 = 94 ± 8%; FVC = 93 ± 9%; FEV_1/FVC = 92 ± 12%). Mean BMI was within the normal range (25 ± 4 kg/m^2) (21). According to reference cut-off points, 3.1% were classified as underweight, 46% were classified as normal weight; 37.6% were classified as overweight, and 12.5% were classified as obese. The prevalence of smoking was 19.4%. The mean 6MWD for the second test was 583 ± 83 m (range: 417-828 m), compared with 577 ± 80 m (range: 397-840 m) for the first test, and the difference between the two was not statistically significant (P = 0.584). During the 6MWT, subjects reached 65 ± 13% of their HRmax (range: 38-98%). Mean 6MWw was 40,893 ± 10,588 kg·m (range: 20,600-71,572 kg·m).

The characteristics of the 134 subjects are summarized in Table 1. Weight, height, RPA, %HRmax at the end of the 6MWT, 6MWD, and 6MWw were greater in males than in females. There was no significant difference between males and females in terms of BMI. Comparisons and correlations between measured 6MWD values and predicted values using previously established reference equations are presented in Table 2. With the exception of that devised by Enright and Sherrill (1), all equations evaluated overestimated 6MWD values in relation to those obtained in the present study.

The mean walking distance prospectively measured in 85 subjects (41 ± 13 years, 165 ± 8 cm, 66 ± 12 kg, and 24 ± 4 kg/m^2) was 571 ± 74 m, representing 99.6 ± 11.9% of the predicted value calculated with our reference equation for 6MWD: $6MWD_m = 622.461 - (1.846 \times Age_{years}) + (61.503 \times Gender_{males = 1;\ females = 0})$. The mean walking distance predicted by means of our reference equation was 575 ± 38 m. The difference between prospectively measured and predicted 6MWD in these subjects was not significant (-3 ± 68 m) and the correlation was significant (r = 0.54; P < 0.0001).

Univariate analysis showed that 6MWD correlated significantly (P < 0.05) with age, height and BMI (Figure 1), as well as with FEV_{1L} (r = 0.65; P < 0.0001), FVC_L (r = 0.65; P < 0.0001) and RPA (r = 0.25; P < 0.01). In the multiple linear regression analysis, age and gender were selected as predictors of 6MWD, jointly explaining 30% of the total vari-

Table 1. Characteristics of the study subjects.

Characteristic	Males (N = 61)	Females (N = 73)
Age in years, median (Interquartile range)	31 (22-37)	35 (24-52)
Height in cm, mean ± SD	172 ± 7	159 ± 6*
Weight in kg, median (Interquartile range)	72 (65-84)	65 (57-73)*
BMI in kg/m^2, median (Interquartile range)	24 (22-27)	25 (23-29)
RPA, mean ± SD	9.0 ± 1.8	7.6 ± 1.4*
6MWD in m, mean ± SD	622 ± 80	551 ± 71*
%HRmax, median (Interquartile range)	60 (53-69)	68 (61-76)*
6MWw in kg·m, median (Interquartile range)	45,000 (38,761-53,956)	34,790 (30,749-41,966)*

BMI = body mass index; RPA = reported physical activity (Baecke questionnaire); HRmax = maximal heart rate; 6MWD = 6-min walk distance; 6MWw = body weight x walk distance product. *P < 0.05 compared to males (Student *t*-test or Mann-Whitney test).

Table 2. Comparisons and correlations between measured and predicted 6-min walk distance using other reference equations in subjects participating in the first part of the study (N = 134).

Equation	N	Measured 6MWD (m)	Predicted 6MWD (m)	Predicted - measured (m)	% Predicted	Correlation (r)
Gibbons et al. (28)	122	657 (512-645)	716 (665-773)*	137 ± 74	80 ± 10	0.50+
Chetta et al. (6)	104	581 (526-648)	624 (594-657)*	32 ± 71	94 ± 11	0.48+
Enright and Sherrill (1)	49	543 ± 71	506 ± 75*	-36 ± 86	109 (95-116)	0.31#
Troosters et al. (5)	31	534 (482-621)	600 (570-663)*	71 ± 76	88 (81-93)	0.47#
Camarri et al. (29)	22	536 (480-630)	653 (634-702)*	115 ± 67	82 ± 10	0.55#

Data are reported as median (Interquartile range), with the exception of some related to the Enright and Sherril equation, which are reported as means ± SD. 6MWD = 6-min walk distance. *P < 0.001: measured *vs* predicted 6MWD; +P < 0.001: significant correlation; #P < 0.05: significant correlation (Spearman rank order correlation: Gibbons et al. and Camarri et al.; Pearson product moment correlation: Chetta et al., Enright and Sherrill and Troosters et al.).

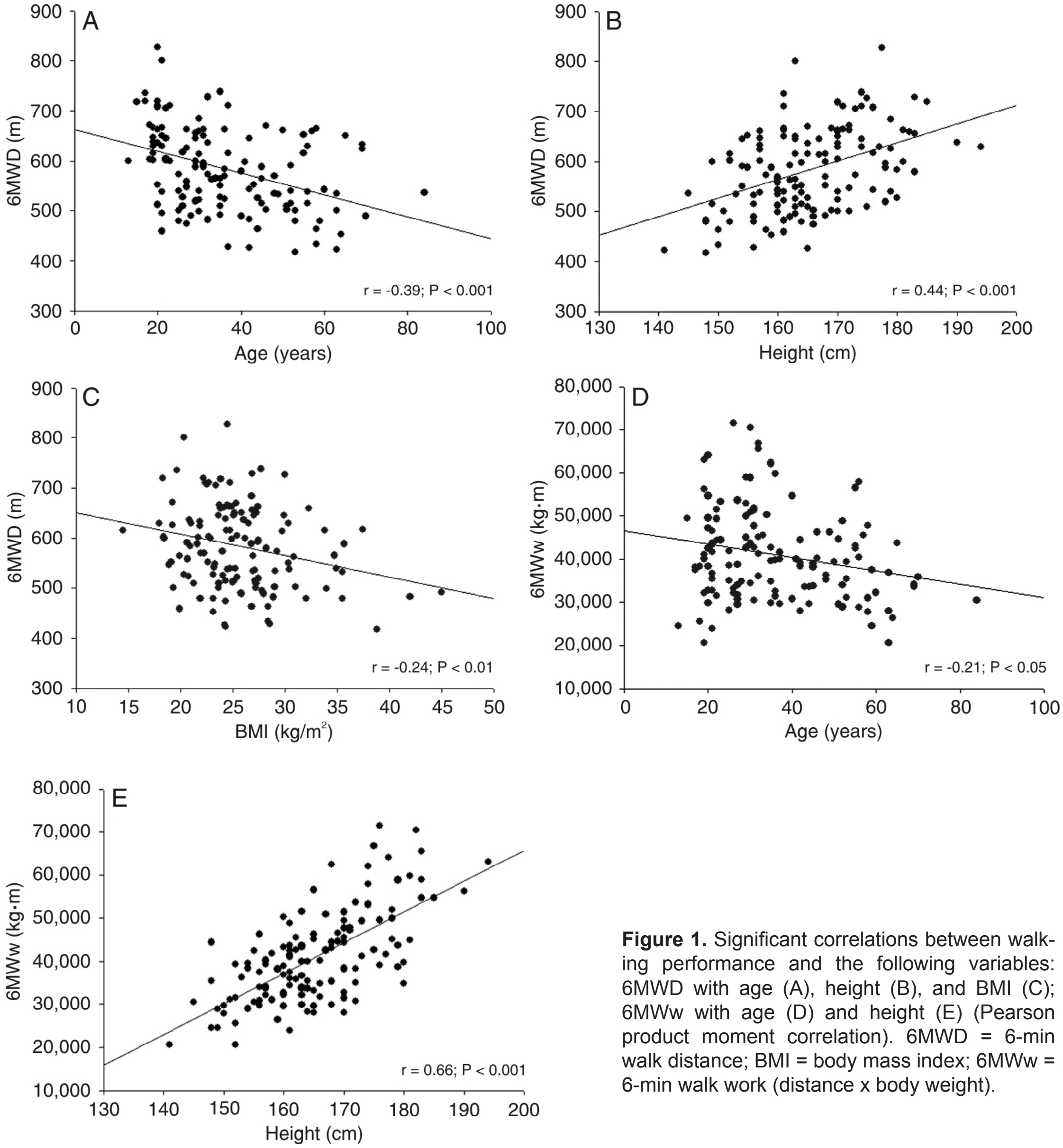

Figure 1. Significant correlations between walking performance and the following variables: 6MWD with age (A), height (B), and BMI (C); 6MWw with age (D) and height (E) (Pearson product moment correlation). 6MWD = 6-min walk distance; BMI = body mass index; 6MWw = 6-min walk work (distance x body weight).

Table 3. Predictive model for the total distance walked in the 6-min walk test in healthy subjects.

Variable	Coefficient	SEM	P	95% confidence interval	
				Minimum	Maximum
Constant	622.461	18.053	<0.001	0.011613	1244.910387
Age, years	-1.846	0.416	<0.001	-0.000624	-3.691376
Gender*	61.503	12.491	<0.001	-0.002684	123.008684

*Gender factor: males = 1; females = 0. 6MWD = 6-min walk distance. Reference equation proposed here: $6MWD_m = 622.461 - (1.846 \times Age_{years}) + (61.503 \times Gender_{males = 1; females = 0})$; $r^2 = 0.300$ (standard error of the estimate = 70.992 m).

ance in 6MWD (Table 3). Age and height correlated significantly with 6MWw (Figure 1), as did FEV_{1L} (r = 0.67; P < 0.0001), FVC_L (r = 0.66; P < 0.0001) and RPA (r = 0.25; P < 0.01).

Thus, we propose the new reference equation cited above for 6MWD.

Discussion

To our knowledge, the present study is the first to investigate predicted values and potential demographic and anthropometric determinants of 6MWD and 6MWw in the Brazilian population and to propose a predictive equation.

Reference equations would permit a more appropriate evaluation of Brazilian patients with chronic diseases that affect exercise capacity. The equations derived from other populations commonly overestimated 6MWD in relation to the values obtained for our subjects. Since we adhered to the guidelines for the 6MWT, established in 2002 (3), we believe that the results of the present study contribute to facilitating the international comparison of 6MWD values.

Age, height, BMI, and gender significantly influenced the 6MWD of our volunteers. After multiple regression analysis, only age and gender were selected as determinants of 6MWD. These findings agree with those of previous studies (6,28). The negative influence of advanced age on the 6MWD might be explained by the gradual reduction in muscle mass, muscle strength and maximal oxygen uptake that typically occurs with aging. The influence of gender on 6MWD might be attributable to the greater absolute muscle strength, muscle mass and height of men compared to women. Our finding that height influences 6MWD agrees with the correlations between height and 6MWD (range: $r = 0.20$ to $r = 0.54$) reported by others (1,5,7,28). This can be attributed to the greater stride length of taller individuals, stride length being a major predictor of gait speed (30). We found only a weak correlation between BMI and 6MWD. This correlation has been previously shown to be nonlinear (4). Obesity increases 6MWw, 6MWD being shorter in subjects with greater body weight or higher BMI (4).

In our study, the reference equation for predicting 6MWD presented a squared correlation coefficient of 0.300, similar to values reported in previous studies, in which it ranged from 0.300 to 0.660 (4,5). Age, height and gender influenced the 6MWw. In fact, 6MWw has been shown to correlate with change in oxyhemoglobin desaturation during walking, with the anaerobic threshold and with maximal oxygen uptake (13). Our results suggest that 6MWw is important for evaluating walking performance.

Potential sources of 6MWD variance other than age, gender or height should be considered. One such source is the psychological status related to exercise capacity in healthy subjects and in patients with pulmonary disease (3). Other potential sources are differences in peripheral muscle conditioning (4,31) and in pulmonary function (29). However, these variables are not as easily assessed as are demographic and anthropometric attributes, since dynamometers and spirometers are necessary to quantify muscle and pulmonary function, respectively.

We observed that the equations devised by Troosters et al. (5), Chetta et al. (6), Gibbons et al. (28), and Camarri et al. (29) overestimated 6MWD in relation to the values obtained for our sample. The cause of the pronounced difference between the measured and predicted 6MWD values might have been multifactorial. Both the standardization of the test and ethnic characteristics should be considered. Among the studies, corridor length varied from 20 m to 50 m and the number of pre-tests for familiarization varied from two to four (5,28,29,32). The level of encouragement might also have influenced the results, since guidelines other than those established by the ATS (33,34) were used in some studies (1,5,29,32). The only equation that underestimated our measured 6MWD was derived from only one test (i.e., without practice) (1). On the other hand, Chetta et al. (6), who adhered to ATS guidelines, devised an equation that only slightly overestimated 6MWD in relation to our findings. These discrepancies may be attributed to population differences between samples. Our volunteers were slightly shorter and our women volunteers had a greater body weight when compared to the subjects studied by Chetta et al. (6). These differences emphasize the importance of developing population-specific reference equations. Accordingly, our additional prospective data confirmed the equation's reliability and also illustrated the errors that could arise from using other equations for the Brazilian population. Therefore, we propose that our reference equation should be used in the Brazilian population.

Some potential limitations of our study should be considered. Both study centers evaluated volunteers for the elaboration of the reference equation and for its validation. Although subjects were selected consecutively when they fulfilled the inclusion criteria, such a convenience sample might have introduced a bias. However, the prevalence of sedentary lifestyle (52.23%) and obesity (12.5%) observed in the present study population agrees with the values previously reported for healthy Brazilian subjects (21,35). In addition, convenience samples have often been included in studies evaluating reference values for 6MWD (1,4-8,10,28,29). Although the sample size was sufficient to elaborate a reference equation, we evaluated a relative small sample in the present study to produce reference values. Nevertheless, our study should be repeated with larger samples.

We conclude that 6MWD and 6MWw present substantial variability in healthy subjects aged 13-84 years. However, an important part of the variability was adequately predicted by demographic and anthropometric attributes. We observed that equations devised for other populations overestimated the 6MWD measured in Brazilian subjects. This study resulted in a reference equation for the prediction of 6MWD in healthy subjects, and this equation can facilitate the assessment of Brazilian patients with diseases that affect their exercise capacity.

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