Reference Equations for the Six-Minute Walk in Healthy Adults

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In order to establish reference equations for prediction of the total distance walked during six minutes (6MWD) for healthy adults, we administered the standardized 6-min walk test to 117 healthy men and 173 healthy women, aged 40 to 80 yr. Oxygen saturation (Sa_{O_2}), pulse rate, and the degree of dyspnea (Borg scale) were determined before and at the end of the walk. The median distance walked was 576 m for men and 494 m for women. The 6MWD was significantly less for men and women who were older and heavier, and for shorter men. The resulting gender-specific regression equations explained about 40% of the variance in the distance walked for healthy adults: for men, 6MWD = $(7.57 \times \text{height}_{cm}) - (5.02 \times \text{age}) - (1.76 \times \text{weight}_{kg}) - 309$ m, and for women, 6MWD = $(2.11 \times \text{height}_{cm}) - (2.29 \times \text{weight}_{kg}) - (5.78 \times \text{age}) + 667$ m. These reference equations may be used to compute the percent predicted 6MWD for individual adult patients performing the test for the first time, when using the standardized protocol. Enright PL, Sherrill DL. Reference equations for the six-minute walk in healthy adults. AM J RESPIR CRIT CARE MED 1998;158:1384–1387.

The ability to walk for a distance is a quick and inexpensive measure of physical function, and an important component of quality of life, since it reflects the capacity to undertake day-to-day activities. The 6-min walk can be performed by many elderly, frail, and severely limited patients who cannot be tested with standard (and more expensive) maximal cycle ergometer or treadmill exercise tests. The distance walked in 6 min (6MWD) is reduced by several types of diseases, including obstructive lung disease, heart failure, arthritis, and neuromuscular disease (1, 2).

Previous studies using the 6-min walk were conducted in groups of patients with a disease associated with physical dysfunction, but did not include relatively healthy persons. We desired a standard measure of physical function in a longitudinal, population-based study, and included the 6-min walk as part of a comprehensive follow-up examination of the adults in the cohort. The results allowed determination of the predictors (based on height, weight, body mass index [BMI], age, and gender) of the 6MWD in the healthy subset of study participants.

METHODS

Study Population

The subjects were participants in the Tucson Epidemiological Study of Airways Obstructive Disease. The study design and methods of data collection have been previously detailed (3). Briefly, the population in this study was a randomly chosen, stratified cluster of persons in Tucson, Arizona, consisting of 3,805 individuals in 1,655 households who were enrolled in 1972 and 1973, with new enrollees added by marriage and birth.

Six-Minute Walk Test

The 6-min walk test was conducted according to a standardized protocol (2). Subjects were instructed to walk from one end to the other of a 100-ft. hallway at their own pace, while attempting to cover as much ground as possible in the allotted 6 min. Technicians encouraged subjects with the standardized statements “You’re doing well” or “Keep up the good work,” but were asked not to use other phrases. Subjects were allowed to stop and rest during the test, but were instructed to resume walking as soon as they felt able to do so. Dyspnea, as measured with the modified Borg dyspnea scale (4), oxygen saturation (Sa_{O_2}), and pulse rate were assessed at the start and end of the 6-min walk test. Subjects were also asked at the end of the walk whether they had experienced any of the following symptoms: dyspnea, chest pain, lightheadedness, or leg pain.

Cardiovascular Assessments

Prior to the 6-min walk test, we measured each subject’s ankle-arm index (AAI), a sensitive subclinical measure of reduced blood flow to the legs (5), performed an electrocardiogram (ECG), recorded the subject’s systolic blood pressure and self-reported experience of high blood pressure, and took a history of stroke, any heart problem, or any kind of heart or lung surgery since the time of the subject’s completion of the last previous questionnaire. Current use of diuretic, antihypertensive, antiarrthymic, and anticoagulant medications was also self-reported.

Pulmonary Assessments

Spirometry was performed according to American Thoracic Society criteria (6), with reference values previously obtained from healthy members of our cohort (7). Subjects were classified as being never-smokers, ex-smokers, or current smokers on the basis of their self-administered questionnaire responses. Other pulmonary data collected

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TABLE 1

EXCLUSIONARY FACTORS FOR THE HEALTHY SUBSET

Factor	No. Excluded
Age > 80 yr	35
BMI > 35	15
AAI < 0.9	39
History of stroke	8
Use of diuretics	42
FEV_1 < 70% predicted	48
Current smoker	52

Definition of abbreviations: AAI = ankle-arm blood pressure index; BMI = body mass index.

Two hundred and nineteen participants were excluded (not the total of 239 given here) because some participants had more than one factor that excluded them from the healthy subset.

included breathing medications, a history of lung cancer, and any serious respiratory illness, lung surgery, or limited activity related to lung disease. The subject's standing height in stocking feet was measured to the nearest centimeter, using a stadiometer, and the subject's weight was measured with a balance beam scale that was recalibrated every month.

Statistical Methods

We decided *a priori* to define the healthy group by excluding subjects with disease-related factors that were significantly negatively associated with 6MWD in the entire cohort. If the factor was a continuous variable, participants who fell beyond the 95th percentile toward abnormality were to be excluded from the healthy group. Therefore, the first step in our procedure was to build a linear regression model to determine the correlates of 6MWD. For the remaining healthy subset of participants, we chose the anthropomorphic factors that were significantly independently associated with 6MWD to enter into a model predicting 6MWD. The lower limit of the normal range was defined as the 5th percentile.

RESULTS

Two hundred and five males and 253 females completed the 6-min walk. The initial regression model (stepwise) determined the factors independently associated with a reduced 6MWD. Table 1 lists the exclusionary factors resulting from this model and the number of participants excluded for each factor. Exclusionary factors included age > 80 yr, BMI > 35 (indicating obesity), AAI < 0.90 (indicating peripheral vascular disease), a history of stroke, use of diuretics (suggesting hypertension or congestive heart failure), an FEV_1 less than 70% predicted (suggesting lung disease), and current smoking. The only anthropomorphic variables that were significant in the model were age and weight, both of which had negative coefficients. Height was significantly correlated with 6MWD in men only. Figures 1 and 2 are scattergrams showing the bivariate association of age with 6MWD in men and women, including

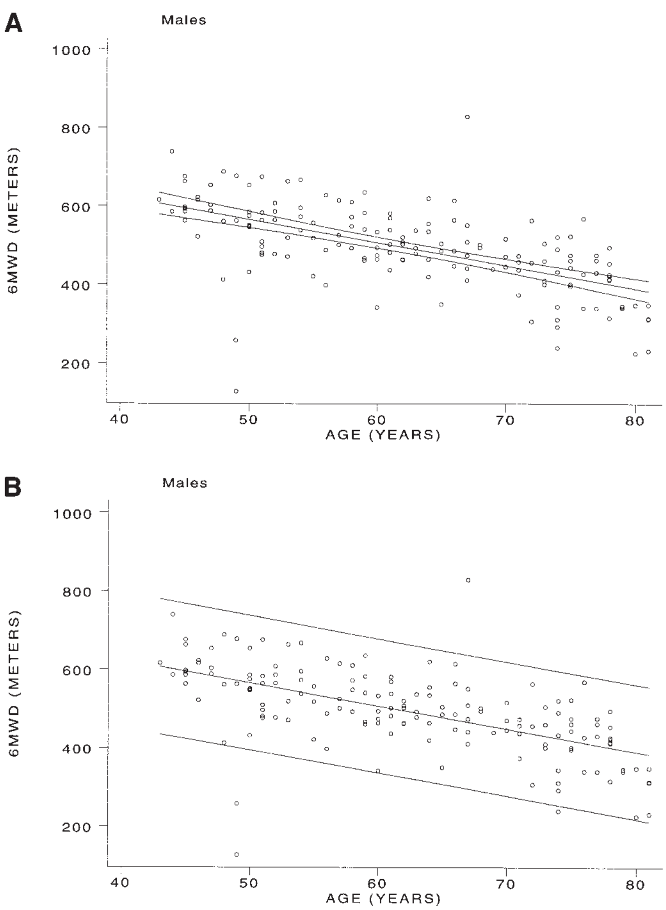

Figure 1. (*A*) Scattergram of the relationship between 6MWD and age in 117 healthy adult men. The linear regression line is superimposed, surrounded with the 95% confidence interval (CI) lines for the regression line, or (*B*), by the CI lines for the individual predicted values.

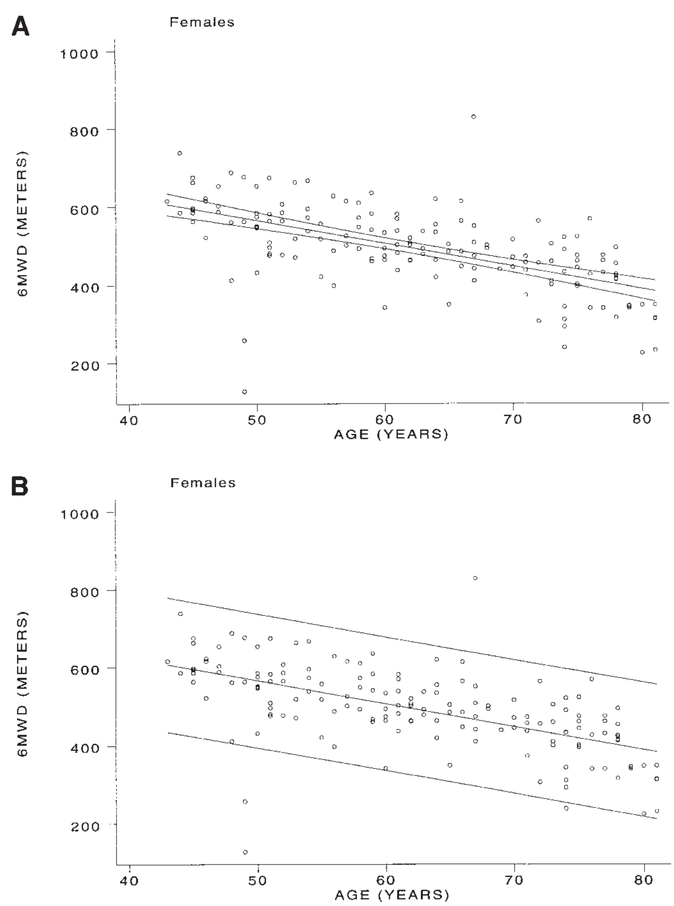

Figure 2. (*A*) Scattergram of the relationship between 6MWD and age in 173 healthy adult women. The linear regression line is superimposed, surrounded with the 95% confidence interval (CI) lines for the regression line, or (*B*), by the CI lines for the individual predicted values.

TABLE 2

CHARACTERISTICS OF THE HEALTHY ADULT PARTICIPANTS

	Median (5th, 95th percentiles)	
Characteristic	Men (*n = 117*)	Women (*n = 173*)
Age	59.5 (43.1, 77.0)	62.0 (45.0, 79.0)
Height, cm	176 (164, 185)	162 (151, 173)
BMI, kg/m^2	27.8 (22.1, 33.9)	25.5 (20.6, 32.4)
Baseline pulse	74 (58, 100)	80 (60, 105)
Change in pulse	+25 (−8, +79)	+20 (−6, +58)
Baseline Sa_{O_2}	96% (92, 98)	96% (93, 99)
Change in Sa_{O_2}	0.0 (−8.0, +2.0)	0.0 (−16.0, +2.0)
FEV_1, %pred	96% (75, 118)	106% (81, 125)
6MWD, m	576 (399, 778)	494 (310, 664)

Definition of abbreviations: BMI = body mass index; 6MWD = 6-min walk distance.

the fitted regression lines. Either weight or BMI were significant when entered into the models, and resulted in nearly equivalent values for R^2.

After the exclusionary factors were applied, 117 men and 173 women remained in the healthy subset. Table 2 gives their characteristics. Table 3 gives the gender-specific equations for predicting 6MWD. These models explained 42% and 38% of the variation in 6MWD for men and women, respectively (R^2 values). After the predicted 6WMD value from Table 3 for an individual patient is computed, the lower limit of the normal range (LLN) for that patient may be obtained by subtracting 153 m from the 6MWD value for men or by subtracting 139 m for women.

DISCUSSION

The 12-min walking test was introduced in 1968 as a guide to physical fitness (8), and was later applied to patients with chronic obstructive pulmonary disease (COPD) (9). It was then found that decreasing the time of the walk to 6 min did not significantly reduce the utility of the test (2). The 6-min walk test has been validated by high correlation with workloads, heart rate, and Sa_{O_2}, the dyspnea responses when compared with standard bicycle ergometry and treadmill exercise tests (10–12). There is a learning effect when the test is performed on two successive days, with a mean 15% improvement in distance walked (13), but this effect is not important when determining cross-sectional correlations, or when using the results as a baseline predictor of later events. Our results apply to the first (initial) 6-min walk performed by a patient.

In the gender-specific models, we found that the anthropometric factors of age, weight, and height (for men) were independently associated with the distance walked. The gradual reduction of skeletal muscle mass and strength that generally occurs with aging (14), and the increased prevalence of debilitating diseases, which we did not objectively measure, are probably responsible for the shorter distance walked in our more elderly study participants. A taller height is associated with a longer stride, which makes walking more efficient, probably resulting in a longer distance walked by taller men.

Obesity increases the workload for a given amount of exercise, probably resulting in the shorter distanced walked by women with a higher body weight or BMI. A small study of elderly men with COPD found that correcting for body weight improved the correlation of 6MWD with maximal oxygen consumption (12). Our results suggest that when 6MWDs are reported in future studies, they should be corrected for age, height, weight, and gender.

About 60% of the variance in 6MWD remains unexplained by our models. Future population-based studies of relatively healthy persons that include the 6-min walk test may be able to provide models that explain more of the variance and thereby narrow the normal range (and increase the lower limit of the normal range provided by our reference equations). For instance, knowledge of exercise habits and cardiopulmonary conditioning, and of the presence of musculoskeletal problems (such as arthritis), might improve future models.

The 6MWD was an excellent independent predictor of morbidity and mortality after 1 yr in 898 patients with heart failure (15). The mean distance walked by these patients was 374 m (SD = 117 m). It remains to be seen whether or not the 6MWD will be a strong independent predictor of morbidity and mortality in population samples or in patients with COPD.

Caution should be exercised when applying our regression equations to patients who have characteristics that fall outside of our cohort, including non-Causians and those younger than 40 yr or older than 80 yr. Larger values may be expected from persons who have previously performed 6-min walk tests and those to whom nonstandardized encouragement is given.

TABLE 3

REFERENCE EQUATIONS FOR 6-MIN WALK DISTANCE IN HEALTHY ADULTS

Men:

$6MWD = (7.57 \times height_{cm}) - (5.02 \times age) - (1.76 \times weight_{kg}) - 309$ m.

Alternate equation using BMI*:

$6MWD = 1{,}140 \text{ m} - (5.61 \times BMI) - (6.94 \times age)$

When using either equation, subtract 153 m for the LLN

Women:

$6MWD = (2.11 \times height_{cm}) - (2.29 \times weight_{kg}) - (5.78 \times age) + 667$ m.

Alternate equation using BMI:

$6MWD = 1{,}017_{\text{ m}} - (6.24 \times BMI) - (5.83 \times age)$

When using either equation, subtract 139 m for the LLN

Definition of abreviations: BMI = body mass index; 6MWD = 6-min walk distance; LLN = lower limit of normal.

* BMI in kg/m^2.

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