Six-min walk test in a healthy adult Arab population

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Summary

Background: The 6-min walk test (6MWT) is a submaximal exercise test used to assess functional status in patients with cardiopulmonary diseases. Regression equations have previously been published as a normal reference for 6-min walk distance (6MWD) in healthy Caucasian adults. However, a recent study showed that the normal predicted 6MWD could differ among ethnic populations. The aim of this study was: (1) to determine the normal 6MWD in a sample of healthy Saudi adults; (2) to create a regression equation for the established 6MWD; and (3) to compare the 6MWD in the present study with previously published equations.

Method: The 6MWT was administered to 298 healthy volunteers (53% males) between the ages of 16 and 50 years.

Result: The average 6MWD was 409 ± 51 m, with longer distances walked by males (429 ± 47 m) than by females (386 ± 45 m) (p < 0.001). The regression equation revealed that height (p < 0.001) and age (p = 0.034) were the most significant predictors of distance (6MWD = (2.81 × height) + (0.79 × age) − 28.5). In addition, the equation explained 25% of the distance variance. All previously published equations overestimated the Saudi 6MWD by 109–340 m.

Conclusion: Saudi populations have significantly shorter 6MWDs than those reported for other ethnic groups. Thus, the Caucasian reference value for the 6MWD should not be used in Saudi subjects, as it overestimates the distance and may interfere with the therapeutic and prognostic value of the test.

Introduction

Objective measurements of exercise are important tools to assess patients with cardiopulmonary disease. Cardiopulmonary exercise tests are the standard methods for measuring exercise capacity, particularly with regards to physical limitation, disease prognosis and responsiveness to treatment. These tests are sensitive and specific but...
require sophisticated equipment, trained technicians and complex data analysis. As an alternative, time-based walk tests are commonly used to assess exercise capacity in patients with cardiopulmonary disease. The 6-min walk test (6MWT) is a self-based walking test that measures the distance walked over a period of 6-min. This test requires a 30 m hallway, and does not require exercise equipment or highly trained technicians. Several studies have reported that 6-min walk distance (6MWD) correlates strongly with variables measured by the cardiopulmonary exercise test, such as maximum oxygen consumption and ventilatory parameters.\textsuperscript{1–4} Subsequent studies have found the 6MWD to be a good predictor of morbidity among patients with pulmonary or cardiac diseases.\textsuperscript{3,5–9}

Variabilities in physical capacity and exercise performance can be determined by measuring cardiopulmonary endurance, musculoskeletal function and body composition. By themselves, these components can be affected by other factors, including age, gender, height, weight, genotype and race. Normal predicted values for 6MWD are based on age, gender, height and weight. Such values are widely used as references for 6MWD in Caucasian healthy adults.\textsuperscript{10–13} However, a small number of studies have reported differences in the normal predicted 6MWDs of other ethnic populations. Poh and associates reported that the normal 6MWD of 35 healthy Singaporean Chinese were 75 m less than those reported for Caucasians.\textsuperscript{14}

Previous reports examining the utility of the 6MWT showed that the test could be an additive tool to assess disease severity and response to treatment, or to predict mortality in patients with several cardiopulmonary diseases. For example, in patients with heart failure or pulmonary hypertension, a 6MWD less than 300 m was an independent predictor of mortality.\textsuperscript{5,6} In another study, a change in 6MWD of 54 m or more reflected a meaningful change in functional status of patients with COPD.\textsuperscript{15} Our laboratory previously reported the mean 6MWD of a group of Saudi patients with respiratory disease. Although these patients experienced mild ventilatory impairments, their walked distances were significantly shorter than those reported for Western populations.\textsuperscript{16} These results suggest that Western 6MWD reference values may be subject to misinterpretation when applied to our populations, and can provide misleading information with regards to therapeutic or prognostic determinants.

Therefore, our study sought to evaluate the distances walked by randomly selected healthy female and male Saudi subjects. In addition, this study examined potential 6MWD-predictive variables in the Saudi population. We have also examined the differences in walking distances of our cohort and previously published equations.

**Methods**

Healthy Saudi volunteers between the ages of 18 and 50 years were randomly recruited to participate in this descriptive, prospective, cross-sectional population based study. The study was conducted in Riyadh city, the capital of Saudi Arabia, with an estimated population of over 5 million inhabitants. In order to get a citywide representative sample, the studied population was selected from the central, northern and southern parts of the city and represented both the public and private sectors. Study subjects were teachers from three public schools, students, workers and visitors of a local university and employees of a local private company. All subjects provided formal consent, and the study design was approved by the King Saud University Research Committee and the Scientific Review Board of the Department of Medicine. Subjects were excluded from the study if they had medical histories that were indicative of cardiovascular or pulmonary disease, current or past histories of smoking,\textsuperscript{17} upper respiratory tract infections within the last 4 weeks, conditions that could affect walking, resting blood pressures higher than 140/90 mmHg, heart rates higher than 100 beats per min, body mass indexes (BMIs) greater than 35 or evidence of ventilatory impairment as measured by spirometry (i.e., forced expiratory volume in 1 s, FEV\textsubscript{1}, values lower than 80%, and FEV\textsubscript{1}/FVC (forced vital capacity) values lower than 70%, of normal predicted value).

**Six-min walk test**

Participants were asked to eat a light morning meal and to wear comfortable clothes and shoes. Tests were conducted at five different sites between 9:00 a.m. and 1:00 p.m. Height and weight were measured using a calibrated scale and body mass indices for each subject were calculated. Heart rate, blood pressure and oxygen saturation were measured using the 506N3 Vital Signs Monitor (Criticare Systems, WI, USA) during a 10–15-min resting period before the test. Subjects were asked to indicate their level of dyspnea perception using a modified 12 point Borg scale, wherein each score (i.e., ranging from 0 to 10) is illustrated by a printed figure. Each subject performed a single 6MWT in a quiet, air-conditioned building containing a 30 m-long corridor with marks at 1 m intervals.\textsuperscript{18} Subjects were asked to walk as far down the length of the corridor as they could, at their own pace, for 6-min. Subjects were informed of the time elapsed every 60 s, using standardized phrases.\textsuperscript{19} Subjects were allowed to stop if they developed symptoms of dyspnea, chest pain, leg cramps or dizziness, but were encouraged to continue walking as soon as they could. At the end of the test, each subject’s heart rate, blood pressure, oxygen saturation and Borg value was measured, and the maximum predicted heart rate (mHR) was calculated (mHR = 220 – age). All tests were conducted and supervised by the same technician at each of the five sites.

**Spirometry**

Spirometry was performed using a standard portable spirometer (Vitalograph alpha, Ireland) that was calibrated on a daily basis. Patients were asked to perform at least three measures, and the largest value was recorded for analysis as recommended by the guidelines of the American Thoracic Society.\textsuperscript{20}

**Statistical analysis**

Data was analyzed using the SPSS statistical software package (SPSS version 13.0, Chicago, IL). Descriptive
statistics were used to summarize the population’s demographic and clinical parameters. Student’s t-tests were used to compare female and male subjects. Six-min walk distances were correlated with patients’ ages, heights, weights, BMIs, heart rates, Borg scores, and FVC and FEV1 values using the Spearman rank correlation coefficient. A stepwise linear regression model was used to determine if any of the above variables were independent predictors of 6MWD. Approximately 80% of the studied population was randomly selected for inclusion in a predictive equation, while the remaining subjects were used as controls. The regression equation was validated by comparing the actual distance walked by the control group with the predicted distance determined by the equation. The mean 6MWD measured of the whole group in our study was compared to the mean distance calculated using each of the five previously published equations of Troosters, Gibbons, Camarri, Enright, and Poh. A paired sample t-test was used to compare two means. Values were considered statistically significant if \( p < 0.05 \).

**Results**

The baseline characteristics of the study population are summarized in Table 1. Of the 362 subjects recruited for participation in this study, 66 were excluded because of high blood pressure, BMIs exceeding 35 kg/m² or ventilatory impairment. Of the 296 remaining subjects, 58 (i.e., 20%) were selected as controls. The remaining population was composed of 127 males and 111 females, with a mean age of 29.3 ± 8.1 years. The ages of females and males were similar. However, the females were overall shorter and leaner than the males. Male and female subjects exhibited similar spirometric measurements and basal heart rates. On the other hand, we observed small but significant difference between the two groups with regards to Borg values and post-test heart rates. Male and female subjects reached 44% and 47% of their maximum predicted heart rates, respectively, at the end of the test.

The overall mean walking distance was 410 ± 52 m, with significantly longer distances walked by males (i.e., 430 ± 48 m) than females (i.e., 386 ± 46 m) \((p < 0.0001; 95\% \text{ CI} = -53 \text{ to } -32)\). There were significant positive correlations between 6MWD and height (i.e., \( r = 0.485, p < 0.0001 \)), and BMI and weight (i.e., \( r = 0.219, p < 0.0001 \)). However, female gender, age, maximum predicted heart rate and Borg values negatively correlated with 6MWD (i.e., \( r = -0.425, p < 0.001; r = -0.289, p < 0.001; r = -0.123, p = 0.034 \) and \( r = 0.118, p = 0.043, \) respectively). BMI was more linearly associated with 6MWD in females than in males. Female subjects with BMIs greater than 25 kg/m² walked shorter distances, while a positive correlation was observed between walking distance and females with BMIs less than 25 kg/m².

A multiple linear stepwise regression analysis model was used to predict 6MWD by subject’s height (i.e., \( p < 0.001; 95\% \text{ CI} = 2.11 \text{ to } 3.12 \)) and age (i.e., \( p = 0.032; 95\% \text{ CI} = -1.52 \text{ to } -1.07 \) (Fig. 1). Approximately one-fourth of the variability in 6MWD was explained by two variables (i.e., \( r^2 = 0.250 \)). Based on the results of correlation and regression analyses, the 6MWD for males and females can be determined by:

\[
6MWD = (2.81 \times \text{height}) + (0.79 \times \text{age}) - 28.5, \quad \text{where} \quad 6MWD \text{ is expressed in meters, age in years and height in centimeters.}
\]

This equation accurately predicted the distances walked by the control group (i.e., measured 6MWD = 407.5 ± 48 m and predicted 6MWD = 408.3 ± 30 m, with mean differences of \(-0.82 \pm 44 m, p = 0.89; 95\% \text{ CI} = -12.6 \text{ to } 10.9\) (Fig. 2).

Fig. 3 compares our predicted 6MWD values with those of five previously published studies. Walk distance was overestimated by all of the previously published equations, except Troosters et al., who overestimated the Saudi walking distance by 340 ± 72 m \((p < 0.001)\), Camarri et al. by 334 ± 51 m \((p < 0.001)\), Gibbons et al. by 330 ± 74 m \((p < 0.001)\), Enright et al. by 278 ± 73 m \((p < 0.001)\) and Poh et al. by 106 ± 81 m \((p < 0.001)\). The 6MWD reference value determined here was substantially lower than previously reported values, which overestimated the Saudi walking distance by 106—340 m. Consistent with our study design, Enright et al. described a 6MWD reference equation for 290 healthy subjects between the ages of 40 and 80 years using single test protocol in the studied cohort. However, that study determined that men walked an average of 576 m and

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Characteristics of the study population.</th>
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<tbody>
<tr>
<td>Variables</td>
<td>Male ((n = 127))</td>
</tr>
<tr>
<td>Age (years)*</td>
<td>28 ± 8</td>
</tr>
<tr>
<td>Height (cm)†</td>
<td>170 ± 5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>76 ± 13</td>
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<tr>
<td>BMI (kg/m²)</td>
<td>26 ± 4</td>
</tr>
<tr>
<td>HR (T0)</td>
<td>79 ± 11</td>
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<tr>
<td>HR (T6)</td>
<td>85 ± 13</td>
</tr>
<tr>
<td>% mHR (T0)*</td>
<td>41 ± 6</td>
</tr>
<tr>
<td>% mHR (T6)†</td>
<td>45 ± 7</td>
</tr>
<tr>
<td>Borg (T0)</td>
<td>0 ± 0</td>
</tr>
<tr>
<td>Borg (T6)</td>
<td>0.1 ± 0</td>
</tr>
<tr>
<td>Predicted FVC%</td>
<td>119 ± 20</td>
</tr>
<tr>
<td>Predicted FEV₁%</td>
<td>124 ± 21</td>
</tr>
<tr>
<td>FEV₁/FVC ratio</td>
<td>113 ± 8</td>
</tr>
<tr>
<td>6MWD (m)</td>
<td>430 ± 47</td>
</tr>
</tbody>
</table>

\[ * \text{ for } p < 0.05. \]
\[ † \text{ for } p < 0.01. \]
\[ ‡ \text{ for } p < 0.001. \]

**Discussion**

The 6MWT has been studied in several healthy populations, including those in the Western hemisphere and Asia. This study sought to define the mean age-predicted 6MWD of a healthy Saudi population and compare this value with those generated by previously reported regression equations. To our knowledge, this is the first study to predict 6MWD in people of Arabic descent, particularly those living in Saudi Arabia.

The 6MWD reference value determined here was substantially lower than previously reported values, which overestimated the Saudi walking distance by 106—340 m. Consistent with our study design, Enright et al. described a 6MWD reference equation for 290 healthy subjects between the ages of 40 and 80 years using single test protocol in the studied cohort. However, that study determined that men walked an average of 576 m and
women walked an average of 494 m, while we determined these values to be 430 m and 386 m, respectively. These differences do not reflect variations in age, height or ventilatory function. Furthermore, Enright recruited patients who were relatively older than our cohort. With regards to pulmonary function, all of our subjects exhibited normal spirometric parameters, excluding the possibility of differences in ventilatory function. Thus, it is possible that this discrepancy reflects differences in the submaximal effort exerted by our subjects compared with those in the Enright study. Our male and female subjects reached an average of 44% and 47% of their maximum predicted heart rates, respectively; while subjects in the Enright cohort reached average of 61–65% of their mHRs.

Studies of exercise physiology have revealed a direct relationship between muscle strength and physical exercise. Decreased physical activity (i.e., inactivity) usually leads to altered muscle metabolism, decreases in muscle mass and lower physical capacity. This relation is more obvious among patients with comorbid conditions, in which the rate of inactivity correlates significantly with 6MWD. Local data suggest there is a high prevalence of physical inactivity among Saudis, particularly those who are middle-aged. Al-Refaee et al. reported inactivity in up to 80% of 1333 randomly selected adult Saudi males, which exceeds values reported for other Westernized countries. These observations support the idea that differences in the reported 6MWD of Saudis and other populations may stem from higher rates of physical inactivity (i.e., which subsequently affect muscle mass and strength) rather than anthropometric characteristics.

Consistent with previous studies, we found that height most strongly correlated with 6MWD and was the predominant variable in the regression equation for male and female subjects. Previous reports have attributed the relationship between height and walked distance to increased leg length, which generates a longer stride. In contrast, weight had a minimum effect on 6MWD and was not represented in the final regression equation. Previous reports of the relationship between weight and 6MWD have been inconsistent. Thus, our results do not necessarily contradict previous studies, as most found weight to be a strong predictor of 6MWD in populations older than our cohort (i.e., older than 40 years). In a study of 79 healthy subjects older than 20 years, weight did not correlate with distance, suggesting that weight is

Figure 1  The relationships between (a) 6MWD and age (i.e., $r = -0.219, p = 0.001$) and (b) 6MWD and height (i.e., $r = 0.485, p < 0.001$).

Figure 2  Actual measured 6MWD and predicted 6MWD calculated with the proposed equation (—) with a 95% confidence interval (.....).

Figure 3  Comparison of actual and predicted 6MWDs from our study and five previous studies. Saudi walking distance was overestimated by 106–340 m in all five of the previous studies.
associated with 6MWD in older subjects. Although gender correlated significantly with 6MWD, it was not represented in our final regression equation. Similar findings were reported in a recent study, wherein height, age and predicted maximum heart rate were the only variables in the final equation and no differences were observed between 6MWD in male and female subjects. As exercise involves complex interactions between the cardiovascular, respiratory and neuromuscular systems, it is likely that most previously published 6MWT reference equations, as well as our equation presented here, lack sufficient variables to sensitively describe the effects of exercise. However, our equation was able to estimate the distance walked within an acceptable range of error when applied to 20% of the recruited sample.

This study was limited by several factors. We did not recruit individuals older than 50 years, due to the high prevalence of hypertension, diabetes mellitus and hyperlipidemia in our local elderly population. Thus, our cohort consisted of middle-aged subjects to eliminate the possibility of subjects with confounding diseases that could affect their walking ability. In addition, several investigators have demonstrated the “learning effect” phenomena in 6MWT, wherein repeating the test more than once significantly increases walking distance. Repetition may be important for cardiopulmonary rehabilitation programs, where it is necessary to familiarize patients with the test. However, we theorized that the single test method was more appropriate for clinical settings, where the test will typically be performed once. Another potential limitation is that the sample studied may not be representative of the entire Saudi population. However, in view that Riyadh is the largest city and a major commercial center of Saudi Arabia that attracts workers, students and visitors from different parts of the country, we believe that the sample and therefore the study results can be extrapolated to the rest of the Saudi population. Finally, we did not assess other potential variables that may have limited our study. As exercise involves complex interactions between the cardiovascular, respiratory and neuromuscular systems, it is likely that most previously published 6MWT reference equations, as well as our equation presented here, lack sufficient variables to sensitively describe the effects of exercise. However, our equation was able to estimate the distance walked within an acceptable range of error when applied to 20% of the recruited sample.

In conclusion, this study highlights the differences in 6MWD between Saudis and Caucasians. Our regression equation will prove useful in future assessments of functional status. As several other studies have shown a correlation between 6MWD and mortality with regards to various cardiopulmonary conditions, our study represents the first step toward establishing a new set of 6MWD values that will aid the development of diagnostic and prognostic markers for these conditions in the Saudi population.

Conflict of interest statement

Hatem Alameri has no conflict of interest to disclose in relation to this work.

Sulaiman Al-Majed has no conflict of interest to disclose in relation to this work.

Abdelrahman Al-Howaikan has no conflict of interest to disclose in relation to this work.

References


