

# Reference values and prediction equations for six-minute walk distance and stair-climbing test performance in apparently healthy Ethiopian adults

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## Abstract

**Background** The six-minute walk test (6MWT) and stair-climbing test (SCT) are simple and practical measures of functional exercise capacity. Interpretation of performance requires appropriate population-specific reference values and prediction equations. However, reference data for apparently healthy Ethiopian adults remain limited. This study aimed to establish reference values and develop prediction equations for six-minute walk distance (6MWD) and SCT performance among apparently healthy Ethiopian adults.

**Methods** A community-based cross-sectional study was conducted among 139 apparently healthy Ethiopian adults aged 18–55 years. Demographic and anthropometric characteristics were collected using standardised procedures. Participants performed the 6MWT and SCT according to standardised protocols. Descriptive statistics and percentile distributions were used to characterise exercise-test performance. Pearson correlation analysis was performed to assess associations between demographic and anthropometric characteristics and exercise-test performance. Multivariable linear regression analyses were conducted to identify independent predictors of 6MWD and SCT performance and to develop prediction equations.

**Results** The study included 139 participants, comprising 82 (59.0%) men and 57 (41.0%) women, with a mean age of  $26.7 \pm 7.1$  years. The overall mean 6MWD was  $587.1 \pm 72.3$  m, and the mean SCT completion time was  $0.656 \pm 0.098$  min. Men achieved a significantly greater 6MWD than women ( $613.4 \pm 68.3$  m vs.  $549.3 \pm 60.6$  m;  $p < 0.001$ ) and completed the SCT in significantly less time ( $0.624 \pm 0.084$  min vs.  $0.700 \pm 0.100$  min;  $p < 0.001$ ). Age was negatively correlated with 6MWD ( $r = -0.224$ ,  $p = 0.008$ ) and positively correlated with SCT completion time ( $r = 0.322$ ,  $p < 0.001$ ). Height and BMI were significantly associated with 6MWD, whereas weight and BMI were positively associated with SCT completion time. In multivariable analyses, age and sex were independent predictors of both outcomes. The 6MWD model explained 25.5% of the variance (adjusted  $R^2 = 0.233$ ), while the SCT model explained 24.9% (adjusted  $R^2 = 0.227$ ).

**Conclusions** This study provides population-specific reference values and prediction equations for 6MWD and SCT performance among apparently healthy Ethiopian adults. Significant sex differences were observed in both exercise tests, with men demonstrating greater walking distances and faster stair-climbing performance. Age and sex were consistent independent predictors of performance, whereas the independent contributions of

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anthropometric variables were less consistent after adjustment. These findings provide locally derived reference data that may support interpretation of functional exercise performance in Ethiopian adults. Further studies involving larger and geographically diverse populations, with external validation of the prediction equations, are warranted.

**Keywords** Functional exercise capacity · Exercise tolerance · Reference standards · Regression models · Healthy adults · Ethiopia

## Introduction

Functional exercise capacity reflects the integrated performance of the respiratory, cardiovascular, circulatory, and musculoskeletal systems during physical activity and is an important indicator of overall health status. Assessment of functional exercise capacity is useful for evaluating disease severity, monitoring treatment response, estimating prognosis, and guiding rehabilitation in individuals with cardiopulmonary and other chronic conditions [1–3].

Among field-based exercise tests, the six-minute walk test (6MWT) is one of the most widely used measures of functional exercise capacity. It assesses the distance an individual can walk on a flat surface over six minutes and provides a practical measure of submaximal exercise performance that reflects the capacity required for activities of daily living [1]. Its simplicity, safety, low cost, and reproducibility have supported its widespread use in patients with chronic obstructive pulmonary disease (COPD), interstitial lung disease, pulmonary hypertension, heart failure, post-tuberculosis lung disease, and other chronic respiratory and cardiovascular disorders [1, 2, 4]. Standardised recommendations from the American Thoracic Society (ATS) and European Respiratory Society (ERS) have further facilitated consistent administration and interpretation of the 6MWT in clinical practice and research [1, 5].

The stair-climbing test (SCT) is another practical field-based measure of functional exercise capacity. Stair climbing requires substantial cardiopulmonary and musculoskeletal effort and has been used to assess exercise tolerance, functional status, and perioperative risk, particularly in patients undergoing thoracic and cardiovascular surgery [6–10]. Because stair climbing represents a common activity of daily living and imposes a relatively high metabolic demand, the SCT may provide complementary information to the 6MWT and has been increasingly used in respiratory, cardiovascular, and rehabilitation settings [9, 11, 12].

Meaningful interpretation of both the 6MWT and SCT requires appropriate reference values derived from healthy populations. Exercise performance is influenced by demographic, anthropometric, physiological, environmental, and population-related characteristics, including age, sex, height, body weight, physical activity, and geographical factors [4, 11–14]. Consequently, prediction equations developed in one population may not accurately represent performance in another. Reference equations for six-minute walk distance (6MWD) have been developed in several regions, including Europe, North America, South America, Asia, and the Middle East, with differences in predicted performance observed across populations [4, 11–14]. Similar population-related variability has been reported for stair-climbing performance, further supporting the importance of population-specific reference data [4, 11–16].

The need for locally relevant reference values is particularly important in sub-Saharan Africa, where demographic characteristics, patterns of habitual physical activity, socioeconomic circumstances, and environmental conditions may differ from those of populations in which many existing reference equations were developed. Ethiopia has substantial geographical and lifestyle diversity, including variation in altitude, transportation patterns, and occupational physical activity, which may influence functional exercise performance. Despite the clinical and research use of functional exercise testing in respiratory medicine, pulmonary rehabilitation, cardiovascular care, and preoperative assessment, clinicians in Ethiopia may have to rely on reference equations derived from non-Ethiopian populations. The applicability of these equations to Ethiopian adults therefore remains uncertain.

To date, there is limited evidence describing reference values for both 6MWD and SCT performance in apparently healthy Ethiopian adults. Establishing locally derived reference values and prediction equations could provide a useful basis for interpreting functional exercise performance and for future clinical and epidemiological research in Ethiopia.

Therefore, this study aimed to establish reference values and develop prediction equations for 6MWD and SCT performance among apparently healthy Ethiopian adults. We additionally examined the associations of demographic and anthropometric characteristics with performance on these two exercise tests.

## Methods

### Study design and setting

A community-based cross-sectional study was conducted among apparently healthy Ethiopian adults. The study was conducted in Jimma, Ethiopia. Participants were recruited from the community and underwent standardised assessment of demographic characteristics, anthropometric measurements, and functional exercise performance.

### Study population and eligibility criteria

Adults aged 18–55 years were eligible for inclusion. Participants were considered apparently healthy based on the absence of a known history of chronic cardiopulmonary or other major medical conditions and the study eligibility assessment (Additional file 1).

Individuals with conditions that could substantially affect exercise performance or prevent safe completion of the exercise tests were excluded. Participants with incomplete data required for the planned analyses were also excluded. After application of the eligibility criteria and exclusion of participants with incomplete data, 139 participants (82 men and 57 women) were included in the final analysis.

### Sample size

The target sample size was approximately 100 participants, based on a conventional rule of 10–15 participants per predictor for the planned multivariable regression models with four candidate predictors (age, sex, weight, and height).

### Data collection and participant characteristics

Demographic and anthropometric characteristics were collected using a standardised data-collection procedure. Variables included age, sex, height, weight, and body mass index (BMI). BMI was calculated as weight in kilograms divided by height in meters squared ( $\text{kg/m}^2$ ). Quality control procedures included training of data collectors in the study protocol, calibration of measurement equipment before data collection, and daily review of completed data-collection forms for completeness and consistency. All measurements were obtained before exercise testing. Participants were assessed under standardised conditions, and the exercise tests were performed according to the study protocol.

### Six-minute walk test

The six-minute walk test (6MWT) was performed according to standardised procedures based on American Thoracic Society recommendations [1]. Participants were instructed to walk along a flat, predefined walking course for six minutes, covering as much distance as possible at their own pace. Standardised instructions and

encouragement were provided during the test. The primary outcome was six-minute walk distance (6MWD), recorded in meters. The test was performed under standardised conditions, and participants were monitored for symptoms and clinical safety throughout the procedure.

## Stair-climbing test

The stair-climbing test (SCT) was used as a second measure of functional exercise performance. Participants ascended a predefined staircase consisting of 70 steps, with a rise of 0.20 m per step, corresponding to a total vertical height of 14.0 m. Participants were instructed to ascend at their fastest safe pace. The time required to complete the prescribed stair-climbing task was recorded in minutes. The primary SCT outcome was stair-climbing completion time, with shorter completion times indicating better exercise performance.

## Statistical analysis

Data were analysed using IBM SPSS Statistics version 27 (IBM Corp., Armonk, NY, USA). Normality of continuous variables was assessed using the Shapiro–Wilk test. Continuous variables were summarised using means and standard deviations, while categorical variables were summarised using frequencies and percentages. Sex-specific differences in exercise-test performance were assessed using appropriate comparative statistical tests. Pearson correlation analysis was used to evaluate the relationships between age, height, weight, BMI, and exercise-test performance. Correlation coefficients ( $r$ ) and corresponding  $p$ -values were reported.

Multivariable linear regression analyses were performed separately for 6MWD and SCT completion time as dependent variables. Age, sex, weight, and height were included as explanatory variables in the final multivariable models. Regression coefficients, standard errors, standardised coefficients,  $p$ -values, and 95% confidence intervals were estimated. Model fit was assessed using  $R^2$  and adjusted  $R^2$ . Statistical significance was defined as a two-sided  $p$ -value  $< 0.05$ . The final prediction equations were derived from the corresponding multivariable regression models. For the regression analyses, sex was coded as a binary variable, with female participants coded as 0 and male participants coded as 1.

## Results

### Participant characteristics

A total of 139 apparently healthy adults were included in the final analysis, comprising 82 (59.0%) men and 57 (41.0%) women. The mean age of the participants was  $26.7 \pm 7.1$  years. Baseline demographic and anthropometric characteristics are presented in Table 1.

**Table 1** Demographic, anthropometric, and resting physiological characteristics of study participants

| Variable                       | Total ( $n=139$ ) | Men ( $n=82$ )   | Women ( $n=57$ ) |
|--------------------------------|-------------------|------------------|------------------|
| Age, years                     | $26.7 \pm 7.1$    | $26.4 \pm 6.5$   | $27.0 \pm 7.9$   |
| Height, cm                     | $167.0 \pm 8.0$   | $171.3 \pm 5.6$  | $160.9 \pm 6.8$  |
| Weight, kg                     | $60.3 \pm 8.8$    | $60.9 \pm 7.4$   | $59.6 \pm 10.5$  |
| BMI, $\text{kg/m}^2$           | $21.7 \pm 3.0$    | $20.8 \pm 2.3$   | $23.0 \pm 3.5$   |
| Systolic blood pressure, mmHg  | $118.2 \pm 13.4$  | $122.3 \pm 13.3$ | $112.2 \pm 11.1$ |
| Diastolic blood pressure, mmHg | $77.0 \pm 10.7$   | $78.9 \pm 10.8$  | $74.2 \pm 10.1$  |

Note: During data verification, the extreme resting heart-rate and respiratory-rate entries were identified as data-entry errors and were removed from the descriptive table. These variables were not included in the regression analyses or prediction equations. *NB*: BMI, body mass index. Values are presented as mean  $\pm$  standard deviation. Values are presented as mean  $\pm$  standard deviation

**Table 2** Reference values for six-minute walk distance among apparently healthy Ethiopian adults

| Percentile       | 6MWD (m)         |
|------------------|------------------|
| 5th              | 467.7            |
| 10th             | 492.0            |
| 25th             | 538.5            |
| 50th (median)    | 590.0            |
| 75th             | 631.5            |
| 90th             | 679.4            |
| 95th             | 700.5            |
| Statistic        | <b>6MWD</b>      |
| n                | 139              |
| Mean $\pm$ SD, m | 587.1 $\pm$ 72.3 |
| Median, m        | 590.0            |
| Minimum, m       | 420.0            |
| Maximum, m       | 765.0            |

Abbreviation: 6MWD, six-minute walk distance

**Table 3** Reference values for stair-climbing test completion time among apparently healthy Ethiopian adults

| Percentile/statistic     | SCT completion time (min) |
|--------------------------|---------------------------|
| 5th percentile           | 0.500                     |
| 10th percentile          | 0.533                     |
| 25th percentile          | 0.583                     |
| 50th percentile (median) | 0.650                     |
| 75th percentile          | 0.700                     |
| 90th percentile          | 0.783                     |
| 95th percentile          | 0.835                     |
| Mean $\pm$ SD            | 0.656 $\pm$ 0.098         |
| Minimum                  | 0.500                     |
| Maximum                  | 0.966                     |
| n                        | 139                       |

Abbreviation: SCT, stair-climbing test

## Six-minute walk distance and stair-climbing performance

The overall mean six-minute walk distance (6MWD) was 587.1  $\pm$  72.3 m, while the mean stair-climbing test (SCT) completion time was 0.656  $\pm$  0.098 min. Men achieved a significantly greater 6MWD than women (613.4  $\pm$  68.3 m vs. 549.3  $\pm$  60.6 m,  $p < 0.001$ ). Men also completed the SCT significantly faster than women (0.624  $\pm$  0.084 min vs. 0.700  $\pm$  0.100 min,  $p < 0.001$ ). The mean 6MWD was 587.1  $\pm$  72.3 m, with a median of 590.0 m and a range of 420–765 m. The 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles were 467.7, 492.0, 538.5, 590.0, 631.5, 679.4, and 700.5 m, respectively (Table 2).

## Reference values for six-minute walk distance and stair-climbing test performance

The distribution of 6MWD in the study population is presented using percentile values. The 5th, 25th, 50th, 75th, and 95th percentiles were 467.7, 538.5, 590.0, 631.5, and 700.5 m, respectively. These values provide descriptive population-specific reference data for 6MWD among the apparently healthy Ethiopian adults included in this study. The mean SCT completion time was 0.656  $\pm$  0.098 min, with a median of 0.650 min and a range of 0.500–0.966 min. The 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles were 0.500, 0.533, 0.583, 0.650, 0.700, 0.783, and 0.835 min, respectively. The distribution of SCT completion time is shown in Table 3. The 5th, 25th, 50th, 75th, and 95th percentiles were 0.500, 0.583, 0.650, 0.700, and 0.835 min, respectively. The percentile distribution indicates substantial variation in SCT performance within the study population (Table 3).

## Sex-specific exercise-test performance

Men demonstrated significantly better performance on both tests. The mean 6MWD was 613.4  $\pm$  68.3 m in men compared with 549.3  $\pm$  60.6 m in women ( $p < 0.001$ ). Similarly, mean SCT completion time was 0.624  $\pm$  0.084 min among men compared with 0.700  $\pm$  0.100 min among women ( $p < 0.001$ ). Men demonstrated significantly greater 6MWD than women (613.4  $\pm$  68.3 m vs. 549.3  $\pm$  60.6 m,  $p < 0.001$ ). Similarly, men completed the SCT significantly faster than women (0.624  $\pm$  0.084 min vs. 0.700  $\pm$  0.100 min,  $p < 0.001$ ) (Table 4).

## Correlations between demographic and anthropometric characteristics and exercise performance

Pearson correlation analysis demonstrated significant associations between participant characteristics and exercise-test performance. Age was inversely correlated with 6MWD ( $r = -0.224$ ,  $p = 0.008$ ), while height showed a

**Table 4** Sex-specific six-minute walk distance and stair-climbing test performance

| Exercise-test outcome    | Men ( <i>n</i> =82) | Women ( <i>n</i> =57) | <i>p</i> -value |
|--------------------------|---------------------|-----------------------|-----------------|
| 6MWD, m                  | 613.4±68.3          | 549.3±60.6            | <0.001          |
| SCT completion time, min | 0.624±0.084         | 0.700±0.100           | <0.001          |

Values are presented as mean±standard deviation. 6MWD, six-minute walk distance; SCT, stair-climbing test

**Table 5** Correlations Between Participant Characteristics and Exercise-Test Performance

| Characteristic | 6MWD correlation                                    | SCT correlation                                    |
|----------------|-----------------------------------------------------|----------------------------------------------------|
| Height         | $r=0.360, p<0.001$ (positive, <i>significant</i> )  | $r=-0.157, p=0.066$ (not significant)              |
| Age            | $r=-0.224, p=0.008$ (negative, <i>significant</i> ) | $r=0.322, p<0.001$ (positive, <i>significant</i> ) |
| Weight         | $r=-0.032, p=0.711$ (not significant)               | $r=0.175, p=0.039$ (positive, <i>significant</i> ) |
| BMI            | $r=-0.280, p<0.001$ (negative, <i>significant</i> ) | $r=0.301, p<0.001$ (positive, <i>significant</i> ) |



**Fig. 1** Association between age and six-minute walk distance among apparently healthy Ethiopian adults. Each point represents an individual participant. The solid line represents the fitted linear regression line. Age was negatively correlated with six-minute walk distance (Pearson  $r = -0.224, p = 0.008$ )

positive correlation ( $r=0.360, p<0.001$ ). BMI was also negatively correlated with 6MWD ( $r=-0.280, p<0.001$ ). In contrast, weight was not significantly associated with 6MWD ( $r=-0.032, p=0.711$ ). For SCT completion time, age ( $r=0.322, p<0.001$ ), weight ( $r=0.175, p=0.039$ ), and BMI ( $r=0.301, p<0.001$ ) were positively correlated, whereas height did not demonstrate a statistically significant association ( $r=-0.157, p=0.066$ ). These findings are illustrated in Table 5; Fig. 1.

Height was not significantly correlated with SCT completion time ( $r=-0.157, p=0.066$ ) (Table 6).

**Table 6** Pearson correlations between demographic and anthropometric characteristics and exercise-test performance

| Variable               | 6MWD, <i>r</i> | <i>p</i> -value | SCT completion time, <i>r</i> | <i>p</i> -value |
|------------------------|----------------|-----------------|-------------------------------|-----------------|
| Age, years             | −0.224         | 0.008           | 0.322                         | <0.001          |
| Height, cm             | 0.360          | <0.001          | −0.157                        | 0.066           |
| Weight, kg             | −0.032         | 0.711           | 0.175                         | 0.039           |
| BMI, kg/m <sup>2</sup> | −0.280         | <0.001          | 0.301                         | <0.001          |

Abbreviations: 6MWD, six-minute walk distance; SCT, stair-climbing test; BMI, body mass index. Statistical significance:  $p < 0.05$

**Table 7** Multivariable linear regression model for six-minute walk distance. A multivariable linear regression model was fitted with 6MWD as the dependent variable and age, sex, weight, and height as independent variables. The model was statistically significant and explained 25.5% of the variance in 6MWD ( $R^2 = 0.255$ ; adjusted  $R^2 = 0.233$ ;  $p < 0.001$ )

| Predictor  | B       | SE      | Standardized $\beta$ | t      | <i>p</i> -value | 95% CI for B      |
|------------|---------|---------|----------------------|--------|-----------------|-------------------|
| Constant   | 327.391 | 146.235 | —                    | 2.239  | 0.027           | 38.163 to 616.618 |
| Age, years | −2.199  | 0.854   | −0.215               | −2.575 | <b>0.011</b>    | −3.888 to −0.510  |
| Male sex   | 43.795  | 14.771  | 0.299                | 2.965  | <b>0.004</b>    | 14.582 to 73.009  |
| Weight, kg | −0.364  | 0.765   | −0.044               | −0.475 | 0.635           | −1.877 to 1.150   |
| Height, cm | 188.293 | 99.733  | 0.208                | 1.888  | 0.061           | −8.961 to 385.546 |

Model statistics:  $R^2 = 0.255$ ; adjusted  $R^2 = 0.233$ ;  $F(4,134) = 11.47$ ;  $p < 0.001$ . Abbreviations: B, unstandardized regression coefficient; SE, standard error;  $\beta$ , standardised regression coefficient; CI, confidence interval; 6MWD, six-minute walk distance. Sex coding: female = 0; male = 1

**Table 8** Multivariable linear regression model for stair-climbing test completion time. A separate multivariable linear regression model was fitted with SCT completion time as the dependent variable and age, sex, weight, and height as independent variables. The model was statistically significant and explained 24.9% of the variance in SCT completion time ( $R^2 = 0.249$ ; adjusted  $R^2 = 0.227$ ;  $p < 0.001$ )

| Predictor  | B       | SE     | Standardized $\beta$ | t      | <i>p</i> -value  | 95% CI for B       |
|------------|---------|--------|----------------------|--------|------------------|--------------------|
| Constant   | 0.449   | 0.198  | —                    | 2.263  | 0.025            | 0.057 to 0.842     |
| Age, years | 0.0038  | 0.0012 | 0.272                | 3.249  | <b>0.001</b>     | 0.0015 to 0.0061   |
| Male sex   | −0.0819 | 0.0200 | −0.414               | −4.087 | <b>&lt;0.001</b> | −0.1216 to −0.0423 |
| Weight, kg | 0.0007  | 0.0010 | 0.064                | 0.688  | 0.493            | −0.0013 to 0.0028  |
| Height, cm | 0.0667  | 0.1353 | 0.055                | 0.493  | 0.623            | −0.2010 to 0.3344  |

Model statistics:  $R^2 = 0.249$ ; adjusted  $R^2 = 0.227$ ;  $F(4,134) = 11.11$ ;  $p < 0.001$ . Abbreviations: B, unstandardized regression coefficient; SE, standard error;  $\beta$ , standardised regression coefficient; CI, confidence interval; SCT, stair-climbing test. Sex coding: female = 0; male = 1

## Multivariable predictors of six-minute walk distance

Multivariable linear regression analysis was performed to identify independent predictors of 6MWD (Table 7). The model, which included age, sex, weight, and height, accounted for 25.5% of the variance in 6MWD (adjusted  $R^2 = 0.233$ ,  $p < 0.001$ ). Age was independently associated with reduced walking distance, with each additional year corresponding to an estimated 2.20-m decrease ( $B = -2.199$ ,  $p = 0.011$ ). Male sex was significantly associated with greater 6MWD ( $B = 43.795$ ,  $p = 0.004$ ). Weight was not an independent predictor ( $B = -0.364$ ,  $p = 0.635$ ), and the association with height approached but did not reach statistical significance ( $B = 188.293$ ,  $p = 0.061$ ).

The resulting prediction equation was:  $6MWD (m) = 327.391 - 2.199 \times \text{age} + 43.795 \times \text{sex} - 0.364 \times \text{weight} + 188.293 \times \text{height}$ , where sex was coded as 0 for women and 1 for men.

## Multivariable predictors of stair-climbing test performance

Multivariable linear regression analysis was conducted to identify independent predictors of SCT completion time (Table 8). The model, which included age, sex, weight, and height, explained 24.9% of the variance in SCT performance (adjusted  $R^2 = 0.227$ ,  $p < 0.001$ ).

Age was independently associated with longer completion time, with each additional year corresponding to an estimated 0.0038-min increase ( $B=0.0038$ ,  $p=0.001$ ). Male sex was significantly associated with shorter SCT completion time ( $B=-0.0819$ ,  $p<0.001$ ). Neither weight ( $B=0.0007$ ,  $p=0.493$ ) nor height ( $B=0.0667$ ,  $p=0.623$ ) demonstrated independent associations with SCT performance. The resulting prediction equation was:

$\text{SCT time (min)} = 0.4490 + 0.0038 \times \text{age} - 0.0819 \times \text{sex} + 0.0007 \times \text{weight} + 0.0667 \times \text{height}$ , where sex was coded as 0 for women and 1 for men.

## Discussion

This study established reference values and prediction equations for six-minute walk distance (6MWD) and stair-climbing test (SCT) performance among apparently healthy Ethiopian adults. The principal findings were that men demonstrated significantly greater 6MWD and faster SCT performance than women, age was associated with poorer performance on both exercise tests, and age and sex remained independent predictors after multivariable adjustment. Anthropometric characteristics were associated with exercise performance in correlation analyses; however, height and weight did not demonstrate statistically significant independent associations in the final multivariable models. The reference values and prediction equations therefore provide preliminary, locally derived information for interpreting functional exercise performance in Ethiopian adults.

The mean 6MWD in this study was  $587.1 \pm 72.3$  m, with a median of 590 m and a range of 420–765 m. This overall performance is broadly comparable to values reported in several healthy adult populations, although differences between studies should be interpreted in the context of differences in participant characteristics and testing protocols. Enright and Sherrill developed reference equations for healthy adults based on a large North American population and demonstrated that demographic and anthropometric characteristics contribute to variation in 6MWD [2]. Similarly, the multinational reference study by Casanova et al. demonstrated substantial variation in 6MWD across seven countries, supporting the importance of population-specific reference standards [5].

Differences in 6MWD between populations may reflect variation in age, sex, body size, habitual physical activity, socioeconomic circumstances, environmental conditions, and methodological characteristics of the test [2]. The present study therefore adds locally derived information for Ethiopian adults. The median 6MWD of 590 m and the 95th percentile of approximately 701 m describe the distribution of performance in this cohort. However, the 5th percentile should be regarded as a descriptive lower reference value rather than a validated clinical threshold, because the study was not designed to establish diagnostic cut-offs.

The mean SCT completion time was  $0.656 \pm 0.098$  min, corresponding to approximately 39 s. In contrast to the 6MWT, fewer population-based reference studies are available for stair-climbing performance, and direct comparisons are complicated by differences in staircase height, number of steps, total vertical distance, instructions, and timing procedures. Stair climbing nevertheless represents a demanding functional activity that integrates cardiovascular, respiratory, and musculoskeletal capacity and has been used in assessment of exercise tolerance and perioperative functional capacity [6–10]. The present study provides descriptive reference values for SCT performance using a standardised staircase and protocol, which may facilitate comparison with future Ethiopian studies using similar procedures.

The simultaneous assessment of 6MWD and SCT is an additional strength of this study. Although both tests assess functional exercise performance, they impose different physical demands. The 6MWT primarily evaluates sustained submaximal walking performance, whereas stair climbing requires a relatively high-intensity, weight-bearing activity over a shorter duration. The availability of reference information for both tests may therefore provide complementary information when functional exercise capacity is assessed in Ethiopian adults.

A clear sex difference was observed in both exercise tests. Men achieved a mean 6MWD of  $613.4 \pm 68.3$  m, compared with  $549.3 \pm 60.6$  m among women, while mean SCT completion time was  $0.624 \pm 0.084$  min among men and  $0.700 \pm 0.100$  min among women. These differences remained statistically significant after adjustment for age, weight, and height, with male sex independently associated with greater 6MWD and shorter SCT

completion time. Sex-related differences in exercise performance have also been described in reference studies of healthy adults [2, 4, 5, 12]. Several physiological factors may contribute to these differences, including variation in skeletal muscle mass, haemoglobin concentration, lung volumes, and maximal aerobic capacity. However, the present study did not directly measure these physiological mechanisms, and therefore such explanations should be considered plausible rather than demonstrated by our data.

Age was another consistent determinant of functional exercise performance. Increasing age was associated with shorter 6MWD and longer SCT completion time. In the multivariable model, each additional year of age was associated with an estimated 2.2-m reduction in 6MWD, while SCT completion time increased by approximately 0.0038 min per year. These findings are consistent with established reference-equation studies demonstrating an age-related decline in functional exercise performance [2, 5]. The relationship is physiologically plausible because ageing is accompanied by reductions in muscle mass and strength, aerobic capacity, cardiovascular reserve, and pulmonary function. Importantly, the association with age persisted after adjustment for sex and anthropometric variables, supporting its relevance when interpreting exercise-test performance.

The correlation analyses demonstrated that height and BMI were significantly associated with 6MWD, while age, weight, and BMI were significantly associated with SCT completion time. However, the multivariable analyses provide a more appropriate basis for identifying independent predictors. After adjustment, height was not independently associated with 6MWD ( $p=0.061$ ), and weight was not independently associated with either 6MWD or SCT completion time. Similarly, height was not independently associated with SCT completion time. Thus, the present findings do not support describing height and weight as independent determinants of both exercise outcomes. Rather, their associations observed in univariable analyses appear to be partly explained by their relationships with age and sex.

The prediction model for 6MWD explained 25.5% of the variance (adjusted  $R^2 = 0.233$ ), while the SCT model explained 24.9% of the variance (adjusted  $R^2 = 0.227$ ). These findings indicate that age, sex, and the anthropometric variables included in the models explain only a proportion of the individual variability in functional exercise performance. Other factors, including habitual physical activity, occupational activity, nutritional status, socioeconomic circumstances, motivation, and other physiological characteristics, may contribute to the remaining unexplained variability. Such factors were not comprehensively assessed in the present study and should be considered in future reference-equation research.

The findings have potential clinical and research relevance. Locally derived reference values may provide a useful starting point for interpreting 6MWD and SCT performance in Ethiopian adults, particularly in respiratory and cardiovascular settings where functional exercise testing is frequently used. The equations may also provide preliminary estimates of expected performance based on age and sex. However, they should not yet be regarded as definitive clinical prediction standards, because the study was conducted in a single geographic setting, included a relatively modest sample, had limited representation of older adults, and lacked external validation. These limitations are particularly important when considering application to patients with chronic respiratory or cardiovascular disease.

## Strengths and limitations

The principal strength of this study is the simultaneous evaluation of two commonly used field-based exercise tests in apparently healthy Ethiopian adults and the generation of population-specific reference values and prediction equations. Standardised procedures were used for exercise testing, and demographic and anthropometric characteristics were evaluated systematically. The inclusion of both 6MWD and SCT provides complementary information on functional exercise performance.

Several limitations should be acknowledged. First, the study was conducted in a single geographic area, which may limit the generalizability of the findings to other Ethiopian populations with different environmental, socio-economic, and lifestyle characteristics. Second, the sample size was modest compared with large international reference studies. Third, participants were predominantly young adults, resulting in relatively limited representation

of older age groups. Fourth, habitual physical activity, occupational workload, nutritional status, and other potentially important determinants of exercise performance were not comprehensively assessed. Finally, the prediction equations were not externally validated in an independent Ethiopian population. Accordingly, the equations should be considered preliminary and require validation before widespread clinical implementation.

### Implications for future research

Future multicentre studies involving larger and geographically diverse Ethiopian populations should validate and refine these reference values and prediction equations. Studies should also examine the effects of altitude, habitual physical activity, occupational activity, socioeconomic characteristics, and other potentially relevant determinants of functional exercise performance. External validation in independent healthy cohorts should precede routine clinical application of the equations, followed by evaluation of their performance in relevant patient populations.

### Conclusion

This study provides population-specific reference values and prediction equations for six-minute walk distance and stair-climbing test performance among apparently healthy Ethiopian adults. Men demonstrated greater six-minute walk distance and faster stair-climbing performance than women, while increasing age was associated with poorer performance on both tests. Age and sex remained independent predictors of both outcomes after multivariable adjustment, whereas anthropometric variables showed less consistent independent associations. These findings provide preliminary locally derived reference data that may support the interpretation of functional exercise performance in Ethiopian adults. However, the prediction equations should be considered preliminary until externally validated in larger, geographically diverse Ethiopian populations and subsequently evaluated for their applicability in relevant clinical populations.

### Abbreviations

|                  |                                       |
|------------------|---------------------------------------|
| 6MWT             | Six-minute walk test                  |
| 6MWD             | Six-minute walk distance              |
| ATS              | American Thoracic Society             |
| BMI              | Body mass index                       |
| CI               | Confidence interval                   |
| COPD             | Chronic obstructive pulmonary disease |
| ERS              | European Respiratory Society          |
| IQR              | Interquartile range                   |
| R <sup>2</sup>   | Coefficient of determination          |
| SCT              | Stair-climbing test                   |
| SD               | Standard deviation                    |
| SEE              | :Standard error of the estimate       |
| SpO <sub>2</sub> | Peripheral oxygen saturation          |

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**Data availability** The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request. De identified participant data, the analysis code (SPSS syntax), and the study questionnaire (English version) are available as supplementary materials or can be provided upon reasonable request to the corresponding author ([kedir.negesso@ju.edu.et](mailto:kedir.negesso@ju.edu.et)).

## Declarations

**Ethics approval and consent to participate** The study was approved by the Institutional Review Board of Jimma University (Approval No. JUIH/IRB/278/25). Written informed consent was obtained from all participants before enrolment. All study procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki.

**Consent for publication** Not applicable. This manuscript does not contain any identifiable individual participant data.

**Competing interests** The authors declare that they have no competing interests.

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