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SIX-MINUTE WALK TEST AND PREDICTION EQUATION FOR SIX-MINUTE WALK DISTANCE IN HEALTHY BANGLADESHI ADULT

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ABSTRACT

Background: The six-minute walk test (6MWT) is a simple, widely used tool to assess functional exercise capacity and monitor therapeutic outcomes in cardiopulmonary diseases. Six-minute walk distance (6 MWD) varies across populations due to ethnicity and geography. In Bangladesh, data on 6 MWT and prediction equations for 6 MWD are lacking. **Objective:** To determine reference 6MWT values and develop a prediction equation for 6MWD in healthy Bangladeshi adults. **Materials and Method:** A cross-sectional study was conducted at the Department of Physiology, Dhaka Medical College, from January to December 2020. A total of 332 healthy adults aged 18–60 years were recruited and randomized into two groups: Group I (n=266) for equation generation and Group II (n=66)for validation. Anthropometric, demographic, spirometric, and 6MWT data (6MWD, heart rate, SpO_2, blood pressure, dyspnea score) were collected using a standardized protocol. Data were analyze dusing Student'st-tests, Chi-square test, Pearson correlation, and stepwise multiple regression with SPSS v26. Significance was set at $p<0.05$. **Results:** Mean 6MWD was 542±76m, with males walking significantly longer distances than females (580± 68m vs. 499 ± 61 m, $p<0.001$). Dyspnea and oxygen saturation remained stable during the test. Pearson correlation showed significant associations of 6MWD with age, height, Body Mass Index (BMI) and pre-test systolic blood pressure. Stepwise regression identified height, age, and gender as independent predictors, explaining 47% of the variance in 6MWD. The generated equation was validated in Group II. **Conclusion:** Age, height, and gender are simple, significant predictors of 6MWD in healthy Bangladeshi adults. These reference values and the prediction equation provide a benchmark for evaluating functional capacityin clinical and research settings.

Keywords: Six-minute walk test, Prediction equation, Functional capacity, Healthy adults.

INTRODUCTION

Walking is an easy and inexpensive way to measure a person's ability to perform daily activities. In individuals with chronic illnesses, functional capacity, or the ability to carry out daily tasks, is often impaired. Therefore, regular assessment of functional capacity, both at the onset and throughout treatment, is crucial[1].

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Cardiopulmonary exercise testing (CPET) is considered the gold standard for measuring functional capacity. However, it is costly, requires specialized equipment, and demands trained staff, making it less accessible to many patients, especially in primary care settings. As a result, there is a need for a simpler, cost-effective alternative that remains reliable[2,3].

The Six-Minute Walk Test (6MWT) is the most commonly used method for evaluating functional capacity. This test is straight forward and affordable, requiring the individual to walk for six minutes at their own pace on a flat surface, such as a hospital corridor. The distance walked in six minutes (6MWD) provides valuable insights into a person's health status and has been linked to mortality risk in various diseases. Studies have demonstrated that the 6MWT closely correlates with CPET results, making it a useful alternative for assessing patient health[4,5].

Currently, the 6MWT is widely used to assess patients with conditions such as heart disease, lung disease, metabolic disorders, and even during post-COVID recovery[6]. However, selecting the appropriate reference equation is crucial for accurate interpretation of a patient's fitness level and progress. Previous studies[7-14] on healthy subjects have reported significant variations in 6MWD, often due to differences in anthropometric factors, demographics, ethnic backgrounds, and the standardization methods used. Furthermore, participants' daily physical activity levels, study attitudes, and other factors may influence 6MWD. To address these variations, the American Thoracic Society (ATS)[15] recommends developing reference values for the 6MWT specific to different ethnic groups.

Although several studies have attempted to predict 6MWT results, few have validated these predictions[7,16]. A study[17] conducted in Bangladesh provided reference values for the 6MWT but did not develop a prediction equation. Therefore, there is a need to establish reference values and a prediction equation for Bengali individuals across various age groups and body types. This will enable healthcare professionals and researchers to better assess patients' health and monitor treatment progress.

The purpose of the Study

1. To measure the 6MWD in a healthy adult Bengali population.
2. To develop and test a prediction equation for 6MWD.
3. To compare the results with prediction equations from previous studies.

MATERIALS AND METHOD

This was a cross-sectional study conducted to evaluate the six-minute walk distance (6MWD) in healthy Bangladeshi adults and to develop a prediction equation. The study was carried out in the Department of Physiology, Dhaka Medical College, Dhaka, from January to December 2020.

Participants were recruited from faculty members, staff, their attendants and relatives, and patient attendants attending various inpatient and outpatient departments at Dhaka Medical College and Hospital. A total of 332 participants were selected according to the inclusion and exclusion criteria. The study included healthy Bengali adults aged 18–60 years of both sexes with BMI:<35kg/m^2. Individuals with a smoking history, hypertension, diabetes mellitus, recent thoracic surgery, pregnancy, known cardiovascular or respiratory disease, or any condition limiting physical activity were excluded. Sample size adequacy was ensured following recommended criteria for regression studies, including a minimum 10:1 participant-to-variable ratio[18,19] and the formula $N \geq 50 + 8k$[20]. Ethical approval was obtained from the Research Review Committee and Ethical Review Committee of Dhaka Medical College. Written informed consent was taken from every participant prior to inclusion in the study.

Study Variables

Independent Variables: Age, sex, height, weight, Body Mass Index (BMI), peripheraloxygen saturation (SpO_2), Modified Borg (MB) dyspnoea score 0-10[21,22], pre-and post-exercise blood pressure, pre- and post-exercise heart rate (HR), and % predicted maximum HR during 6MWT[21].

Dependent Variables: Six-minute walk distance (6MWD), inmeters.

Study Procedure

The purpose and method of the study were explained to each participant. A detailed history (personal, medical, drug and family history) was obtained, and base line measurements of blood pressure, heart rate, peripheral oxygen saturation (SpO_2), perceived dyspnoea using the MB dyspnoea score were recorded using a structured questionnaire.

Six-Minute Walk Test (6MWT)

The 6MWT was performed following ATS standardized guidelines[23]. Participants rested for atleast 10minutes prior to testing. The test was conducted on a 30-meter flat corridor marked at 3-meter intervals. Each participant was instructed to walk as far as possible for six minutes. Standardized encouragement was provided every minute. Rest was permitted without stopping the timer.

Heart rate, % predicted maximum heart rate and SpO_2 were monitored continuously. Immediately after the test, blood pressure, heart rate, SpO_2, and Borg scores for dyspnoea and leg fatigue were recorded. The distance walked was calculated from the number of completed laps.

Statistical Analysis

Data were analyzed using SPSS version 26. Continuous variables were expressed as mean ± SD, and categorical variables as percentages. Independent t-test and chi-square test were used to compare groups. Pearson correlation coefficients assessed associations between dependent and independent variables. Stepwise multiple regression analysis was performed to identify predictors of 6MWD and generate prediction equations. Paired t-test was used to compare measured and predicted 6MWD values.

RESULTS

General Characteristics of the Total Subjects (N =332)

Out of 332 healthy adults aged 18–60 years, only four subjects were excluded due to elevated blood pressure before initiation of the 6MWT. The remaining subjects were randomized into two subgroups: study group (n_S = 266) and comparison group (n_C= 66).

Both groups were comparable in baseline characteristics including age, height, weight, BMI, and 6MWD, with no statistically significant differences (Table 1).

Table1: General characteristics of the two sub groups (N=332)

Variables	Studygroup(ns=266) Mean ± SD	Comparisongroup (nc=66) Mean ± SD	p-value
Gender(n,%)	Male:140(52.6%) Female:126 (47.4%)	Male:34(51.5%) Female:32 (48.5%)	0.871
Age (years) Range	37.19±11.03 (18–60)	36.76±10.97 (18–60)	0.755
Height(cm) Range	159.31±9.33 (135–186.5)	158.89±8.12 (145–183)	0.738
Weight(kg) Range	65.40±10.82 (35.6–91.6)	64.17±11.16 (33.3–92.0)	0.415
BMI (kg/m²) Range	25.81±3.71 (16.93–34.73)	25.37±3.81 (15.20–34.92)	0.396
6MWD (m) Range	542.22±76.77 (372–750)	549.91±79.95 (390–741)	0.470

N= Total number of subjects, n_s= Study group , n_c= comparison group .Results expressed as mean±SD. *p< 0.05consideredsignificant.*

Demographic, Anthropometric and Spirometric Characteristics of Study Subjects (ns= 266)

Among the 266 study participants, 140 were males and 126 were females. Except for age and BMI, all anthropometric variables showed significant sex differences. Males were significantly taller and heavier than females ($p< 0.001$). Details are presented in Table 2.

Table 2: Demographic characteristics of the study subjects (ns=266)

Characteristics	Male (n = 140) Mean±SD(Range)	Female (n = 126) Mean±SD(Range)	*p*-value	Total (n_s = 266) Mean±SD(Range)
Age (years)	37.66± 11.09(18–60)	36.67±10.98(18–60)	0.469	37.19± 11.03(18–60)
Height(cm)	165.07± 7.56(135–185.5)	152.90± 6.53(140.5–185)	<0.001*	159.31± 9.34(135–185.5)
Weight(kg)	69.38± 10.53(35.6–91.6)	60.96± 9.33(40–89)	<0.001*	65.40± 10.82(35.6–91.6)
BMI (kg/m²)	25.44±3.36(16.93–32.8)	26.22± 4.03(17.1–34.7)	0.086	25.81± 3.71(16.93–34.7)

N= Total number of subjects, n_s= Study group ,n_c= comparison group .Results expressed as mean±SD. *p< 0.05consideredsignificant.*

Six-Minute Walk Test (6MWT) Results of the Study Subjects (ns =266)

All participants completed the 6MWT according to protocol. No test was terminated prematurely and no adverse events occurred.

The primary outcome was the six-minute walk distance (6MWD), with additional measurements including HR, SpO_2, BP, Borg dyspnea score, and % of maximal predicted HR. Significant sex differences were found in pre-and post-test HR, SBP, and 6MWD. Males walked a greater distance than females ($p < 0.001$). Results are shown in Table 3.

Table 3 : Six-minute walk test results of the study subjects (n_s=266)

Characteristics	Male(n=140) Mean ± SD (Range)	Female (n = 126) Mean±SD(Range)	Total Mean±SD(Range)	*p*-value
Pre-testHR(bpm)	80.91±10.30	86.56±9.62	83.59±10.35	<0.001*
Pre-test SpO_2(%)	98.66± 0.96(52–113)	98.73± 0.93(61–101)	98.69± 0.94(52–113)	0.525
Pre-testSBP (mmHg)	113.71± 12.70(92–100)	109.94± 14.54(96–100)	111.93± 13.71(92–100)	0.025*
Pre-test DBP (mmHg)	78.43± 6.46(80–135)	76.90± 7.95(80–135)	77.71± 7.23(80–135)	0.086
Post-testHR (bpm)	99.68± 13.64(58–144)	106.78± 12.06(77–138)	103.04± 13.37(58–144)	<0.001*
Post-test SpO_2(%)	98.48± 0.78(96–100)	98.74± 0.93(97–100)	98.70± 0.94(86–100)	0.603
Post-testSBP (mmHg)	121.14± 12.14(90–145)	115.87± 15.30(80–150)	118.64± 13.95(80–150)	0.002*
Post-testDBP (mmHg)	80.54± 6.20(60–95)	79.52± 8.33(50–95)	80.06± 7.29(50–95)	0.259
Borgscore	2.62± 0.49(2–3)	2.72± 0.50(2–4)	2.67± 0.49(2–4)	0.097
%maxHR	72.78± 7.95(52.1–92)	74.80± 8.30(56.5–95.3)	73.74± 8.17(52.1–95.3)	0.044*
6MWD (m)	580.8± 68.50(411–750)	499.37± 61.33(372–640)	542.22± 76.77(372–750)	<0.001*

N=Total subjects; ns =study subjects; n_C=comparison subjects; 6MWD=six-minute walk distance.
p< 0.05considered significant.

Six-Minute Walk Test Results of the Comparison Group (n_c=66)

The mean 6MWD of the comparison group was 549.91±79.95m. Similar to the study group, males walked significantly farther than females (*p*< 0.001). Detailed results are presented in Table 4.

Table 4: Six-minute walk test results of the comparison group (n_c= 66)

Characteristics	Male(n=34) Mean ± SD (Range)	Female(n=32) Mean ± SD (Range)	Total Mean ± SD (Range)	*p*-value
Pre-testHR(bpm)	82.24±10.66 (65–113)	88.88±10.19 (64–111)	85.45±10.88 (64–113)	0.012
Pre-test SpO_2(%)	98.88±0.73 (97–100)	98.63±1.60 (91–100)	98.76±1.23 (91–100)	0.399
Pre-testSBP(mmHg)	116.76±12.96 (90–135)	106.50±15.25 (80–135)	111.79±14.93 (80–135)	0.004
Pre-testDBP(mmHg)	78.82±6.52 (60–85)	74.68±9.21 (60–85)	76.85±8.13 (60–85)	0.039
Post-testHR (bpm)	97.29±11.07 (78–135)	108.72±14.27 (84–148)	102.83±13.87 (78–148)	0.001
Post-testSpO_2(%)	98.59±0.78 (97–100)	98.72±0.92 (96–100)	98.65±0.85 (96–100)	0.537
Post-test SBP (mmHg)	125.15±11.45 (100–140)	113.91±14.58 (85–140)	119.70±14.14 (85–140)	0.001
Post-test DBP (mmHg)	81.76±6.50 (60–90)	77.97±9.15 (60–90)	79.92±8.06 (60–90)	0.055
Borgscore	2.47±0.51 (2–3)	2.84±0.45 (2–4)	2.65±0.51 (2–4)	0.002
%maxHR	71.82±8.45 (55.8–91.1)	74.90±8.39 (57.4–92.9)	73.31±8.50 (55.8–92.9)	0.142
6MWD (m)	589.15±74.05 (396–741)	508.22±63.90 (390–660)	549.91±79.95 (390–741)	<0.001

n= Number of participants in each group within the comparison group; HR=heart rate, SBP=systolic blood pressure, DBP=diastolic blood pressure, $SpO_{2=}$oxygen saturation, 6MWD-six-minute walk distance. *p<0.05 considered significant.*

Bivariate Correlation Between 6MWD and Study Variables (n_s=266)

Pearson's correlation analysis demonstrated that 6MWD was significantly associated with age, height, BMI, and pre-test SBP in both males and females.

Age showed a strong negative correlation, height appositive correlation, and BMI a negative correlation with 6MWD. The results are summarized in Table 5.

Table 5: Correlation coefficients between 6MWD and study variables (n_s=266)

Variables	Males(n=140) r-value	r^2	p-value	Females(n=126) r-value	r^2	p-value
Age(years)	–0.465**	0.216	<0.001	–0.394**	0.155	<0.001
Height(cm)	+0.407**	0.166	<0.001	+0.202*	0.041	0.023
Weight(kg)	+0.060	0.004	0.484	–0.161	0.026	0.071
BMI (kg/m²)	–0.195*	0.038	0.021	–0.265**	0.070	0.003
Pre-testHR	–0.091	0.008	0.283	+0.095	0.009	0.292
Pre-testSpO_2	–0.138	0.019	0.104	–0.063	0.004	0.481
Pre-testSBP	–0.192*	0.037	0.023	–0.208*	0.043	0.019
Pre-testDBP	–0.151	0.023	0.075	–0.201*	0.040	0.024
Post-testHR	+0.025	0.001	0.767	+0.245**	0.060	0.006
Post-testSpO_2	–0.140	0.020	0.100	+0.059	0.003	0.509
Post-testSBP	–0.143	0.020	0.092	–0.235**	0.055	0.008
Post-testDBP	–0.120	0.014	0.158	–0.243**	0.059	0.006
Borg score	+0.016	0.000	0.847	+0.082	0.007	0.359
%maxHR	+0.121	0.015	0.155	+0.159	0.025	0.075

n= Number of participants in each group within the study group

Step wise Multiple Linear Regression Analysis

Pearson's correlation analysis identified age, height, BMI and pre-test systolic blood pressure as significant correlates of 6MWD inthe combined data set of males and females. These

variables, along with gender, were entered into a stepwise multiple linear regression model. Three models were generated (Table 6).

Among the three models, Model 3 demonstrated the best predictive accuracy, withthe highest multiple correlation coefficient (R = 0.685), the highest coefficient of determination (R^2 = 0.472), and the lowest standard error of estimate (SEE=56.12).Models 1 and 2 were there fore rejected.

Final Prediction Equation (Model 3)

6MWD(m)=245.264+(2.576×heightincm)–(2.381×age in years)–(52.395× gender)
Gender: male =0,female=1;R^2= 0.472

Height, age and gender were significant predictors (p<0.001), collectively explaining 47% of the variance in 6MWD. Height had the strongest positive association, while age and female gender were negatively associated with 6MWD. BMI, weight and other 6MWT parameters did not contribute significantly to the model.

Table 6: Step wise Multiple Linear Regression Analysis of Predictors of 6MWD (N=266)

Model	Variable	B (Unstandardized)	Std. Error	*p*- value	95% CI for B	SEE	R	R^2
1	Constant	-182.721	67.269	0.007	-315.174 to-50.268	64.07	0.553	0.306
	Height(cm)	4.551	0.422	0.000	3.721to5.381			
2	Constant	-79.932	64.291	0.215	-206.522 to 46.659	59.42	0.637	0.405
	Height(cm)	4.418	0.391	0.000	3.647to5.189			
	Age(years)	-2.196	0.331	0.000	-2.848to-1.543			
3	Constant	245.264	83.090	0.003	81.654 to 408.873	56.12	0.685	0.472
	Height(cm)	2.576	0.490	0.000	1.611 to 3.540			
	Age(years)	-2.381	0.315	0.000	-3.001 to-1.762			
	Gender (F=1, M=0)	-52.395	9.139	0.000	-70.389 to- 34.400			

Notation: B=regression coefficient; SEE =standard error of estimate; R=multiple correlation coefficient.

Reliability of the Derived Prediction Equation
In the comparison group(n=66;34males), the mean measured 6MWD was 549.91±79m. The predicted 6MWD using the newly derived regression equation was 541.6 ± 49 m. The mean difference of 7.69±10m was not statistically significant (p=0.293), confirming good reliability and internal validity of the equation (Table 7).

Comparison with Published Regression Equations
Measured 6MWD values were compared with predicted values from nine foreign reference equations. Equations from Portugal[22], USA African-Americans[12], China[13], Korea[9] and Indonesia[10] tended to overestimate the 6MWD for Bangladeshi adults. In contrast, equations from India[11], Saudi Arabia[7] and Pakistan[8] tended to underestimate the distances. All differences were statistically significant (p < 0.001) except the comparison with the present study equation (Table 7).

Table 7: Comparison of Measured and Predicted 6MWD Using Current and Foreign Regression Equations.

ReferenceEquation	Actual6MWD(m) Mean ± SD	Predicted 6MWD (m) Mean± SD	Difference(m) Mean ± SD	*p*- value
Currentstudy	549.9±79.95	541.6±49.16	7.69±10.34	0.293
Oliveiraetal. (2018)[22]	542.2±76.77	607.2±39.43	-64.9±59.3	<0.001
Fernandesetal.(2016)[11]	542.2±76.77	498.7±31.8	43.5±61.9	<0.001
Alqahtani(2017)[12]	542.2±76.77	654.7±39.31	-112.5±62.8	<0.001
Kimetal. (2018)[9]	542.2±76.77	582.0±27.9	-39.8±65.6	<0.001
Zouetal. (2017)(Male)[13]	580.8±68.5	600.1±30.5	-19.3±56.8	<0.001
Zouetal.(2017) (Female)[23]	499.4±61.3	567.7±23.2	-68.4±57.1	<0.001
Nusdwinuringtyas et al. (2014)[10]	542.2±76.77	559.1±33.3	-16.8±67.1	<0.001
Alamerietal.(2009)[7]	542.2±76.77	448.5±27.2	93.7±69.7	<0.001
Raoet al. (2013)[8]	542.2±76.77	367.4±134.6	174.7±107.3	<0.001

DISCUSSION

This is the first study to establish a prediction equation for the six-minute walk distance (6MWD) using the 6MWT in apparently healthy Bangladeshi adults.

In the present study, males walked significantly farther than females, and 6MWD was significantly correlated with age, height, and pre-test systolic blood pressure (SBP) in both sexes. Stepwise multiple regression analysis identified height, age, and gender as significant predictors, explaining 47% of the total variance ($R^2 = 0.47$). This is higher than previously published equations, where R^2 ranged from 0.20 to 0.33[8-11,13,14,23].

Some studies reported higher R^2 values (0.52–0.65) when physiological variables such as % predicted maximal HR were included[12,24]. However, these variables are only measurable after test completion and may not reliably indicate effort intensity, limiting their practical relevance[25,26].

The mean 6MWD was 542.22 ± 76 m, with males at 580.8 ± 68 m and females at 499.37 ± 61 m. The greater distance walked by males may be due to taller stature and greater muscle mass and strength[27,28]. Sex-related differences in 6MWD are widely reported in adults, though studies in children often show no such differences due to musculoskeletal similarities before adolescence[29,30].

Age was negatively correlated with 6MWD and was a predominant predictor in the regression equation, consistent with studies from multiple countries[13,22,23,31-34]. Muscle mass, strength, and maximal oxygen uptake decline with age[31,32]. Conversely, in children and adolescents, 6MWD may increase with age due to physical maturation[33,34].

Height was positively correlated with 6MWD, likely because taller individuals have longer stride lengths, increasing walking efficiency[15,18,22,23,27]. Weight was not a significant predictor, likely because the study involved only healthy adults. Previous studies report inconsistent associations between weight and 6MWD in adults[7,27,35], with some finding stronger correlations in older populations or children under 30 kg[16,26,36].

BMI was negatively correlated with 6MWD, though not included in the final regression model. Subjects with BMI >35 kg/m² were excluded, limiting the range needed to detect its effect[27].

Comparison with international prediction equations revealed systematic differences. Equations from Portuguese[22], Afro-American[12], Korean[6], and Indonesian[10] populations over estimated 6MWD, whereas equations from Indian[11], Pakistani[8], and Saudi Arabian[7] populations underestimated it. Differences may be due to variations in standardization methods, anthropometry, demographics, and racial background.

Technical aspects of 6MWT, such as corridor length and practice walks, also affect 6MWD[15]. Longer corridors and practice walks can improve walking distance due to reduced turning and learning effects. Our study followed a single 6MWT on a 30-meter corridor without practice, consistent with some previous studies. Differences in % maximal HR, pulmonary capacity, motivation, physical activity, and nutritional status may also contribute to variation between populations[7].

Our equation was prospectively validated in a separate subgroup, confirming its reliability[7,16,37]. Limitations include exclusion of socioeconomic status, physical activity scores, peripheral muscle strength, cognitive status, lean body mass, leg length, dietary habits, and psychological factors, which may influence 6MWD.

CONCLUSION

This study established the first population-specific prediction equation for the six-minute walk distance (6MWD) in apparently healthy Bangladeshi adults aged 18–60 years. Height, age, and gender were significant predictors, explaining 47% of the variance in 6MWD. Males walked significantly farther than females, and 6MWD was positively associated with height and negatively with age.

Comparison with international equations demonstrated that population-specific factors, including anthropometry, demographics, and exercise capacity, significantly influence 6MWD. The proposed equation provides a reliable reference for clinical and research assessments of functional capacity in healthy Bangladeshi adults.

Future studies should consider additional variables such as physical activity, socioeconomic status, peripheral muscle strength, and psychological factors to further improve predictive accuracy.

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CONFLICT OF INTEREST

There is no conflict of interest.

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