Original article

Walk performance in Thai men and women: physical activity dependence

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Background: Six-minute walk test (6MWT) is a measure of functional capacity and a predictor of morbidity and mortality in the elderly. Published reference equations for the six-minute walk distance (6MWD) were derived from healthy subjects with sufficient physical activity, and may not be valid for patients with limited physical activity.
Objective: To measure 6MWD in healthy individuals with sufficient (Suff) and insufficient (Insuff) levels of physical activity in Thai, and to compare the measured 6MWD with those calculated using published reference equations.
Methods: Healthy volunteers aged 45-65 years (77 men and 85 women) performed three standard 6MWT. Physical activity levels were determined using a one-week recall physical activity questionnaire. The subjects were classified as having sufficient or insufficient levels of physical activity.
Results: 6MWD of the Suff group was greater than the Insuff group in both men (701 ± 89 m *vs.* 652 ± 55 m, p = 0.005) and women (619 ± 49 m *vs.* 571 ± 35 m, p <0.001). The predicted 6MWD from published reference equations underestimated the measured 6MWD of men in Suff group, while it overestimated the measured 6MWD of women in Insuff group.
Conclusion: Level of physical activity affected 6MWD of the subjects. Published references must be carefully applied for predicting 6MWD of individuals with various levels of physical activity.

Keywords: Asian, healthy, physical activity, six minute walk test

The six-minute walk test (6MWT) is a measure of functional capacity and a predictor of morbidity and mortality [1]. It is relatively easy to administer, well tolerated and superior in reflecting activities of daily living [2]. This measurement is widely used in patients with cardiopulmonary diseases [3, 4]. Moreover, there has been proposal to use it as an indicator of overall physical capacity and mobility in the elderly [5, 6].

Factors influencing 6MWT performance have been extensively investigated. Previous studies have identified a number of factors of variability in the 6MWD [5-14]. This suggests poor reliability and generalization of the published reference equations

of 6MWD and the need to develop population specific references. According to the guideline for 6MWT by American Thoracic Society (ATS) [1], different 6MWT protocols induce difficult comparison of the results and conclusions between studies. Quite recently, Poh et al. [15] suggested that different body anthropometric characteristics and racial influences might be important in variation of 6MWD predictions. Their study supported that reference equations for 6MWD should be developed specifically to racial populations [15].

Previous studies have demonstrated that 6MWT performance was significantly associated with the levels of habitual activity and self-reported physical activity limitations in elderly individuals [5, 6]. However, some studies reported that in healthy subjects, 6MWD was not related to physical activity [11-13, 15]. Discrepancies between the studies on the relationship of physical activity and 6MWD have not been clearly revealed.

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There are recent studies [12, 13, 15] in which physical activity levels of subjects were considered as the subjects' characteristics. However, the published equations for predicting 6MWD failed to take physical activity levels fully into account [9, 13, 15, 16]. Using 6MWD reference values derived from healthy and physically-active populations may lead to unrealistic goals for planning medical care and functional improvement. In particular, this must be considered for cardiopulmonary patients whose physical activity is quite limited. It is unclear whether 6MWD of healthy persons with insufficient physical activity differs from those with sufficient physical activity.

In this study, we evaluated the influence of physical activity level as a potential factor of variability in current 6MWD reference equations. By measuring 6MWD in Thai men and women with two different levels of physical activity, we compared actual walk distance with predicted distance calculated using published reference equations for Caucasian or Asian populations.

Methods

Subjects

One hundred sixty two healthy Thai men (n=77) and women (n=85) aged 45 to 65 years volunteered for the study. The subjects were recruited from the Bangkok Metropolitan area.

Subjects were qualified for the study if they had no documented diseases or conditions listed in the exclusion criteria. Those were diagnosed cardiovascular diseases, family history of atherosclerotic diseases at early ages (first-degree relative; men before 55 years and women before 65 years), diagnosed dyslipidemia, using medications potentially affecting heart rate, history of diabetes mellitus, body mass index above $18.5\text{-}30\,\text{kg/m}^2$, resting blood pressure >150/100 mmHg, resting heart rate (HRrest) >100 beats per minute, abnormal lung function in terms of FEV1 <80% of predicted value or FEV1/FVC <70% (FEV1= forced expiratory volume for one second, FVC= forced vital capacity), upper respiratory tract infection for the past four weeks, using of ambulatory aids, leg length discrepancy >3 cm, history of claudication, severe or disabling pain of musculoskeletal origin, being pregnant, experiencing 6MWT for the past two months. All subjects provided written informed consent before participation. The study was approved by the Ethics Committee of the Faculty of Medicine, Chulalongkorn University.

Baseline measurement (physical and physiological)

Height, weight, leg length, normal and fast stride lengths, resting heart rate, and blood pressure were determined to provide baseline characteristics of the subjects. Leg length on both sides was measured while the subjects lied on their back and was taken as the distance from anterior superior iliac spine to medial malleolus. When leg length discrepancy was less than 3 cm, the average value was used for data analysis. Normal and fast stride lengths were measured while the subject was walking 10 normal and 10 fast steps, respectively. The averages of 10 steps of normal walk and fast walk were collected for data analyses. FEV1 and FVC were measured as the parameters of pulmonary function using a handheld spirometer (Spirobank®, MIR, Rome, Italy).

Physical activity determination

All subjects completed a subjective physical activity questionnaire verbally conducted by one investigator to determine the amount of physical activity performed in the previous week [17]. Questionnaire responses were used to classify the subjects, based on the number of minutes undertaking moderate to vigorous physical activities, as sufficient (>150 minutes per week) physical activity, insufficient (30-150 minutes per week) physical activity for health benefits, or inactive (<30 minutes per week). Individuals who were inactive were included in the group of insufficient physical activity. The specific detail on definition of physical activity levels was referred to the report of Survey of Physical Activity Levels of Western Australian Adults 1999 [17]. Metabolic equivalent (MET) for intensity stratification of physical activity was determined according to the published database [18]. Energy expenditure per week (kcal/week) was calculated by (MET) x (weight) x (hours)/(week) of moderated to vigorous activities lasting more than 10 minutes.

Six-minute walk test

Subjects were asked to abstain from food, caffeine, all tobacco products, and alcohol for six hours prior to testing. In addition, vigorous physical activity was not allowed in the previous 24 hours. The 6MWT sessions were performed within seven days of the first screening day. Three consecutive 6MWTs were completed within one day.

During the test, the subjects wore comfortable clothing and appropriate walking shoes. The 6MWT protocol was based on published guidelines [1], using a straight 30 meters indoor track with each one meter of the track length marked by a piece of adhesive tape. Subjects performed three 6MWTs separated by 20-minute rest intervals. The next walk test was conducted only when the heart rate had returned to resting level. During all walk tests, the heart rate was checked each minute via a heart rate monitor (Polar, Kempele, Finland). At the end of each 6MWT, a glass of water was offered to the subjects. Encouragement was given in a standardized fashion according to the guidelines for the 6MWT [1].

Data analysis

Standard statistical methods were used to calculate mean and standard deviation (SD). Repeated one-way ANOVA and pair-wise comparisons with Bonferroni adjustment were used to compare variables between the three tests. Unpaired t-test was used to compare 6MWD between subjects with sufficient and insufficient physical activity, and between men and women.

The measured 6MWD was compared with the predicted values calculated using the regression equations by Poh et al. [15] and Camarri et al. [13] as follows:

Poh et al. equation
$$6MWD\ (m) = 5.50\ (\%predHRmax) + 6.94\ (height, cm) - 4.49\ (age, year)$$
$$- 3.51\ (weight, kg) - 473.27. \tag{1}$$

Camarri et al. equation
$$6MWD\ (m) = 64.69 + 3.12\ (height, cm) + 23.29\ (FEV1, litre). \tag{2}$$

To compare actual walk distance (AWD) and predicted walk distance (PWD), we introduce the percentage difference:

% Difference of walk distance =
(PDH-AWD)/(AWD) (x100%). (3)

The greatest distance of the three tests were used when the data were compared between groups. Intraclass correlation coefficient and coefficient of variation were calculated to determine reproducibility of the 6MWD.

The relationships between maximum 6MWD (best of the three tests), subject's physical characteristics (age, sex, height, weight, BMI, leg length, normal stride length, and fast stride length), FEV1, mean HR (heart rate averaged during the 6MWT), peak walking heart rate (expressed as percentage of age-predicted maximal heart rate, %predHRmax), and energy expenditure per week was examined using Pearson's univariate correlation coefficients (r). Forward stepwise multiple regression analysis was performed to determine their contribution to maximum 6MWD. Analyses were performed using the SPSS computer package (Version 14). An alpha value of 0.05 was used to determine statistical significance.

Results
Characteristics of the subjects

Characteristics of the participants, classified by having sufficient physical activity and insufficient physical activity, were shown in **Table 1** and **2**. Individuals who were sedentary (6 men and 10 women) were included in the groups with insufficient levels of physical activity.

Six-minute walk distance

Among our healthy subjects, there were no premature terminations of 6MWT. None of the subjects required a rest during 6MWT. The averaged maximum of 6MWD was 635 ± 75 m (range 489-994 m) for the whole group. 6MWD increased significantly between test 1 and test 2 (598 ± 70 *vs.* 614 ± 74 m, $p < 0.001$) and between test 2 and test 3 (614 ± 74 *vs.* 629 ± 75 m, $p < 0.001$). Maximum walk distance was significantly greater ($p < 0.001$) in the men (677 ± 77 m; range 517-994 m) than the women (597 ± 49 m; range 489-743 m). The intraclass correlation coefficient for the three tests was 0.95 and the coefficient of variation was 12.07%.

Walk distance was greater in subjects with sufficient activity than in those with insufficient activity (657 ± 81 m *vs.* 612 ± 62 m, $p < 0.001$). In men, the sufficient activity group had significantly greater 6MWD than the insufficient activity one (702 ± 89 and 653 ± 56 m, p=0.005). Likewise, women with sufficient activity had a significantly greater 6MWD than women with insufficient activity (620 ± 49 and 571 ± 35 m, $p < 0.001$).

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Table 1. Physical characteristics of the subjects. Values are expressed as means±SD.

Characteristics	Men with sufficient activity (n=37)	Men with insufficient activity (n=40)	Women with sufficient activity (n=45)	Women with insufficient activity (n=40)
Age (year)	52.7±5.7	54.4±5.2	53.8±6.0	54.6±5.1
Weight (kg)	67.4±6.7	68.4±7.2	55.0±7.6	56.2±6.8
Height (cm)	168.6±5.0	168.4±5.8	154.6±5.9	155.8±4.9
Body mass index (kg/m²)	23.7±2.2	24.1±2.3	22.9±2.6	23.1±2.4
Leg length (cm)	85.0±3.7	85.0±4.2	78.0±4.0	78.8±3.5
Normal stride length (m)	0.68±0.09	0.67±0.06	0.61±0.08	0.59±0.09
Fast stride length (m)	0.92±0.09	0.89±0.07	0.77±0.08	0.74±0.07

Table 2. Physiological characteristics at rest of the subjects.

Characteristics	Men with sufficient activity (n=37)	Men with insufficient activity (n=40)	Women with sufficient activity (n=45)	Women with insufficient activity (n=40)
Systolic blood pressure (mmHg)	117.1±14.1	118.7±11.5	114.4±11.2	113.2±11.7
Diastolic blood pressure (mmHg)	82.2±8.4	81.7±8.8	76.1±9.9	76.5±8.4
FEV1 (litre)	3.23±0.46	3.11±0.43	2.22±0.39	2.18±0.31
FVC (litre)	3.64±0.52	3.51±0.51	2.48±0.44	2.43±0.43
FEV1/FVC (%)	89.08±7.74	89.21±9.18	89.99±8.20	90.50±7.78
Resting heart rate (beat/minute)	68.4±10.4*	73.8±11.0	72.8±7.4	74.7±7.9
Mean heart rate (beat/minute)	124.0±17.7	128.5±19.4	127.5±13.2	129.1±14.1
%PredictHRmax	79.1±12.2	82.7±13.7	82.9±10.7	83.0±10.2

%predHRmax = percentage of age-predicted maximal heart rate. Significant difference between men with sufficient and insufficient activity, *p = 0.03. Values are expressed as means±SD.

The measured (actual) walk distance (AWD) was compared to the predicted walk distance (PWD) using Poh et al. equation (1) and Camarri et al. equation (2) (**Table 3**). As a whole group, individuals with sufficient physical activity performed (657±81 m) better than predicted values by Poh et al. equation (1) (641±69 m, p<0.05) and Camarri et al. equation (2) (629±41 m, p<0.001). Walk distance, predicted by both equations, overestimated actual distance covered by our subjects who had insufficient physical activity (612±62 m, p<0.001 for comparisons with both predicted values).

Men with sufficient physical activity walked a greater distance by 42±64 m (p<0.001) and 36±91m (p <0.05) than those predicted by Poh et al. (1) and

Camarri et al. equation (2), respectively. On the contrary, women with insufficient physical activity walked a shorter distance by 51±47 m (p<0.001) and 30±33 m (p<0.001) than those predicted by Poh et al. (1) and Camarri et al. equation (2), respectively. In addition, women with sufficient physical activity walked a greater distance by 20±50 m (p <0.05) than those predicted by Camarri et al. equation (2).

Pearson correlation analyses showed that there was a relationship between 6MWD and height (r=0.52, p <0.001), leg length (r=0.46, p <0.001), normal stride length (r=0.32, p <0.001), fast stride length (r=0.52, p <0.001), weight (r=0.32, p <0.001), FEV1 (r=0.44, p <0.001), energy expenditure/week (kcal/wk) (r = 0.49; p < 0.001), mean HR (r = 0.25; p = 0.001),

Table 3. The actual walk distance and the predicted walk distances by Poh et al. equation (1) and Camarri et al. equation (2) in Thai men and women.

	Men with sufficient activity (n=37)	Men with insufficient activity (n=40)	Women with sufficient activity (n=45)	Women with insufficient activity (n=40)
Actual walk distance (AWD, m)	702±89	653±56	620±49	573±36
Poh et al. equation (1)				
Predicted walk distance (PWD, m)	660±77**	670±87	626±59	623±62**
% Difference of walk distance (equation 3)	-6.0%	2.6%	1.1%	8.9%
Camarri et al. equation (2)				
Predicted walk distance (PWD, m)	666±24*	663±25	599±25*	602±19**
% Difference of walk distance (equation 3)	-5.1%	1.5%	-3.2%	5.2%

Values are expressed as mean±SD, *$p < 0.05$, compared to AWD. **$p < 0.001$, compared to AWD.

%predHRmax (r=0.24, p=0.002), and sex (r=0.53, p<0.001) but not with age (r= -0.08, p=0.337), nor body mass index (r=-0.04, p=0.586).

Significantly high correlations were demonstrated between height and leg length (r=0.92, p<0.001), and between normal stride length and fast stride length (r=0.70, p<0.001). In addition, height was strongly correlated with normal stride length (r=0.48, p<0.001) and fast stride length (r=0.67, p<0.001). Significantly high correlation was found between meanHR and %predHRmax (r=0.97, p<0.001), and between weight and body mass index (r=0.73, p<0.001).

In stepwise multiple regression, sex, weekly energy expenditure, mean HR, fast stride length, weight and height were identified as independent contributors to 6MWD and together explained 58% of the variance in 6MWD (p<0.001).

The prediction equations were also determined according to physical activity classification. The variance in 6MWD can then be distinctively explained when the model was separately derived from the subjects with sufficient physical activity and insufficient physical activity. In the sufficient physical activity group, sex, mean HR, and weekly energy expenditure were independent contributors of 6MWD explaining 52% of the variance in 6MWD (p<0.001). In the insufficient physical activity group, height, fast stride length, mean HR, and sex were independent contributors of 6MWD explaining 57% of the variance in 6MWD (p<0.001).

Discussion

The present results demonstrated that 6MWD of healthy subjects aged 45-65 years was significantly related with the levels of physical activity. Both men and women with sufficient physical activity walked a greater distance than their counterparts did with insufficient physical activity. Walk distance predicted by the reference equations derived from both Asian or Caucasian subjects [13, 15] generally made underestimation and overestimation when the subjects were classified by sufficient and insufficient physical activity. As a whole group, predictors of 6MWD were sex, weekly energy expenditure, mean HR during walk test, fast stride length, weight, and height.

A number of previous studies showed either positive [5, 6] or no effect [11, 13, 15] of physical activity on walk performance. These conflicting results might be due to the variation of the subject characteristics, study designs, and physical activity measurements. In fact, the majority (86-90%) of subjects in the previous studies [13, 15] reported their physical activity as sufficient for health benefits according to the published guideline [9], thus diluting the influence of the insufficient activity in a much smaller number of subjects. In the group of individuals who were physically active, the effect of physical activity might not be distinctive. In our study, individuals with sufficient physical activity had a better 6MWD than ones having insufficient physical activity. This was evident even when analyses were performed in men

or women. Similar to the previous studies [11, 13, 15], our subjects appeared healthy. Hence, the discrepancy could be mainly because the present study was particularly designed to investigate the effect of physical activity. Our result clearly demonstrated that physical activity significantly influence walk performance in healthy individuals. Thus, it may be suggested that the effect of physical activity levels should be taken into account when using reference equations.

In order to reduce the prediction variation originating from diversity of 6MWT protocols, we compared our results with the studies by Poh et al. [15] and Camarri et al. [13] as they followed the ATS guidelines for 6MWT [1]. Similar to the result of the previous study [15], we found that the maximum distance was mostly attained in the third round test. This was likely due to familiarization and learning effect, as previously demonstrated [7, 19-21].

Diversity of the characteristics of the population may have been one of the key factors causing error of prediction. The non-homogeneity of physical activity of the subjects being studied is likely to play a role on such problem. In recent studies [13, 15] recruited healthy subjects were in majority of sufficient physical activity. Yet their predictions underestimated the distance covered by our subjects, men in particular, with sufficient activity as shown in **Table 3**. The underestimation could be partly due to the contaminating effect of non-homogeneous physical activity of the minority subjects having insufficient physical activity in their studies.

In the present study, difference in 6MWD between the sufficient and insufficient physical activity groups is approximately 50 meters (**Table 3**). This different distance may be meaningful after a course of therapy in certain disease patients. According to Holland et al [22], only a 29-34 meter improvement in 6MWD indicated a clinical significance in patients with diffuse parenchymal lung disease. Furthermore, 6MWD may not solely be used as the outcome before and after therapy. The reference value derived from specific levels of physical activity would inform how far the patient is from the standard. This could be easily perceived by the patient as one of the treatment targets.

Published regression equations derived from Caucasian subjects overestimated 6MWD of Singaporean Chinese men and women [15]. This evidence supported the notion that there is racial influence on 6MWT performance. Accordingly, reference of 6MWD should be racial specific. However, when compared to the predictions obtained from either Caucasians [13] or Asians [15], the sufficient physical activity subjects had a greater walk distance and the insufficient physical activity subjects had a shorter walk distance. Therefore, the effect of physical activity may override the effect of race or racial associated body anthropometric characteristics. It is of special interest that in Thai women with insufficient physical activity the predicted 6MWD from both Caucasian and Asian equations overestimated the actual 6MWD. This overestimation is likely to result in an unrealistic goal for chronically ill female patients who mostly have difficulties maintaining sufficient physical activity.

Conclusion

6MWD differed between healthy individuals with sufficient and insufficient levels of physical activity. Physical activity classification affects the results of prediction equations both in both men and women. Using the published reference equations without physical activity consideration should be cautiously interpreted particularly for patients with limited functional abilities.

Acknowledgements

References

1. American Thoracic Society. ATS Statement: Guidelines for the six-minute walk test. Am J Respir Crit Care Med. 2002; 166:111 -7.

2. Solway S, Brooks D, Lacasse Y, Thomas S. A qualitative systematic overview of the measurement properties of functional walk tests used in the cardiorespiratory domain. Chest. 2001; 119:256-70.

3. Pashkow P, Ades PA, Emery CF, Frid DJ, Houston-Miller N, Peske G, et al. Outcome measurement in cardiac and pulmonary rehabilitation. J Cardiopulm Rehabil. 1995; 15:394-405.

4. Peeters P, Mets T. The 6-minute walk as an appropriate exercise test in elderly patients with chronic heart failure J Gerontol A Biol Sci Med Sci. 1996; 51:M147-51.

5. Harada ND, Chiu V, Stewart AL. Mobility-related

function in older adults: assessment with a 6-minute walk test. Arch Phys Med Rehabil. 1999; 80: 837-41.

6. Lord SR, Menz HB. Physiologic, psychologic, and health predictors of 6-minute walk performance in older people Arch Phys Med Rehabil. 2002; 83:907-11.

7. Wu G, Sanderson B, Bittner V. The 6 minute walk test: how important is the learning effect? Am Heart J. 2003; 146:129-33.

8. Bautmans I, Lambert M, Mets T. The six-minute walk test in community dwelling elderly: influence of health status. BMC Geriatr. 2004; 4:6.

9. Enright PL, Sherrill DL. Reference equations for the six-minute walk in healthy adults. Am J Respir Crit Med. 1998; 158: 1384 -7.

10. Chetta A, Zanini A, Pisi G et al. Reference values for the 6-min walk test in healthy subjects 20-50 years old. Respir Med. 2006; 100: 1573-8.

11. Gibbons WJ, Fruchter N, Sloan S, Levy RD. Reference values for a multiple repetition 6 minute walk test in healthy adults older than 20 years. J Cardiopulmonary Rehabil. 2001; 21: 87-93.

12. Troosters T, Gosselink R, Decramer M. Six minute walking distance in healthy elderly subjects. Eur Respir J. 1999; 14: 270-4.

13. Camarri B, Eastwood PR, Cecins NM, Thompson PJ, Jenkins S. Six minute walk distance in healthy subjects aged 55-75 years. Respir Med. 2006; 100: 658 -65.

14. Ben Saad H, Prefaut C, Tabka Z, Mtir AH, Chemit M, Hassaoune R, et al. 6-minute walk distance in healthy North Africans older than 40 years: influence of parity. Respir Med. 2009; 103:74-84.

15. Poh M, Eastwood PR, Cecins NM, Ho KT, Jenkins SC. Six-minute walk distance in healthy Singaporean adults cannot be predicted using reference equations derived from Caucasian populations. Respirology. 2006; 11: 211-6.

16. Enright PL, Mary AM, Vera B, Tracy RP, Robert M, Alice A, et al. The 6-min walk test; a quick measure of functional status in elderly adults. Chest .2003; 123: 387-98.

17. Bull F, Milligan R, Rosenberg M, MacGowan H. Physical activity levels of Western Australian adults 1999. Health Department of Western Australia and Sport and Recreation Way2GO. Western Australian Government, Perth, 2000.

18. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc. 2000; 32(9Suppl): s498-504.

19. Knox AJ, Morrison JFJ, Myers MF. Reproducibility of walking test results in chronic obstructive airways disease. Thorax. 1988; 43:388-92.

20. Hamilton DM, Haennel RG. Validity and reliability of the 6-minute walk test in a cardiac rehabilitation population J Cardiopulm Rehabil. 2000; 20:156-64.

21. Kervio G, Carre F, Ville NS. Reliability and intensity of the six-minute walk test in healthy elderly subjects. Med Sci Sports Exerc. 2003; 35:169 -74.

22. Holland AE, Hill CJ, Conron M, Munro P, McDonald CF. Small changes in six-minute walk distance are important in diffuse parenchymal lung disease. Respir Med. 2009; 103:1430-5.