Developing Standard Reference Data for Thai Children from a Six-Minute Walk Test

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Background: *The six-minute walk test (6MWT) is a useful test for pre-and post-treatment comparisons, measuring functional status and predicting morbidity and mortality. The test is not widely used with children because the exact reference data in healthy children are often not known and the test requires concentration and co-operation from the participants, which is harder to manage in children. Data for children have been studied in many countries, but data for Thai children is limited.*
Objective: *To establish reference values for a six-minute walking distance (6MWD) of healthy Thai children aged between 9 and 12 years.*
Material and Method: *A cross-sectional study was conducted in healthy children attending the 4 to 6 grades of seven primary schools in Songkla province in southern Thailand. The tests were conducted according to the American Thoracic Society (ATS) guidelines between June and September 2008. The potential variables were evaluated for their relations and confounding factors. Reference curves were developed.*
Results: *Seven hundred thirty nine students were recruited for the study, 403 boys (54.5%) and 336 girls (45.5%). Only one girl could not complete the test. The mean 6MWD was 677 (± 62.2) meters. The average walking distance was 36.4 meters greater in boys than girls (693.5 and 657.1 meters, respectively). The walking distance increased with age from 9 to 12 years of age in boys, but it decreased with age in girls after 11 years old. There were no unexpected events during or after the tests. Multivariate analysis showed that the 6MWD correlated to age, sex, weight and heart rate differences. Age-specific centile curves of 9 to 12 years for the 6MWD in each sex were developed.*
Conclusion: *6MWT, a practical simple test, is one of several modalities for objective evaluation of functional exercise capacity. The reference value of 6MWT for healthy Thai children aged 9 to 12 years was calculated and reported.*

Keywords: *Reference, Six-minute walk test, Children*

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Exercise is physical exertion of the body. The aim of exercise is to develop and maintain physical fitness in all human organ systems, especially the cardiovascular, respiratory, metabolic and musculoskeletal systems, which work in harmony. Diseases or morbidities can affect this important activity.

An exercise test is a tool or modality to assess the overall human bodily functions, although mainly the cardiovascular and respiratory systems. Nowadays, there are many tests used for the evaluation of exercise performance, including complicated, expensive methods that provide good information but need specialist instructors and uncomplicated methods that are less expensive and easy to perform but lack rigorous information. The selection of the test chosen often depends upon individual measurement strategies and resources[1].

The walk test represents a submaximal level of functional capacity, which reflects normal daily activities. Subsets of the walk test include time-based tests (*e.g.* the six-minute walk test (6MWT) or the twelve-minute walk test (12MWT)), fixed-distance tests (*e.g.* the one-mile walk test), controlled-pacing incremental tests (*e.g.* the incremental shuttle walk test) and velocity-determined walk tests (*e.g.* the self-paced walk test)[2]. A systematic review of the measurement properties of functional walk tests found that the 6MWT is easy to conduct and is safer, better endured and more reflective of daily activities than other walk tests[2]. Another previous study

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demonstrated that the 6MWT is a valid and reliable functional walk test for healthy children[3].

According to the published guidelines of the American Thoracic Society (ATS), a 6MWT should be administered in a clinical setting[1,4]. Currently, the main applications for giving a 6MWT are pre- and post-treatment comparisons of certain parameters, measuring functional status and predicting morbidity and mortality[1,4]. Although it is a useful test in a clinical setting, it is not widely used in pediatric practice due to the lack of reference data in healthy children and the test needs concentration and co-operation from the participants, which is more difficult to obtain in children than in adults. At present, only a few studies have established data for healthy children[5-7], and most of those studies were conducted in Europe or America. Recently, the first study attempting to establish standard reference data in healthy Asian children aged 7-16 years was published[8]. Our objective was to develop a user friendly and replicable 6MWT reference range of data for Thai children.

Material and Method

Healthy Thai children from the 4 to 6 grades of primary schools in Hat Yai municipality, Songkla province, were randomly recruited in this study. The principal of each school randomly selected healthy students whose parents agreed to their child's participation and gave informed consent. The exclusion criteria were children with underlying diseases, especially cardiovascular diseases, respiratory diseases or neuromuscular diseases, history of acute illness within the two weeks prior to selection, a history of taking medication that might affect the walk test, and unobtainable informed consent. The record form included questions such as date of birth, underlying diseases, long-term medications, exercise time and TV watching time. The data collection was conducted between June and September 2008. The selected children were interviewed by researchers and examined by physicians to confirm their status as eligible subjects. Height and weight were measured in the standard position using a Harpenden stadiometer and a beam balance scale. Leg length measured the distance from the anterior superior iliac spine (ASIS) to the medial malleolus in the upright position using a standard tape.

Six-minute walk test

The 6MWTs were performed according to the ATS guidelines[1,4]. The technicians who administered the 6MWTs were informed about and trained to use the standard protocol. The tests were conducted between 8.30 am and 11.30 am at a location established on the grounds of each school. The five 30-meter walking courses were measured on long, flat, straight, hard ground by a standard 30-meter tape. The walking courses were marked at every meter. The starting lines and turnaround points were also marked. The overall distance of each lap was 60 meters. The participants were told to wear comfortable clothes and appropriate shoes and to avoid vigorous exercise for at least two hours before the test. A warm-up period before the test was not permitted, but a light meal was allowed. The participants had to rest in a chair, located near the starting line, at least 10 minutes before beginning the test. During this waiting period, respiratory rate, pulse rate and blood pressure were measured and the participants were asked to rate their baseline fatigue or dyspnea using the rating of perceived exertion Borg CR10 scale (Table 1)[9]. The technicians were instructed to give their test directions in a standard way and they demonstrated the procedure to the participants. The technicians arranged the participants in groups with five subjects or less per group on the starting line. A standard stopwatch was used to time the six minutes of each test. A rubber band was given to each participant after completing each lap as a counting token. During the testing, the technicians used standard phrases of encouragement to encourage the participants in the same way. When the six minutes was completed, the participants were told to stop walking. For each participant, the rubber bands were counted and the partial additional distance was recorded using the markers on the course and the total distance walked was recorded. Respiratory rate, pulse rate and blood pressure were measured and the participants were asked to rate their post-walk Borg CR10 scale score by the same technicians. Post-walk symptoms such as dizziness, chest discomfort, leg or thigh pain and syncope were asked for and recorded. The participants were congratulated and offered a drink of water and after a few minutes rest were sent back to their classes.

Statistical analysis

Descriptive statistics including mean, standard deviation (SD) and percentiles were used. The comparison of factors between the two groups was determined using the Student's t-test.

The variables (age, weight, height, leg length, exercise time, TV watching time, resting respiratory

rate, resting heart rate and heart rate differences) were evaluated in relation to the six-minute walking distance (6MWD) by univariate analysis with the Spearman's correlation test then adjusted to multivariate analysis using forward stepwise multiple linear regression. Analyses were performed using R software. The p-value < 0.05 indicated statistical significance.

The median, SD and third, fifth, tenth, twenty-fifth, fiftieth, seventy-fifth, ninetith, ninety-fifth and ninety-seventh centiles of the 6MWD at ages 9, 10, 11, and 12 years were computed independently for boys and girls. Centile charts were constructed using the maximum penalized likelihood LMS method. Median (M) and standard deviation (SD) were calculated for each age. The 6MWD of each age (yr) in each centile (α) was derived from[10].

$$6MWD(yr)_{\alpha} = M(yr) + [SD(yr) \times Z_{\alpha}]$$

; Where Z_{α} is the α centile of the normal distribution.

The study was approved by the Ethics Committee of the Faculty of Medicine, Prince of Songkla University.

Results

Seven hundred thirty nine students, 403 boys (54.5%) and 336 girls (45.5%), were recruited from seven primary schools and participated in the 6MWT. Only one eleven-year-old-girl could not complete the test. In this case, the test was terminated due to tiredness and dizziness after she had walked for four minutes and had covered 420 meters. A physical examination in this girl was unremarkable and symptoms improved shortly after rest. All others completed the test without cessation.

The demographic characteristics of the participants are given in Table 2. The mean age of the students was 11.1 years. Girls were significantly taller

Table 1. Ratings of perceived exertion of the Borg CR10 scale

Rating	Perceived exertion	Remark
0	None at all	How you feel when lying in bed or sitting in a chair relaxed
1	Very little	Little or no effort
2	Little	Target range: How you should feel with a little exercise or activity, such as normal walking
3	Moderate	
4		
5	Strong	
6		
7	Very strong	How you felt after the hardest work you have ever done
8		
9		
10	Extremely strong	Don't work this hard!

Table 2. Demographic characteristics and the six-minute walk test results

	Boys (n = 403)	Girls (n = 336)	p-value	Total
Age (yr)	11.2 (1.0)	11.0 0.9)	0.016	11.1 (1.0)
Weight (kg)	34.8 (9.5)	36.0 (9.9)	0.107	35.3 (9.7)
Height (cm)	140.3 (8.9)	142.4 (8.3)	<0.001	141.3 (8.7)
Resting RR (cycles/min)	19.9 (1.9)	20.5 (2.0)	<0.001	20.2 (2.0)
End of exercise RR (cycles/min)	29.5 (5.2)	30.1 (5.6)	0.094	29.8 (5.4)
Resting HR (beats/min)	83.0 (10.3)	87.3 (10)	<0.001	85.0 (10.4)
End of exercise HR (beats/min)	113.1 (15.2)	119.1 (14.4)	<0.001	115.8 (15.1)
Resting systolic BP (mmHg)	103.4 (11.4)	104.2 (12.7)	0.365	103.7 (12)
End of exercise systolic BP (mmHg)	113.7 (14.4)	116.1 (14)	0.026	114.8 (14.3)
Resting diastolic BP (mmHg)	63.6 (10.8)	64.9 (10.8)	0.1	64.2 (10.8)
End of exercise diastolic BP (mmHg)	68.1 (13.5)	71.6 (12.6)	<0.001	69.7 (13.2)
Six-minute walk distance (m)	693.5 (65.7)	657.1 (51.1)	<0.001	677.0 (62.2)

than boys. The mean resting respiratory rate, heart rate, and blood pressure were within normal values. The children spent about 9 hours per week on average watching television with only 3.6 hours per week for exercise.

The mean 6MWD was 677 (± 62.2) meters, and was 36.4 meters greater in boys than girls (693.5 vs. 657.1 meters, respectively). Generally, distance increased with age in both sexes, although there was a slight decrease in distance in girls over 11 years of age (Fig. 1). Average heart rate increased about 40% from baseline. The maximum heart rate and systolic blood pressure were 164 beats/min and 180 mmHg, respectively. Resting respiratory rate and heart rate were significantly greater in girls, but at the end of the test, there were no differences between sexes. The average difference between systolic blood pressures was greater than between diastolic pressures (11.1 vs. 5.5 mmHg, respectively). At the end of the tests, most of the subjects perceived a moderate degree of exertion (mean Borg scale = 5.7). Thigh or leg pain was the most common complaint of the participants after the test (16.9%), whereas chest discomfort and dizziness were uncommon (8.5% and 4.3%, respectively). There were no unexpected events during and after the tests.

Univariate analyses between the 6MWD and demographic characteristics showed age, sex, weight, time spent watching TV and heart rate differences correlated well to the 6MWD. The more time spent TV watching, the less distance covered in the 6MWD. Multivariate analysis between 6MWD and demographic characteristics showed only age, sex, weight and heart rate differences correlated to 6MWD (Table 3). Age, male gender and heart rate differences correlated positively to walking distances, but weight did not. Finally, centile curves were constructed based on our findings. The age-specific centile curves are

Table 3. Multivariate analysis between 6MWD and demographic characteristics

	Adjusted coefficient (95% CI)	p-value
Age (yr)	18.68 (12.79, 24.56)	< 0.001*
Sex (girls vs boys)	-35.47 (-43.84, -27.1)	< 0.001*
Weight (kg)	-2.27 (-2.89, -1.66)	< 0.001*
Heart rate difference (beats/min)	0.55 (0.26, 0.84)	< 0.001*

* Indicates statistical significance

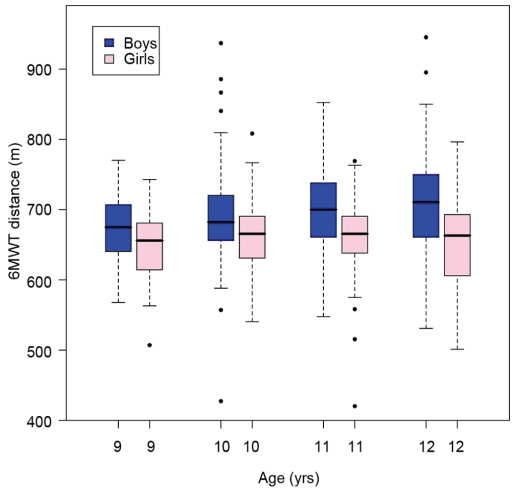

Fig. 1 6MWD in boys and girls in each age group

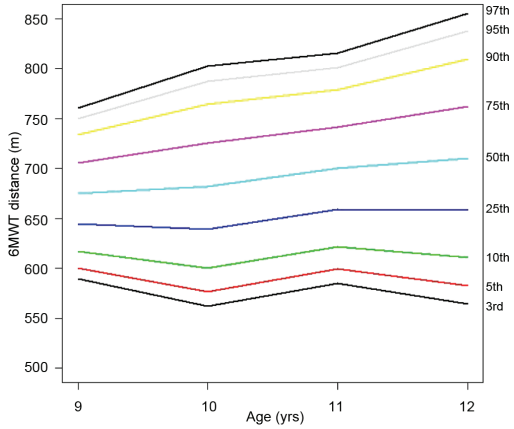

Fig. 2 Centile curves for 6MWD in boys

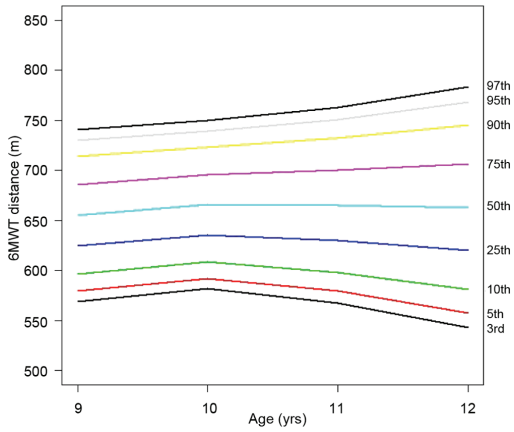

Fig. 3 Centile curves for 6MWD in girls

shown in Fig. 2 and 3 for the 6MWD for boys and girls, respectively.

Discussion

The 6MWT is accepted as a valid and reliable functional walk test for healthy children[3]. It is feasible and useful, easy to conduct, inexpensive, safe and well endured by young children[2].

This is the first study that attempts to provide standard reference data for the 6MWD of healthy Thai children aged 9-12 years. This data may be useful in clinical settings for different purposes when the test is performed according to the standard guidelines[1,4]. The evaluation of the functional status of certain patients can be done using our normal reference values. The use of pre- and post-treatment comparisons is an important tool to evaluate the efficacy of medical or surgical interventions in pediatric patients with cardiovascular and respiratory diseases.

The mean walking distances of our study were similar to the studies by Geiger et al[6] and Li et al[8] (boys = 693.5 ($\pm$ 65.7) vs. 672.8 ($\pm$ 61.6) vs. 680.9 ($\pm$ 65.3) meters and girls = 657.1 ($\pm$ 51.1) vs. 661.9 ($\pm$ 56.7) vs. 642.7 ($\pm$ 58.9) meters, respectively), although the latter population were slightly taller and heavier. In the study of Lammers et al[7], the walking distances were shorter than in our study (512 $\pm$ 41 meters).

There are many factors influencing the results of a 6MWT[1]. Participants with shorter stature, greater body weight, older age, female gender, impaired cognition and cardiovascular and pulmonary and/or musculoskeletal diseases tend to walk shorter distances. Conversely, participants with greater height, longer legs, male gender, high motivation, or who have previously done the test tend to have longer walking distances.

In our study, the 6MWD correlated only to age, sex, weight and heart rate differences. The walking distance increased with age in both boys and girls. However, the walking distance slightly decreased in the girls after 11 years old. This data is similar to the study of Geiger et al[6], which was conducted in healthy Caucasian children and adolescents aged 3-18 years. Lammers et al[7] also found an increase in walking distances with age in UK children from the age of 4 to 11 years. In addition, the longer time children spent watching television, the lower their walking distance. This may explain the general observation that sedentary children tend to exercise less and weigh more.

Although girls were significantly taller and longer legged than boys, boys covered a greater walking distance than girls, which agreed with previous studies[5,6,8].

Participants with a greater difference in heart rates before and after the test managed longer walking distances, possibly reflecting more competence in response to exercise. In our study, the heart rates of the participants increased about 40% on average from baseline, which is similar to the study by Lammers and colleagues[7], but lower than other studies that found an increase of 50-80% from the baseline[6,8]. This level of increased heart rate reflects a submaximal level of functional capacity, when compared with the targeted heart rate that represents what the maximum effort would be, according to the formula 90% of (220-age in years)[11].

Based on the results of this study, we developed age-specific centile curves for the 6MWT for boys and girls that is easy to use and should provide a first-stage but reasonably accurate reference range of data for Thai children, to be fine-tuned as further data become available. This data are different from the previous study by Li et al[8] that established standard reference data for the 6MWT in healthy Chinese children aged 7-16 years as height-specific centile curves.

In conclusion, reference data for the six-minute walk test in healthy Thai children aged 9 to 12 years for boys and girls was developed. It should be useful for reference in future studies evaluating pediatric patients' cardiovascular and respiratory functional status.

Potential conflicts of interest

None.

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การพัฒนาข้อมูลอ้างอิงมาตรฐานสำหรับเด็กไทยจากการทดสอบเดินหกนาที

นครินทร์ ตนคลัง, สุภาพร โรยมณี, สมเกียรติ โสภณธรรมรักษ์

ภูมิหลัง: *การทดสอบเดินหกนาทีเป็นการทดสอบที่มีประโยชน์ในการเปรียบเทียบระหว่างก่อนและหลังการรักษา การประเมินสภาวะของร่างกายและการพยากรณ์โรค แต่ในเด็กยังไม่มีการใช้อย่างแพร่หลายเนื่องจากไม่มีค่าอ้างอิง และการทดสอบต้องอาศัยความตั้งใจและความร่วมมือของผู้ทำการทดสอบซึ่งทำได้ยากในเด็ก ในปัจจุบันเริ่มมีการศึกษาหาค่าอ้างอิงมากขึ้นในหลายประเทศแต่ยังมีน้อยในประเทศไทย*

วัตถุประสงค์: *เพื่อศึกษาหาค่าอ้างอิงของการทดสอบเดินหกนาทีในเด็กไทยที่มีสุขภาพดี อายุระหว่าง 9 ถึง 12 ปี*

วัสดุและวิธีการ: *เป็นการศึกษาแบบภาคตัดขวาง ทำการทดสอบในเด็กที่มีสุขภาพดี เรียนชั้นประถมศึกษาปีที่ 4 ถึง 6 ของ 7 โรงเรียน ในจังหวัดสงขลา ขั้นตอนการทดสอบอ้างอิงตามการทดสอบเดินหกนาทีของ American Thoracic Society (ATS) ได้ทำการทดสอบในแต่ละโรงเรียนระหว่างเดือนมิถุนายนถึงเดือนกันยายน พ.ศ. 2551 นำข้อมูลที่ได้มาศึกษาความสัมพันธ์ระหว่างตัวแปรต่าง ๆ กับระยะทางที่เดินได้ใน 6 นาทีและสร้างกราฟค่าอ้างอิง*

ผลการศึกษา: *มีนักเรียนเข้าร่วมการศึกษาทั้งหมด 739 คน เป็นเพศชาย 403 คน (ร้อยละ 54.5) และเพศหญิง 336 คน (ร้อยละ 45.5) มีเด็กหญิงหนึ่งคนที่ทำการทดสอบไม่สำเร็จ ระยะทางเฉลี่ยที่เดินได้ใน 6 นาที คือ 677(± 62.2) เมตร โดยเพศชายเดินได้ระยะทางเฉลี่ยมากกว่าเพศหญิง 36.4 เมตร (693.5 และ 657.1 เมตร ตามลำดับ) ระยะทางที่เดินได้เพิ่มขึ้นตามอายุที่มากขึ้นแต่ในเพศหญิงระยะทางมีการลดลงหลังจากอายุ 11 ปี ในระหว่างการทดสอบไม่พบภาวะแทรกซ้อนที่รุนแรง เมื่อนำข้อมูลไปวิเคราะห์ทางสถิติแบบถดถอยพหุพบว่าระยะทางที่เดินได้มีความสัมพันธ์กับอายุ เพศ น้ำหนัก และค่าความแตกต่างของอัตราการเต้นหัวใจก่อนและหลังการทดสอบ ได้สร้างกราฟค่าอ้างอิงแสดงความสัมพันธ์ระหว่างระยะทางที่เดินได้ใน 6 นาที กับอายุ ในเพศชายและเพศหญิงของ เด็กไทยอายุ 9 ถึง 12 ปี*

สรุป: *การทดสอบเดินหกนาที เป็นการทดสอบหนึ่งในหลายวิธีที่ใช้ในการประเมินสมรรถภาพการออกกำลังสามารถทำได้ง่าย การศึกษานี้ได้รายงานและพัฒนากราฟ อ้างอิงจากการทดสอบเดินหกนาทีสำหรับเด็กไทยที่มีสุขภาพดี อายุ 9 ถึง 12 ปี*