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RESEARCHARTICLE

REFERENCE VALUES OF THE SIX-MINUTE-WALK TEST FOR CHILDREN AND ADOLESCENTS

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ABSTRACT

Background: The six-minute walk test is a simple, safe and well established assessment tool to assess exercise tolerance and endurance. **Objectives:** The aims of this study were to establish reference values of the six-minute walk test for children and adolescents aged from 12 to 18 years old and to compare between girls and boys regarding these values. **Methods:** 900 Egyptian healthy children of both sexes participated in this study. They were recruited from different preparatory and secondary schools located in three governorates of Egypt (Al-Ghariba, Al-Menofia and Kafrelsheikh) on the basis of 300 children from each governorate. They were classified according to age into three age groups (group I from 12:14 years; groups II from 14:16 years and group III from 16:18 years) with 300 children in each age group. The six-minute walk distance was measured for each child. **Results:** The overall mean of the six-minute walk distance was 550.28±64.74 meters with a maximum value of 711 meters and a minimum value of 402 meters. It was increased with age increment reaching to maximum mean value of 567.64±49.62 and 618.03±52.94 meters for girls and boys respectively at age group III and 570.14±66.49 for all children. The results revealed no significant differences between girls and boys mean values of the six-minute walk distance in group I(p=0.068). However, there was a significant difference between girls and boys mean values of the six-minute walk distance in both group II and III (p=0.001). **Conclusion:** This study provided reference values of the six-minute walk test for children and adolescents aged from 12-18 years which were affected by age and gender.

INTRODUCTION

Functional exercise capacity is a measuring method of the individual's ability to perform meaningful tasks on a safe and dependable basis aiming to collect information about the functional limitations of a person with medical impairment (Li *et al.,* 2007). Functional endurance is necessary for individuals to live independently without accommodation in community settings (Andrews *et al.,* 2010).Timed walk tests such as the six-minute walk test (6MWT) is commonly employed for testing functional exercise capacity (Bernard *et al.,* 2014). It assesses all of the systems required for exercise and reflects the submaximal level of exercise capacity (American Thoracic Society [ATS], 2002). It has been validated in cardiopulmonary disorders and neurological disorders as an exercise capacity test (Du Bois *et al.,* 2011).The 6MWT is an endurance test with high reliability and validity (Arafah *et al.,* 2015), that allows for the assessment of walking capacity, disease progression, and treatment efficacy (Andersen *et al.,* 2016).The 6 MWT is one of the low technology tests that have been recommended as first line exercise screening test in the most recent functional guidelines (Brunelli *et al.,* 2013).The assessment of functional capacity using the six-minute walk test (6MWT) is gaining increased interest in the cardiovascular field (Ramos *et al.,* 2018). Beside its effectiveness for the assessment of functional capacity, it is easy to administrate, safe, inexpensive, valid, and reliable in patients with cardiovascular diseases (Bellet *et al.,* 2012 and Papathanasiou *et al.,* 2013). The measured distance (6MWDM) is the direct outcome of the 6MWT; predict values (6MWDP) are estimated from indirect methods such as models obtained from healthy populations (Casanova *et al.,* 2011).The 6MWT is a practical simple test that requires 100-feet (ft) (30 meters) hallway but no exercise equipment or advanced training for technicians. It measures the distance that a person can quickly walk on a flat, hard surface in a period of 6-minutes described as the 6MWD (ATS, 2002). The use of the reference values for the 6MWT brings a more precise interpretation of this test in clinical practice and research. However, health professionals from countries that do not have reference values for the 6MWT should be aware about the selection of a reference value established in another country.Otherwise, the test interpretation can be compromised (Cacau *et al.,* 2016).Lack of 6MWD reference values for normal, healthy children hinders the

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clinical usefulness of this test in thepediatric age group (Li *et al.,* 2007).Some studies established reference values of the 6MWT forchildren and adolescents. Li *et al.* (2007) constructed standard reference for the 6MWT in healthy Chinese children aged from 7-16 years and found that the mean of the 6MWD was 642.7±58.9 meters. Geiger *et al.* (2007) provided 6MWD for healthy Caucasian children and adolescents of a population-based sample from the age of 3 to 18 years and reported a mean of 612.86±63.23 meters. Ulrich *et al.* (2013) reported a mean of reported a mean of in healthy children and adolescents in Switzerland between 5 and 17 years of age. Chen *et al.* (2015) reported that a mean of 6MWD was 513±64 meters; also they stated that there is an overall linear trend of increase in the 6MWD between 7 and 17 years of age. Fitzgerald *et al.* (2016) found that the mean of the 6MWD was 528.42±67.77meters for Ireland children aged between 4-17 years. Abdel Rahman *et al.* (2017) provided 6MWD for healthy Egyptian children aged from 6 to 12 years and reported an overall mean of 589.79±4.68 meters. These previous studies showed that the normal references for 6MWD could differ among ethnic populations. Until now, data on normal values of the 6MWD performed according to ATS standards for healthy children living in Arabic countries are very rare and highly warranted in order to have comparative data for children with disease. Therefore; the aims of the present study was to provide reference values of the 6MWD for children and adolescents, aged 12–18 years living in Egypt and to compare between girls and boys regarding these values.

MATERIALS AND METHODS

Subjects: This study was conducted on 900 Egyptian healthy schoolchildren of both sexes. Their age ranged between 12 and 18 years. The study was conducted in different preparatory and secondary schools that were located in the Lower Egypt. As the Lower Egypt consists of eleven governorates, subjects were selected from three of them which are Al-Ghariba, Al-Menofia and Kafrelsheikhon the basis of 300 children from each governorate. These three governorates represent 23% of the population of the Lower Egypt and 13.5% of the total population of the Egypt in 1/1/2015.Students were included if they: a) are Egyptian healthy schoolchildren, b) aged from 12 to 18 years, c) had normal weight according to body mass index (BMI)-for-age percentile for girls and boys (from 5th percentile to less than the 85th percentile) (Morgan, 2006). The students were excluded if they have: a)Overweight and obesity, b) Cardiorespiratory problems including asthma, bronchiectasis, congenital heart deficit, hypertension (systolic blood pressure of more than 180 mmHg and diastolic blood pressure of more than100 mmHg), unstable angina and/or myocardial infarction during the previous month, c) Resting heart rate of more than 120 beat /minute, d) Diabetes mellitus or cancer, e) Exercise problems such as neuromuscular or musculoskeletal diseases, f) Hospital admissions within the past three months, g) A common cold within the last four weeks and h) Long-term medications and any fracture within the past six months. Children were classified according to age into three groups with 300 children in eachgroup (150 girls and 150 boys) (Table 1).

Sampling method: Stratified random sampling from three governorates (Al-Ghariba, Al-Menofia and Kafrelsheikh) within three age groups.

Study Design: A cross-sectional study was conducted to specify normal reference values for the 6MWT for Egyptian healthy school children and adolescents aged between 12 to18 years old.

Instrumentation for data collection: Vital signs monitor (2009 Shenzhen Mindary Bio-Medical Electronics Co., Ltd., China) was used to measure pulse rate and blood pressure. It is reliable for determining pulse rate and blood pressure 10 minutes before and one minute after application of the 6MWT (Solwayv *et al.,* 2001). A digital weight/height scale was used to measure height and weight. BMI-percentile-for-age calculator (https://nccd.cdc.gov/dnpabmi/calculator.aspx) was used to measure BMI-percentile-for-age. Required equipment for 6MWT were stopwatch, mechanical lap counter, two small cones to mark the turnaround points, a chair that can be easily moved along the walking course, brightly colored tape and the 6MWT worksheets.

Procedures: Approval from the Ministry of Education and the participated schools as well as written consent from students' parents or legal guardians was obtained before starting the study. After collecting the consents forms, the students were examined by the school's physician for the inclusion and exclusion criteria. In the examination area, each student was asked to remove the shoes in preparation to stand on the digital weight/height scale. The height in centimeter (cm) and weight in kilograms (kg) ofeach student were then measured.

The BMI percentile was calculated (http://www.betterhealth.vic.gov.au/bhcv2/bhcsite.nsf/pages/bmi4child).In each participated school, a same corridor length was prepared with the same environment. The 6MWT was performed in the morning at 8:30 am, indoors, along a long, flat, straight, enclosed corridor with a hard surface that is seldom traveled. The length of the corridor was 20-meters (m) and marked every 3-meter. The turnaround points marked with a cone (such as an orange traffic cone). A starting line marked on the floor using brightly colored tape. For 6MWT administration, students were asked to wear appropriate comfortable shoes, a light meal was acceptable before the test, students had not have exercised vigorously within 2 hours of beginning the test, no "warm up"period before the test was allowed. Each student was tested separately with no other students in the examination area. The 6MWT was then administered for each child according to guidelines provided by the American Thoracic Society (ATS, 2002). During the study, none of the walk tests had to be prematurely terminated and none of the subjects required a rest.

Data Analysis: All data were analyzed by statistical package for the social sciences (SPSS) version 19. Descriptive statistics including means and standard deviations for age, weight, height, and 6MWD were calculated for the students in each age group as well as for all students. Unpaired t-test was used to compare between girls and boys regarding the means of the 6MWD. Comparative studies were finally conducted between the mean differences of the 6MWD in the three age groups by using one way analysis of variance (one-way ANOVA) test to show the statistical significance among as well as within the age groups. In case of significance, least significant difference (LSD) test was performed to detect pairs of age groups significantly different. In all statistical tests, the alternative hypothesis was accepted at 5% level of probability ($\alpha \leq 0.05$).

RESULTS

The general characteristics of the participants as well as 6MWD are represented in table (2). The overall mean of the 6MWD was 530.42±56.38 meters for girls, 570.14±66.49 meters for boys and 550.28±64.74 meters for all children. The results revealed that the 6MWD was increased with age increment reaching to maximum mean value of 567.64±49.62and 618.03±52.94 meters for girls and boys respectively at age group III and 570.14±66.49 for all children (Table 2). Un-paired sample t-test was conducted to test the significant difference between girls and boys within each age group for 6MWD.The results revealed no significant differences between girls and boys mean values of the 6MWD ingroup I (p=0.068). However, there was a significant difference between girls and boys mean values of the 6MWD in group II (p=0.001) and group III (p=0.001), as well as there was a significant difference between girls and boys mean values of the 6MWD of all children (p=0.001). One-way ANOVA test revealed significant difference among the three age groups regarding the 6MWD (Table 3a). This significant difference was observed between age groups I and II as well as between age groups II and III (Table 3b).Results revealed a high positive correlation between the 6MWD and age, height as well as weight for girls, for boys as well as for all children (Table 4).

DISCUSSION

This study was conducted to provide reference values for the 6MWT and to compare between boys and girls regarding the 6MWD for Egyptian healthy children and adolescent aged from 12 to 18 years.The 6MWT is growing its importance in clinical practice and in scientific context because it is of easy implementation, low cost and the maximal walked distance represents high prognostic value in several cardiopulmonary disorders (Boxer *et al.,* 2010 and Maltais *et al.,* 2014). This test is also widely used to assess exercise capacity before and after an intervention, such as an exercise-training program (ATS, 2002).The use of 6MWT in children has been relevant to assess exercise tolerance in pathological conditions such as cardiovascular diseases, asthma, cystic fibrosis, end-stage renal disease and pulmonary hypertension (Bartels *et al.,* 2013). This simple test has been increasingly used over the past decade in healthy children because it is quick, easy to administer, especially in an evaluation setting without specific instrumentations, inexpensive, well understood, accepted and tolerated and more reflective of daily living activities than other exercise tests (Geiger *et al.,* 2007).Even though it is common that clinicians and researchers use reference values from foreign samples, values of 6MWD between countries are divergent. Different studies demonstrate that there is a large variability (up to 159 meters) in children of different nationalities (Cacau *et al.,* 2016). Moreover, demographic and anthropometrics characteristics such as age, gender, height and weight could affect the performance of the test (D'Silva *et al.,* 2012).This study provides the first reported data on reference values for 6MWD for Egyptian healthy children and adolescent aged between 12 to 18 years to help health professional in assessment of functional capacity for their patients by comparing with norms. Our study shows that the 6MWD in healthy children and adolescents is feasible and is related to gender and age. In the present study, our results showed that the overall mean of the 6MWD was 550.28±64.74 meters. The maximum 6MWD was 711 meters and the minimum mean value 6MWD was 402 meters for all participated children. There were different studies established different values for the 6MWD more related and close to age in our results. Ulrich *et al.* (2013) examined the values for the 6MWTfor healthy children and adolescents in Switzerland between 5 and 17 years of age and found that the mean of the 6MWD was 618±79 meters. Chen *et al.* (2015) reported that a mean of 6MWD was 513±64 meters and stated that there is an overall linear trend of increase in the 6MWD between 7 and 17 years of age. Fitzgerald *et al.* (2016) found that the mean of 528.42±67.77meters for children aged between 4-17 years. Our study revealed that the mean of the 6MWD was 530.42±56.38 meters for girls and 570.14±66.49 meters for boys. The maximum of the 6MWD was 673 and 711 meters for girls and boys respectively, while the minimum of the 6MWD was 409 and 402 meters for girls and boys respectively. Saad *et al.* (2009) reported an overall mean for the 6MWD was 694±72 meters and 707±102 meters for healthy North African girls and boys respectively aged between 6 and 16 years. Kanburoglu *et al.* (2014) also investigated the reference values of the 6MWT for healthy Turkish children and adolescents aged between 11 and 18 years and found that the mean 6MWD for normal weight girls and boys was 530±92 meters and 542±97 meters respectively.

A direct comparison of our findings to reference values reported for children living in other countries is difficult because each study organized its data in a different way. The different protocols used to perform the 6MWT, mostly explains the variability of results observed in the different studies. Discrepancies in reported 6MWD among studies may be due to cultural differences among countries regarding physical activity level and fitness. As the 6MWT is a measure of sub maximal exercise capacity, a sedentary lifestyle and low aerobic fitness may negatively affect a child's performance. Environmental factors might have contributed to different physical activity levels among children (Dourado, 2010).The explanation for the different performances observed among different ethnicities is not a simple one. The level of encouragement, the length and layout of the track and the number of tests performed for familiarization purposes significantly influence the 6MWD. Additionally, the demographic, anthropometric and nutritional differences observed among the different ethnicities evaluated must be considered. Greater height and higher amount of lean mass observed in Caucasians have a significant impact on the 6MWD. Therefore, ATS encourages the scientific community to use the standardization of the 6MWT suggested in its consensus and to develop reference values of the 6MWD for several ethnicities.

In the present study, the 6MWD was increased with age increment reaching to maximum mean value of 567.64±49.62 and 618.03±52.94 meters for girls and boys respectively at age group III (16-18 years) and 570.14±66.49 for all children. A long list of studies has been conducted and concluded that a wide range of reference values of the 6MWT for children between the ages of 12 and 18 years have been reported in previous studies (Geiger *et al.,* 2007; Li et al 2007; Ben Saad *et al.,* 2009; Ulrich *et al.,* 2013 and Kanburoglu *et al.,* 2014). Nevertheless, only two of them Ulrich *et al.* (2013) and Kanburoglu *et al.* (2014) gave age-by-age reference values and also these studies are disagreed with our findings as they demonstrated a decline in the 6MWD after the age of 12 till

Table1. Age specific groups for participants

Group Number	I	II	III
Age (Years)	12:14	14:16	16:18

Table2. Means and standard deviations of the demographics and the six-minute walk distance for the participated students

Age Groups	Participants	Age (year)	Weight (kg)	Height(cm)	BMI-percentile	6MWD (meters)
I	All (N.=300)	12.50±0.50	43.19±5.54	151.23±7.45	56.39±19.59	511.45±44.32
(12-13 years)	Boys (N.=150)		42.33±5.57	150.07±7.74	57.75±19.10	521.15±47.38
	Girls (N.=150)		44.05±5.40	152.39±6.99	55.03±20.04	501.74±38.82
II	All (N.=300)	14.50±0.50	49.90±6.80	158.08±6.58	51.93±20.72	546.55±63.50
(14-15 years)	Boys (N.=150)		51.53±7.08	160.50±6.86	53.63±21.01	571.23±59.58
	Girls (N.=150)		48.26±6.10	155.67±5.31	50.24±20.35	521.87±57.57
III	All (N.=300)	16.98±0.81	57.50±8.20	164.31±8.16	48.87±21.43	592.83±57.10
(16-18 years)	Boys (N.=150)		61.85±7.84	169.71±7.06	50.82±20.21	618.03±52.94
	Girls (N.=150)		53.16±5.96	158.92±5.02	46.92±22.49	567.64±49.62
All	All (N. =900)	14.66±1.94	50.20±9.07	157.88±9.15	52.40±20.80	550.28±64.74
(12-18 years)	Boys (N.=450)		51.90±10.54	160.09±10.80	54.07±20.28	570.14±66.49
	Girls (N.=450)		48.49±6.91	155.66±6.41	50.73±21.20	530.42±56.38

N: number of students. Kg: kilograms. cm: centimeter. BMI: Body mass index. 6MWD: six-minute walk distance.

Table 3a.ANOVA test for comparison among the three age groups regarding the six-minute walk distance

Source	DF	SS	MS	F. ratio	P. value
Between groups	2	999810.596	499905.298	162.020	0.001*
Within groups	897	2767645.960	3085.447		
Total	899	3767456.556			

DF: Degree of freedom. **SS:** Sum of squares. P: Probability value. MS**:** Mean of squares.

Table 3b. Post hoc multiple comparison test (LSD) for the six-minute walk distance for all age groups

Means	Age Groups	I	II	III
511.45	I		0.001*	0.001*
546.55	II			0.001*
592.38	III			

*: Donates pairs of age groups significantly different at $\alpha \leq 0.05$.

Table 4. Correlation between six-minute walk distance and age, height as well as weight

Variable	Participants	Six-Minute Walk Distance(meters)	
		r	*p**
Age (Years)	All (N= 900)	0.536	0.001*
	Boys (N=450)	0.612	0.001*
	Girls (N=450)	0.510	0.001*
Height (cm)	All (N= 900)	0.448	0.001*
	Boys (N=450)	0.474	0.001*
	Girls (N=450)	0.283	0.001*
Weight (kg)	All (N= 900)	0.461	0.001*
	Boys (N=450)	0.489	0.001*
	Girls (N=450)	0.337	0.001*

N: number of students. r: Pearson correlation. p: probability value.*: Correlation is significant at 0.05 level. cm: centimeter. Kg: kilograms.

age of 14, but Kanburoglu *et al.* (2014) also found that there were gradually increases until the age of 17 which was in agreement with our findings. Our results are also concomitant with Klepper and Muir (2011) who suggested that the 6MWD increased with age with exception of the 10-year-old group, which had the lowest 6MWD as they had the highest prevalence of overweight (32%) and obesity (39%).The fact that 6MWD results do not linearly increase with age was an unpredictable finding. This may be due to the ever-changing hormones and energy levels or the discrepancy of inner motivation of teenagers at different ages (Butt *et al.,* 2011).In the current study, there was a significant difference between girls and boysfor all age groups and in each age group regarding the 6MWD being higher in boys than girls on all age group except in age group I (12-13 years) where there was no significant difference between both genders being higher in boys.

Our findings regarding the difference in the 6MWD due to gender agreed with Roush *et al.* (2006) who suggested that any development of reference values for 6MWT for the sample must be sex specific. Li *et al.* (2007) also found a significant sex difference in 6MWD. Klepper and Muir (2011) and Tonklang *et al.* (2011) stated thatthe variable sex influenced the distance, being higher in boys than in girls. On the other hand, Lammers *et al.* (2008) reported no significant difference between boys and girls. Dourado (2010) stated that children did not show an influence of sex on the walked distance which could be easily explained by the higher number of musculoskeletal similarities observed between the sexes before adolescence. The influence of sex after the onset of adolescent can be attributed to the higher muscle mass and strength observed in men in absolute values. Pathare *et al.* (2012) also did not detect any significant differences in6MWD based on sex.

It was noted that at all age group, boys were found to have greater 6MWD than girls, possibly as a result of their greater muscle mass and the ability to achieve higher levels of physical activity. We could not exclude the possibility of physical fitness as an important determining factor for 6MWD, and this could have explained the sex difference demonstrated. Pradon *et al.* (2013) stated that the 6MWD may be a good indicator of lower limb muscle strength, and lower limb strengthening may improve gait capacity. Arellano (2015) revealed that the skeletal muscles of men are faster and render higher maximum output compared to women's skeletal muscles. Estrogen-B seems to have an effect in muscle contractile speed, making men more efficient in producing power. Men also release testosterone which is very important in muscle-building.

The results of this study revealed a high positive correlation between the 6MWD and weight, height as well as age.This was supported by Li *et al.* (2007) who found that height, age, and weight before and after the walk test were significantly associated with 6MWD but height had the best correlation with 6MWD. Taller people could have larger stride length and thus greater walk distances. Lammers *et al.* (2008) also reported that the distance walked correlated with weight, height and age with no significant difference between boys and girls. Abdel Rahman and Alnegimshi (2014) found a high positive correlation between the 6MWD and height. On the other hand, Klepper and Muir (2011) stated that there were no significant associations between the 6MWD and other variables with the exception of BMI in males. In general, taller individuals tend to have longer leg length and consequently wider last (Goemans *et al.,* 2013). It is also well known that oldest children and adolescents have better exercise performance than youngest ones (Lammers *et al.,* 2008). This may be a reflection of greater stature and greater influence of anabolic hormones throughout the growth (Bell *et al.,* 2010). Moreover, Kanburoglu *et al.* (2014) also suggested that the correlation of the 6MWD with height, weight, and BMI is not sufficient to recommend routine usage of predictive equations. Instead, the present study provides new 6MWD standard curves that can be used in the care of pediatric patients between the ages of 12 and 18 years.

It is frequently proposed that predictive equations derived from anthropometric measurements may be used to estimate 6MWD (Poh *et al.,* 2006 and Lammers *et al.,* 2008). In most of these studies, the predictive equations show a high variability in their predictive power. To prevent discrepancies between nations, Li *et al.* (2007) suggested using height-specific standards for the 6MWT. The variations in methodological details during the performance of 6MWT may be one crucial factor that affects the results of 6MWT. Although the ATS has published a guideline to standardize 6MWT, several differences were still noted among various studies. First, the level of encouragement during the test varied. In one study, they counted down the time left every minute, while investigators of another study did not regularly inform the participants about any diminished time element. To avoid competition, the 6MWT should be performed separately or one by one. In addition, the track length varied from 20 to 50 meters among the studies. All these methodological variations may result in differences in the 6MWD of children from different studies. A more strict standardization for the performance of 6MWT may reduce this difference (Chen *et al.,* 2015).

Limitations: In our study, the 6MWD was measured only once for every child. Therefore, we cannot provide information on the test–retest reliability. We did not include an instrument to measure specific motivation in our study. As we included several children of each age group, we believe that the inter-individual differences in motivation would somehow equilibrate around the average. Although we tried to include consecutive children living in different areas without any selection criteria, we cannot exclude a selection bias with potentially more motivated subjects being investigated by us. Our reference values are only usable for the age group we investigated. Thus, they will not apply for very young children and toddlers, in which a 6MWD test might as well be difficult to perform. Despite these limitations, in our experience, the present form of the 6MWD is easy performable and useful as comparative measures in the management and follow up of children and adolescents with cardio respiratory diseases.

Conclusion

It has concluded that there are specific standard values for the 6MWD of Egyptian healthy children and adolescents aged between 12-18 years that are differ from other investigated healthy children and adolescents of racial differences. The 6MWD is a simple, practical means and useful tool in the assessment of exercise capacity in children and adolescents. The 6MWD is highly affected by age and height and was increased with age increment reaching maximum mean value of 567.64±49.62 and 618.03±52.94 meters for girls and boys respectively at age group III (16-18 years) and 570.14±66.49 for all children. These standards may serve as useful references for future clinical and research studies. We recommended application of further researches to identify additional factors influencing the 6MWT.

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