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ORIGINAL RESEARCH

Arm span as a predictor of the six-minute walk test in healthy children



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Abstract

Background: Six-minute walk test (6MWT) is the most used test to assess functional capacity. Including arm span in the prediction equations for 6MWT performance might be an alternative for use in traditional reference equations.

Objective: The aim was to investigate the usability of arm span to predict the 6MWT distance in healthy children.

Methods: 262 healthy children aged between 6 and 12 years old participated in this study. 6MWT was conducted according to the standardized protocol. Height, weight, and arm span were measured before performing the 6MWT. A multiple stepwise linear regression analysis was used to generate the regression model.

Results: The 6MWT distance had strong positive correlations with age, arm span, height, and weight ($p < 0.001$). There was also a very strong correlation between arm span and height ($p < 0.001$). Age and arm span were found as significant predictors in the first regression model. These two variables explained 60.2% of the variance in the 6MWT distance. Age and height were also found as significant predictors, explaining 60.5% of the variance in the 6MWT distance. The two following formula were obtained to predict the 6MWT distance: $(-23.09 + (31.12 \times \text{Age}) + (2.39 \times \text{Arm span}))$ or $(-80.0 + (28.98 \times \text{Age}) + (2.92 \times \text{Height}))$.

Conclusions: The results suggest that the combination of arm span (or height) and age are strong predictors of the 6MWT distance in healthy children.

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Introduction

A cardiopulmonary exercise test, during which maximum oxygen consumption is measured, is accepted as the gold standard in the measurement of exercise capacity.¹ Although considered the most accurate method for measuring exercise capacity, the test requires expensive equipment and specialized staff.² Because cardiopulmonary exercise test is impractical and unfeasible in clinical settings, several submaximal exercise tests have been developed as an alternative. Among those, the six-minute walk test (6MWT) is the most well-established and used test in clinical settings and research.³ The 6MWT is easier to administer, more acceptable, and provides a better reflection of activities of daily living than other walk tests.⁴ Additionally, the 6MWT is increasingly used in children.⁴

A large number of studies have been conducted to determine factors affecting the performance on the 6MWT.⁴⁻¹³ In the majority of these studies, anthropometric measurements were used, and height was shown to be a significant predictor of the 6MWT distance.⁴⁻¹⁴ However, measurement of height may not give accurate results in some situations, especially due to spinal deformities such as scoliosis and kyphoscoliosis, which are frequently seen in children during developmental stages.^{15,16} Arm span, instead of height, is used for calculating body mass index in children with spinal deformity.¹⁶ In addition, arm span has been shown to be closely associated with pulmonary function parameters and nutritional status in children, adults, and older people.¹⁷⁻¹⁹ Because the relationship between height and arm span can vary with age and population, estimating height from arm span can be difficult. Therefore, including arm span in the prediction equations for the 6MWT distance might be a better alternative than indirectly predicting height from arm span for use in traditional reference equations.¹⁹ To the best of our knowledge, arm span has not been investigated as a predictor of the 6MWT distance in children. If a prediction equation using arm span was as good as one using height, it could be used to predict the 6MWT distance in children with spinal deformities, in whom height does not give accurate results. Therefore, this study aimed to investigate the potential for arm span to create a prediction equation of the 6MWT distance in healthy children.

Methods

Design and population

Typically developing children aged 6–12 years were recruited from 4 randomly selected local primary schools for this cross-sectional study. Children who were able to understand and fully comply with the assessments were included in the study. Schools were visited by the researchers, and an invitation letter with a questionnaire to identify health-related problems and demographic characteristics were sent to the parents of eligible children. Parents completed the questionnaire a few days before the testing. Children with known chronic cardiorespiratory, neurological, or musculoskeletal disorders, or who had a common cold within the last four weeks were excluded from the study. A total of 262

eligible children were stratified into seven age subcategories with a one-year interval between 6 and 12 years.

Because there was no study that used arm span as a predictor for the 6MWT, it was not possible to directly calculate a desired a priori sample size. But, it has been shown that the performance on the 6MWT was moderately correlated with spirometric values,^{5,13} and the prediction equations of spirometric values using arm span were previously reported.¹⁹ Therefore, a priori sample size was calculated as 146 for a medium effect size (0.15) and a power of 0.99 using G*Power (Ver. 3.1.9.4, University of Dusseldorf, Germany).²⁰ Due to the indirect calculation, the power was set at a higher threshold. This study included all 262 participants of a previously published study.¹⁴

This study was approved by the Ethics Committee of Dokuz Eylül University with the approval number "1060-GOA". Permission to conduct the study was also obtained from the Turkish National Education Ministry and school authorities. Informed consent was obtained from the parents of the children before participation.

Measurements

The participants' height and weight were determined using standardized anthropometric methods prior to testing on the 6MWT. Arm span was measured by positioning the participants, heels together with the back against a flat wall and the arms stretched sideways with the palms facing the investigator. The distance between the tips of the middle fingers was measured.

The 6MWT was conducted according to the standardized protocol described by the American Thoracic Society guidelines.²¹ The 6MWT was performed in a flat, straight corridor. Each participant walked along a 30 m tape line, with cones placed at each end of the course. The participants were told to avoid vigorous exercise within 2 hours before the test. No "warm-up" period before the test was allowed and the participants sat at rest in a chair, located near the starting position, for at least 10 minutes before the test started. The participants were asked to walk for 6 minutes at their best pace but not to run or race. Encouragement during the testing was standardized ("keep going", "you are doing well") and the announcement of time remaining was given to the participants. No comments were made regarding the participant's performance.

Statistical analysis

The normality of the data distribution was verified using the Kolmogorov-Smirnov test, the skewness and the kurtosis of the sample, and the graphical representation of the distribution. Descriptive statistics were calculated for each age group and all participants. Arm span, height, weight, and 6MWT distance were compared according to sex for each age group and all participants using a *t* test. Pearson product-moment correlation coefficient was used to examine associations between age, arm span, height, and weight. Correlation coefficients > 0.5 were considered as strong, 0.3 to 0.5 as moderate, and 0.2 to 0.3 as weak.²² A multiple stepwise linear regression analysis was used to generate the regression model for 6MWT distance as the dependent vari-

Table 1 Characteristics of the participants by age group and comparisons between sexes.

Age (years)	Number	Height (cm)		Arm span (cm)		Weight (kg)		6MWT (m)	
		Mean $\pm$ SD	<i>p</i>	Mean $\pm$ SD	<i>p</i>	Mean $\pm$ SD	<i>p</i>	Mean $\pm$ SD	<i>p</i>
6	Total (39)	118.0 $\pm$ 4.6		114.2 $\pm$ 4.7		22.5 $\pm$ 3.2		443.4 $\pm$ 64.9	
	Female (20)	116.9 $\pm$ 4.4	0.86	114.8 $\pm$ 4.9	0.40	22.4 $\pm$ 3.0	0.79	437.7 $\pm$ 71.0	0.58
	Male (19)	117.1 $\pm$ 4.8		113.5 $\pm$ 4.4		22.6 $\pm$ 3.5		449.4 $\pm$ 59.0	
7	Total (39)	125.3 $\pm$ 4.8		122.4 $\pm$ 5.2		25.5 $\pm$ 4.8		488.2 $\pm$ 52.1	
	Female (25)	125.8 $\pm$ 5.1	0.36	122.7 $\pm$ 5.0	0.63	25.8 $\pm$ 4.7	0.57	491.7 $\pm$ 54.4	0.59
	Male (14)	124.4 $\pm$ 4.3		121.9 $\pm$ 5.7		24.9 $\pm$ 5.0		482.1 $\pm$ 49.2	
8	Total (38)	131.4 $\pm$ 7.2		128.4 $\pm$ 6.7		29.1 $\pm$ 4.8		545.1 $\pm$ 57.9	
	Female (19)	130.7 $\pm$ 8.6	0.33	127.9 $\pm$ 8.0	0.69	28.4 $\pm$ 5.7	0.40	537.3 $\pm$ 61.3	0.42
	Male (19)	132.6 $\pm$ 5.5		128.8 $\pm$ 5.3		29.7 $\pm$ 3.6		552.8 $\pm$ 54.9	
9	Total (40)	134.9 $\pm$ 4.8		131.70 $\pm$ 5.83		31.9 $\pm$ 5.9		556.4 $\pm$ 52.2	
	Female (22)	134.6 $\pm$ 5.8	0.66	131.1 $\pm$ 7.2	0.45	30.8 $\pm$ 6.0	0.20	559.3 $\pm$ 54.8	0.70
	Male (18)	135.3 $\pm$ 3.3		132.4 $\pm$ 3.6		33.2 $\pm$ 5.5		552.8 $\pm$ 50.1	
10	Total (36)	140.4 $\pm$ 8.1		138.7 $\pm$ 8.4		36.0 $\pm$ 8.8		604.9 $\pm$ 59.9	
	Female (18)	138.9 $\pm$ 8.0	0.28	136.5 $\pm$ 7.9	0.12	35.1 $\pm$ 8.7	0.56	586.8 $\pm$ 57.0	0.07
	Male (18)	141.9 $\pm$ 8.3		140.9 $\pm$ 8.4		36.8 $\pm$ 9.0		622.9 $\pm$ 58.7	
11	Total (38)	144.9 $\pm$ 8.1		144.2 $\pm$ 9.3		37.0 $\pm$ 8.5		681.5 $\pm$ 113.6	
	Female (21)	144.0 $\pm$ 8.3	0.45	142.6 $\pm$ 10.1	0.25	35.1 $\pm$ 8.2	0.14	657.5 $\pm$ 112.7	0.15
	Male (17)	146.1 $\pm$ 8.1		146.1 $\pm$ 8.0		39.4 $\pm$ 8.6		711.2 $\pm$ 110.7	
12	Total (32)	153.8 $\pm$ 5.0		152.8 $\pm$ 5.8		45.7 $\pm$ 6.5		720.1 $\pm$ 109.0	
	Female (16)	152.9 $\pm$ 4.5	0.35	152.0 $\pm$ 4.4	0.42	45.4 $\pm$ 6.2	0.85	706.0 $\pm$ 79.9	0.26
	Male (16)	154.6 $\pm$ 5.4		153.7 $\pm$ 6.9		45.9 $\pm$ 6.9		734.3 $\pm$ 133.2	
Total	Total (262)	134.8 $\pm$ 12.8		132.6 $\pm$ 13.7		32.1 $\pm$ 9.4		572.6 $\pm$ 117.7	
	Female (141)	134.0 $\pm$ 12.5	0.25	131.6 $\pm$ 13.1	0.23	31.3 $\pm$ 9.1	0.11	561.9 $\pm$ 109.6	0.07
	Male (121)	135.8 $\pm$ 13.2		133.7 $\pm$ 14.4		33.1 $\pm$ 9.7		585.1 $\pm$ 125.9	

able. The model was used to examine the influence of age, arm span, weight, and height on the 6MWT distance. The effect size, f^2 value, was calculated based on the formula, $f^2 = R^2 / (1 - R^2)$. The f^2 value was interpreted as small (0.02), moderate (0.15), and large (0.35). All data were analyzed using SPSS for Windows software (Version 23.0. Armonk, NY: IBM Corp.).²²

Results

All participants completed the entire 6MWT according to the protocol and thus no data were excluded from the analysis. There was no adverse effect during the tests. The characteristics of the participants are presented in Table 1. Arm span, height, weight, and 6MWT distance increased steadily with age. Arm span, height, weight, and 6MWT were not significantly different between sexes for all age groups ($p > 0.05$) (Table 1). The arm span/height ratio was 0.98 ± 0.02 indicating arm span was slightly less than height. As indicated in Table 2, the 6MWT distance had a strong positive correlation with age, arm span, height, and weight ($p < 0.001$). There was also a very strong correlation between arm span and height ($p < 0.001$).

Age (years) and arm span (cm) were found as significant predictors of 6MWT distance (m) in the first regression model. These two variables explained 60.2% of the variance with a large effect size ($f^2 = 1.51$) (Table 3). Age (years) and height (cm) were also found as significant predictors in a second regression model,

Table 2 Correlation coefficients between the 6MWT distance, age, and anthropometric variables.

Variables	6MWT	Arm span	Height	Weight
Arm span	0.73	–		
Height	0.74	0.97	–	
Weight	0.61	0.85	0.85	–
Age	0.76	0.87	0.87	0.74

All correlation coefficients are significant at $p < 0.001$.

Table 3 Multiple stepwise linear regression model of the 6MWT distance as dependent variable against age and arm span.

Variables	<i>B</i>	Beta	<i>t</i>	<i>p</i>
Age	31.12	0.52	6.57	<0.001
Arm span	2.39	0.27	3.51	0.001

Adjusted $R^2 = 0.602$, $f^2 = 0.56$.

explaining 60.5% of the variance in the 6MWT distance, with a large effect size ($f^2 = 1.53$) (Table 4). The 6MWT distance can be predicted with the formulas; 6MWT distance = $-23.09 + (31.12 \times \text{Age}) + (2.39 \times \text{Arm span})$ or 6MWT distance = $-80.0 + (28.98 \times \text{Age}) + (2.92 \times \text{Height})$.

Table 4 Multiple stepwise linear regression model of the 6MWT distance as dependent variable against age and height.

Variables	B	Beta	t	p
Age	28.98	0.48	6.18	<0.001
Height	2.92	0.31	4.05	<0.001

Adjusted $R^2 = 0.605$, $f^2 = 0.59$.

Discussion

This study investigated the usability of arm span instead of height to predict the 6MWT distance in healthy children. The results suggest that either height or arm span, when combined with age, explain approximately 60% of the variance in the 6MWT distance.

There are numerous studies reporting a significant correlation between arm span and height in children and adults.^{23–27} However, in some studies, the agreement between arm span and standing height has been found to be poor.^{28,29} Despite some inconsistencies, most of the studies reveal a close relationship between height and arm span but do not allow a direct interpretation of the relationship between arm span and 6MWT distance. Unlike standing or sitting height, arm span would be least affected by spinal deformity. Therefore, assessing arm span is a practical and commonly used method to assess “real height” in children with scoliosis or other diseases.^{30,31} According to the results of our study, height and arm span were both strongly correlated with the 6MWT distance.

The influence of sex, age, anthropometric attributes, geography, environment, ethnicity, lifestyle, and cultural differences on performance on the 6MWT has been investigated in several studies.^{5–10} The results of previous studies have shown that height, age, and weight were also significantly correlated with the 6MWT distance.^{5–9} Present guidelines have indicated that the 6MWT distance is influenced by age, sex, height, weight, and motivation.^{32,33} Our study has revealed for the first time that arm span was also a significant predictor of the results on the 6MWT in healthy children.

Our results indicated that there was no difference in the 6MWT between female and male participants. Therefore, our reference equation can be used for both female and male children. The previous studies support this finding as they also have demonstrated no significant difference in the 6MWT between female and male children.^{7,8,10,11} A study conducted in the UK demonstrated that age alone explained 41% of the variance in 6MWT performance, and if height and weight were added, 44% of the variation could be explained.⁷ Another study conducted on Caucasian children showed that in addition to age, reference equations must take height and weight into account.¹² In our study, a combination of age and height explained 60.5% of the variance in the 6MWT, which was similar to a combination of age and arm span (60.2%).

In many studies, it has been reported that the arm span was longer than height.^{28,34–36} However, in this study, consistent with the results of another study conducted on Turkish children, height was slightly more than arm span.³⁷ These

results suggest that published prediction equations for the 6MWT, using anthropometric measures, may not be applicable to different ethnicity.

This study has some limitations. First, no patient population was included. Second, although the children were recruited from randomly selected schools located in two cities of Turkey, the selection in each school was conducted by convenience. Last, due to practical and economic limitations, other factors, such as cardiorespiratory fitness, socioeconomic condition, psychosocial status, motivation, level of physical activity, and level of sexual maturation, which are known factors that may influence performance on the 6MWT, were not investigated.³⁸ Therefore, our results may not be representative of all populations and should be interpreted with caution.

Conclusion

The combination of arm span (or height) and age were found to be strong predictors of the 6MWT distance (i.e. the measurement of exercise capacity) in healthy children. The results of the study suggest that arm span, instead of height, may be used for prediction of the 6MWT distance in healthy children.

Conflicts of interest

The author declares no conflicts of interest.

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References

1. Mezzani A, Hamm LF, Jones AM, et al. Aerobic exercise intensity assessment and prescription in cardiac rehabilitation: a joint position statement of the European Association for Cardiovascular Prevention and Rehabilitation, the American Association of Cardiovascular and Pulmonary Rehabilitation and the Canadian Association of Cardiac Rehabilitation. *Eur J Prev Cardiol.* 2013;20:442–467.
2. Noonan V, Dean E. Submaximal exercise testing: clinical application and interpretation. *Phys Ther.* 2000;80:782–807.
3. Puente-Maestu L, Palange P, Casaburi R, et al. Use of exercise testing in the evaluation of interventional efficacy. *Official ERS Statement.* 2016;47:429–460.
4. D'Silva C, Vaishali K, Venkatesan P. Six-minute walk test-normal values of school children aged 7–12 y in India: a cross-sectional study. *Indian J Pediatr.* 2012;79:597–601.
5. Li AM, Yin J, Au JT, et al. Standard reference for the six-minute-walk test in healthy children aged 7 to 16 years. *Am J Respir Crit Care Med.* 2007;176:174–180.
6. Geiger R, Strasak A, Treml B, et al. Six-minute walk test in children and adolescents. *J Pediatr.* 2007;150:395–399, 399.e391–392.

7. Lammers AE, Hislop AA, Flynn Y, et al. The 6-minute walk test: normal values for children of 4–11 years of age. *Arch Dis Child*. 2008;93:464–468.
8. Priesnitz CV, Rodrigues GH, Stumpf Cda S, et al. Reference values for the 6-min walk test in healthy children aged 6–12 years. *Pediatr Pulmonol*. 2009;44:1174–1179.
9. Ben Saad H, Prefaut C, Missaoui R, et al. Reference equation for 6-min walk distance in healthy North African children 6–16 years old. *Pediatr Pulmonol*. 2009;44:316–324.
10. Limsuwan A, Wongwandee R, Khowsathit P. Correlation between 6-min walk test and exercise stress test in healthy children. *Acta Paediatr*. 2010;99:438–441.
11. Klepper SE, Muir N. Reference values on the 6-minute walk test for children living in the United States. *Pediatr Phys Ther*. 2011;23:32–40.
12. Ulrich S, Hildenbrand FF, Treder U, et al. Reference values for the 6-minute walk test in healthy children and adolescents in Switzerland. *BMC Pulm Med*. 2013;13:49.
13. Li AM, Yin J, Yu CC, et al. The six-minute walk test in healthy children: reliability and validity. *Eur Respir J*. 2005;25:1057–1060.
14. Ozcan Kahraman B, Yuksel E, Nalbant A, et al. Reference values and prediction equation for the 6-minute walk test in healthy children aged 6–12 years old. *Turk J Med Sci*. 2019;49:1126–1131.
15. Zieliński J. Six minute walking test: an old tool with new applications. *Multidiscip Resp Med*. 2010;5:1.
16. Opoku H, Yirerong T, Osei-Onwona B, et al. The use of arm span as a substitute for height in calculating body mass index (BMI) for spine deformity patients. *Spine Deform*. 2018;6:220–225.
17. Datta Banik S. Arm span as a proxy measure for height and estimation of nutritional status: A study among Dhimals of Darjeeling in West Bengal India. *Ann Hum Biol*. 2011;38:728–735.
18. Chhabra S. Using arm span to derive height: Impact of three estimates of height on interpretation of spirometry. *Ann Thorac Med*. 2008;3:94.
19. Golshan M, Crapo RO, Amra B, et al. Arm span as an independent predictor of pulmonary function parameters: validation and reference values. *Respirology*. 2007;12:361–366.
20. Faul F, Erdfelder E, Lang A-G, et al. G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39:175–191.
21. Laboratories ATSCoPSfCPF. ATS statement: guidelines for the six-minute walk test. *Am J Respir Crit Care Med*. 2002;166:111–117.
22. Cohen J. *Statistical power analysis for the behavioural sciences*. Hillsdale, NJ: Erlbaum; 1988.
23. Ter Goon D, Toriola AL, Musa DI, et al. The relationship between arm span and stature in Nigerian adults. *Kinesiology*. 2011;43:38–43.
24. Yabancı N, Kiliç S, Şimşek I. The relationship between height and arm span, mid-upper arm and waist circumferences in children. *Ann Hum Biol*. 2010;37:70–75.
25. Monyeki KD, Sekhatha MM. The relationships between height and arm span, mid-upper arm and waist circumferences and sum of four skinfolds in Ellisras rural children aged 8–18 years. *Public Health Nutr*. 2016;19:1195–1199.
26. Cheng JC, Leung SS, Chiu BS, et al. Can we predict body height from segmental bone length measurements? A study of 3,647 children. *J Pediatr Orthop*. 1998;18:387–393.
27. Supare MS, Bagul AS, Pandit SV, et al. Estimation of Stature from Arm Span in Medical Students of Maharashtra, India. *Ann Med Health Sci Res*. 2015;5:218–221.
28. Torres LA, Martinez FE, Manço JC. Correlation between standing height, sitting height, and arm span as an index of pulmonary function in 6–10-year-old children. *Pediatr Pulmonol*. 2003;36:202–208.
29. Hickson M, Frost G. A comparison of three methods for estimating height in the acutely ill elderly population. *J Hum Nutr Diet*. 2003;16:13–20.
30. Yim AP, Yeung HY, Hung VW, et al. Abnormal skeletal growth patterns in adolescent idiopathic scoliosis – a longitudinal study until skeletal maturity. *Spine (Phila Pa 1976)*. 2012;37:E1148–E1154.
31. Cipriano GF, Brech GC, Peres PA, et al. Anthropometric and musculoskeletal assessment of patients with Marfan syndrome. *Rev Bras Fisioter*. 2011;15:291–296.
32. Enright PL. The six-minute walk test. *Respir Care*. 2003;48:783–785.
33. Sitbon O, Humbert M, Nunes H, et al. Long-term intravenous epoprostenol infusion in primary pulmonary hypertension: prognostic factors and survival. *J Am Coll Cardiol*. 2002;40:780–788.
34. Engstrom FM, Roche AF, Mukherjee D. Differences between arm span and stature in white children. *J Adolescent Health Care*. 1981;2:19–22.
35. Yun D-J, Yun D-K, Chang Y-Y, et al. Correlations among height, leg length and arm span in growing Korean children. *Ann Hum Biol*. 1995;22:443–458.
36. Zverev Y, Chisi J. Estimating height from arm span measurement in Malawian children. *Coll Antropol*. 2005;29:469–473.
37. Yabancı N, Kiliç S, Şimşek I. The relationship between height and arm span, mid-upper arm and waist circumferences in children. *Ann Hum Biol*. 2010;37:70–75.
38. Dourado VZ. Reference equations for the 6-minute walk test in healthy individuals. *Arq Bras Cardiol*. 2011;96:e128–e138.