The Turkish Journal of Pediatrics 2023; 65: 13-23
https://doi.org/10.24953/turkjped.2021.5103

Original Article

Correlation between anthropometric measurements of height and arm span in Indonesian children aged 7-12 years: a cross-sectional study

Rahmayani Rahmayani, Fernando Rumapea, Rodman Tarigan, Eddy Fadlyana, Meita Dhamayanti, Kusnandi Rusmil

Department of Child Health, Faculty of Medicine Universitas Padjajaran - Hasan Sadikin General Hospital, Bandung, Indonesia.

ABSTRACT

Background. Height is an anthropometric measurement that serves as the most constant indicator of growth. In certain circumstances, arm span can be used as an alternative to height measurements. This study aims to analyze the correlation between anthropometric measurements of height and arm span in children aged 7-12 years.

Methods. A cross-sectional study was carried out from September to December 2019 in six elementary schools in Bandung. Children aged 7-12 years were recruited with a multistage cluster random sampling method. Children with scoliosis, contractures, and stunting were excluded from the study. Height and arm span were measured by two pediatricians.

Results. A total of 1,114 children, comprising 596 boys and 518 girls, fulfilled the inclusion criteria. The ratio of height to arm span was 0.98-1.01. The regression equation used to predict height through measurement of arm span in male subjects was Height = 21.8623 + 0.7634 x Arm span (cm) + 0.0791 x age (month); R2 = 94%; standard error of estimate (SEE): 2.66 and that in female subjects was Height = 21.2395 + 0.7779 x Arm span (cm) + 0.0701 x age (month); R2 = 95.4%; SEE: 2.39. The predicted height and the average actual height were not significantly different. There is a strong correlation between height and arm span in children aged 7-12 years.

Conclusions. Arm span can be used to predict the actual height of children aged 7-12 years and as an alternative measurement for growth.

Key words: anthropometric, arm span, height, children, growth.

Growth is an important indicator to assess children's nutritional and health status.[1,2] The growth of children can be assessed through history taking, physical examination, and anthropometric measurement. The anthropometric measurements that are routinely performed include the measurement of body weight, length/height, and head circumference.[3] Body length/height is considered crucial in assessing nutritional status, calculating body mass index (BMI), calculating drug doses, blood pressure, kidney function, lung function, and health monitoring.[4-6] According to World Health Organization (WHO) guidelines, the measurement of length/height for children aged above 2 years should be performed by having the children stand up straight barefoot with the back of the head, shoulders, buttocks, calves, and heels against the wall.[7] Due to several different circumstances, such as deformities of the lower limb, fractures, limited mobility, amputations, lower limb contractures, paraplegia, and pain, a proper measurement of height cannot be

✉ Rahmayani Rahmayani
rahma.yani.nfs@gmail.com

Received 22nd December 2021, revised 12th July 2022, accepted 9th November 2022.

performed.[6,8-10] Therefore, other methods are required to measure height.[3,5]

Several anthropometric measurements such as arm span, crown-rump length, sitting height, and segmental length (knee height, upper arm length, tibial length can be used as alternatives.[5] Arm span measurement has been found to provide a good predictive value for height and has been widely used as an alternative to height measurement.[11-13] The arm span is measured from the tip of the right middle finger to the tip of the left middle finger, either in a sitting or standing position (CDC 2009), as long as the arms can be fully stretched. This measurement requires two examiners.[14,15] The limitation of this measurement is that it cannot be performed on children with contractures or spastic hands.[5]

The use of arm span measurement in predicting height has been widely studied. Forman et al.[5] reported that the correlation of arm span to body height (r=0.97) was stronger than that of ulnar length to body height (r=0.91). Yousafzai et al.[16] compared arm span, arm length, and tibial length to body height and found the highest correlation coefficients for arm span (r^2=0.93), compared to arm length (r^2=0.81) and tibial length (r^2=0.72). These studies showed that arm span has a very strong correlation in predicting height compared to the other measurements.

The Center for Disease Control and Prevention (CDC) reported that the ratio of arm span to height was 1:1.[14] Lee et al.[13] in Taiwan demonstrated that the ratio of arm span compared to height was 0.98-1.03. Meanwhile, Mazicioglu et al.[10] in Turkey found that the ratio of arm span and height on 50th percentile was 0.99-1.01. The ratio of height to arm span can vary according to age, gender, and ethnicity.[17]

Data from Indonesia's National Socioeconomic Survey in 2018 showed that there were 31.59% of children aged 0-17 years suffering from health complaints, of which 15.89% of them had limitations on daily activities due to illnesses. As many as 1.11% of children aged 2-17 years were found to have long-term physical, mental, intellectual, or sensory disabilities.[18] This study was, therefore, conducted to analyze the correlation between the anthropometric measurements of arm span to body height in children aged 7-12 years.

Material and Methods

Study Population

The subjects of this study were children aged 7-12 years who were recruited from six elementary schools in Bandung, Indonesia with multistage cluster random sampling, as follows: (1) 3 out of 30 districts in Bandung were selected. (2) Out of every district, 3 public and private elementary schools were selected. (3) Out of the selected school, one class was selected from every grade (grades 1-6), of which all students in the selected classes were selected to be the research subjects.

The inclusion criteria of the study were healthy children whose parents consented to the participation of their children in the study by signing an informed consent. The exclusion criteria included children with scoliosis, stunting, and contractures. Scoliosis is a disorder in which the spine curves laterally >10^o with rotation of the spine. For the examination of scoliosis we used the Adams forward bend test in a standing and bent-forward position in order to assess the spinal symmetry from the back and from the side of the subject. The subject was asked to stand and bend forward with hands on the waist. The examiner then assessed the spinal symmetry from the back and from the side of the patient. Any spinal abnormalities, e.g. a rib hump, were considered signs of scoliosis. Stunting was defined as height according to age <-2 SD. Meanwhile, contracture was defined as reduced passive range of motion due to limitation of joints, muscles and soft tissue.

By using an observational analytic design with a cross-sectional method, the study was conducted from September to December 2019.

Clinical Evaluation

The height and arm span were measured by using 200-cm iron measuring tapes from Nankai brand (approval number 4478/PKTN.4.7/12/2018) and Ikoala brand (approval number 4477/PKTN.4.7/12/2018), which had been calibrated at the Director of Metrology of Directorate General of Consumer Protection and Orderly Commerce in Bandung.

Height measurement was performed on the subject while standing using a 200-cm, Nankai-brand measuring tape. The subject was asked to stand up straight with the back of the head, shoulders, buttocks, calves and heels against the wall barefoot. Any headdresses were removed. The subjects were asked to face straight ahead on a Frankfort horizontal plane and then to take a deep breath. Height was measured with the help of a stature meter, which was pulled until it pressed down against the crown of the head. The results were documented with an accuracy of 0.1 cm. Arm span was measured by two examiners. The subjects were asked to stand up straight with the arms stretched perpendicular to the trunk, assisted by the examiner. The arms were stretched maximally. The length of arm span was measured from the tip of the right middle finger to the tip of the left middle finger. Measurements were performed at the back of the body. The results were documented with the accuracy of 0.1 cm. All measurements were taken twice and the results of the measurements were documented based on the average value of the two measurements.

Outcome Variables

The assessed variables included anthropometric data and general characteristics of the subject. The data for general characteristics were taken from the school records, which included age, gender, parents' educational level, parents' occupation, family income, and ethnicity. Anthropometric data included arm span, body height, and body weight.

Sample Size Calculation

The sample size was calculated using an 80% power test, with a minimum correlation of r=0.4 and a significance level of 5%. Using this formula, the minimum sample size for each age group was 54 subjects. Therefore, the total number of samples needed for six age groups of 7-12 years were 324 subjects. With the anticipation of a 10% dropout rate, the final number of samples needed were 360.

Statistical Analysis

If the data distribution was normal, correlations between numerical variables were analyzed using Pearson correlation. Multivariate analysis was performed using multiple linear regression and a p value <0.05 was considered to be statistically significant. A concordance correlation was used to assess the difference between the predicted height and the actual height.

Ethical Consideration

This study has been approved by the Research Ethics Committee of the Faculty of Medicine Universitas Padjadjaran (approval number 1171/UN6.KEP/EC/2019)

Validity of Anthropometric Measurements

Before starting the data collection, a validity test was performed to assess the intra- and inter-observer validity. The test was conducted by two investigators, in which each investigator recorded two measurements. The validity and reliability tests were performed on 30 samples. The validity test showed that the height and arm span measurements between the two investigators had no significant differences (p>0.05). The reliability test also showed a good correlation between the measurements performed by the two investigators.

Results

Based on the data from six selected schools, there were 1,279 children aged 7-12 years. Of those, 165 children were excluded from the study due to several reasons, including 145 children with a Z-score of height for age <-2 SD (stunting), 2 children with contractures, and 18 children who were absent during the data collection. Hence, a total of 1,114 children underwent measurements and data collection for basic characteristics and anthropometric measurements (body weight, height, and arm span). The data for basic characteristics were taken from the student data record. (Fig. 1).

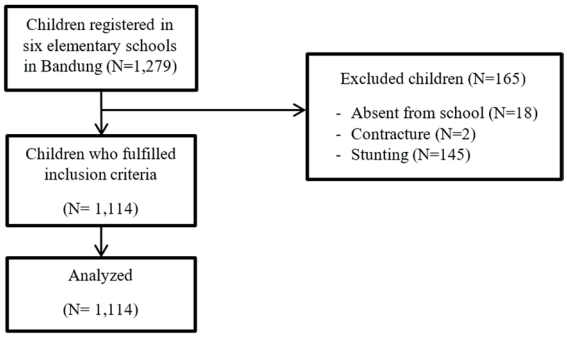

Fig. 1. Subject Selection Flow.

The sociodemographic characteristics and body mass index distribution of the children are shown in Table I. A total of 1,114 children were analyzed, of whom 596 were boys (53.5%) and 518 were girls (46.5%). For the distribution of age, most of the subjects were at the age of 11 years (20.9 %), followed by the age of 7 years (19.8%), and, finally, the age of 12 years (10.9%). Sundanese made up the majority of ethnic groups (85.1%). The majority of the subjects were categorized as having a normal nutritional status (86%).

The distribution of height and arm span of subjects were presented in figure 2 and figure 3. Both figures display the data distribution from +3 SD to -3 SD. The data in -2 SD and -3 SD of height and arm span does not indicate that those with stunting were recruited, rather it is the result of data distribution of the subjects enrolled.

Table I. Sociodemographic and body mass index distribution of the study children.

Characteristics	Total	%
Age (years)		
7 years (84-95 months)	221	19.8
8 years (96-107 months)	189	17.0
9 years (108-119 months)	170	15.3
10 years (120-131 months)	180	16.2
11 years (132-143 months)	233	20.9
12 years (144-155 months)	121	10.9
Gender		
Male	596	53.5
Female	518	46.5
Ethnic Group		
Sundanese	948	85.1
Javanese	74	6.6
Others	92	8.3
Body Mass Index		
> 2 SD	57	5.1
+ 1 – +2 SD	80	7.2
-2 – + 1 SD	958	86
-3 – <-2 SD	14	1.3
<-3 SD	5	0.4

Table II demonstrates the average value, range, and ratio of height and arm span for each age group. The ratio of height to arm span in this study was between 0.98-1.01. Height was found to be the same as arm span at the age of 7-10 years for both male and female subjects. At the ages of 11 and 12, arm span was found to be greater than body height (>1 cm), for both male and female subjects.

Table III shows the anthropometric measurements of body height, weight, arm span, and BMI in both male and female subjects. This table also shows no significant differences between male and female measurements ($p>0.05$).

Table IV shows the correlation between height and arm span as well as between height and age. The result showed a significant difference between the variables ($p <0.05$) with a strong correlation ($r>0.7$).

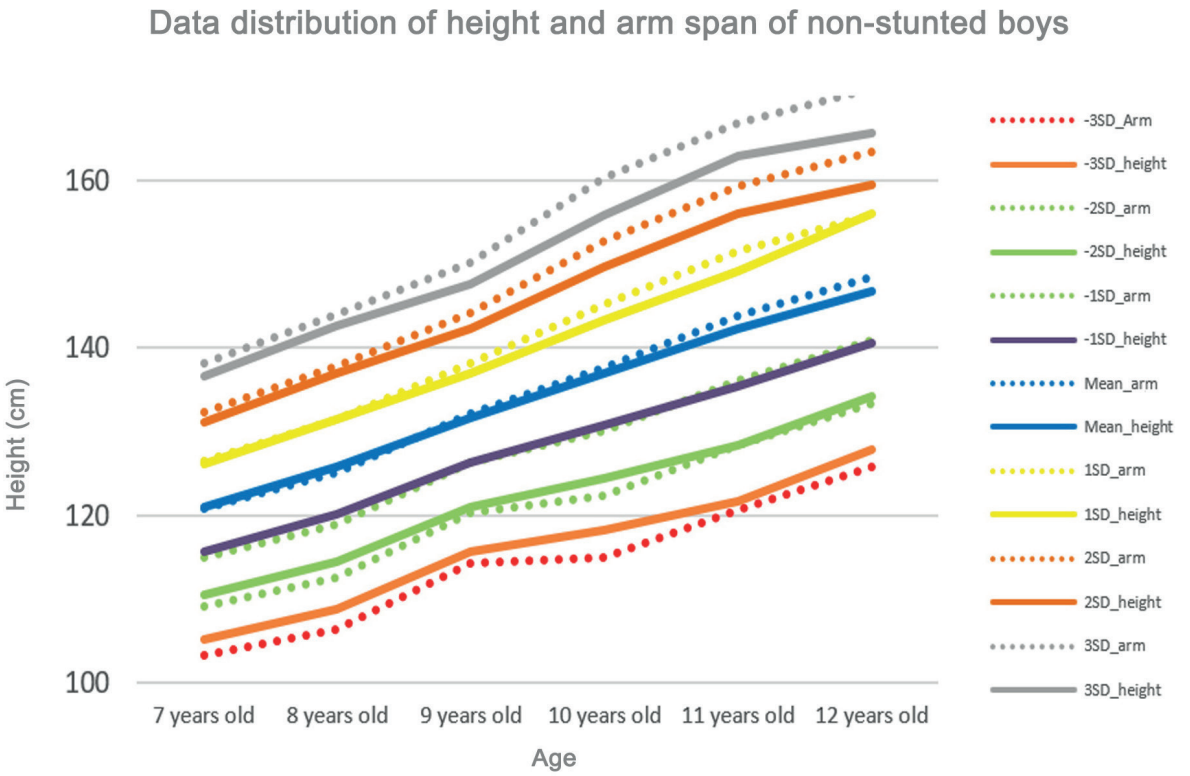

Fig. 2. Height and arm span of male subjects.

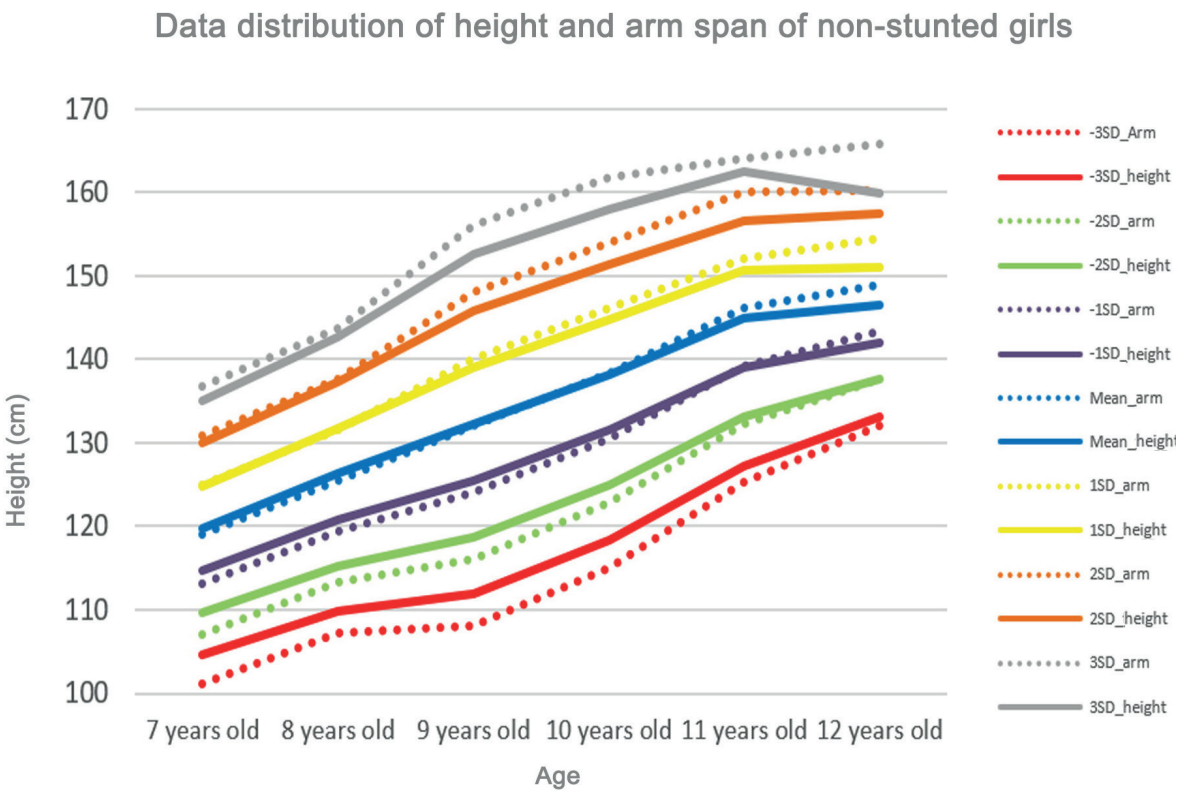

Fig. 3. Height and arm span of female subjects.

Table II. Distribution of height, arm span and height/arm span ratios according to age groups and gender.

Anthropometric Measurement	Child age (year)					
	7	8	9	10	11	12
Male	(n=129)	(n=95)	(n=90)	(n=85)	(n=127)	(n=70)
Height (cm)						
Mean (SD)	120.96 (5.23)	125.76 (5.66)	131.60 (5.34)	137.06 (6.30)	142.29 (6.88)	146.81 (6.31)
Range	111.4-137.8	117.2-147.1	122.70-147.9	125.8-155.8	131.2-161.0	135.0-166.4
Arm span (cm)						
Mean (SD)	120.74 (5.83)	125.20 (6.30)	132.25 (5.97)	137.66 (7.58)	143.79 (7.72)	148.41 (7.54)
Range	108.6-143.0	113.5-146.7	121.0-148.7	124.4-163.9	129.2-168.2	135.3-163.1
Height to arm span ratio	1.00	1.00	1.00	1.00	0.99	0.99
Height to arm span difference (HAD)	0.22	0.56	-0.65	-0.60	-1.50	-1.60
Female	(n=92)	(n=94)	(n=80)	(n=95)	(n=106)	(n=51)
Height (cm)						
Mean (SD)	119.79 (5.07)	126.26 (5.48)	132.21 (6.79)	138.15 (6.60)	144.88 (5.88)	146.49 (4.47)
Range	113.1-135.1	116.3-138.4	121.7-154.1	126.0-154.9	131.2-159.1	137.9-156.9
Arm span (cm)						
Mean (SD)	119.01 (5.95)	125.95 (6.11)	132.05 (7.99)	138.75 (7.81)	146.16 (6.95)	148.92 (5.62)
Range	105.6-135.5	112.7-139.5	119.1-158.9	124.1-158.0	132.4-169.9	137.8-163.4
Height to arm span ratio	1.01	1.00	1.00	1.00	0.99	0.98
Height to arm span difference (HAD)	0.78	0.31	0.16	-0.60	-1.28	-2.43

Table III. Comparison of anthropometric measurements in male and female children.

Anthopometric Measurements	Gender		p value*
	Male (n = 596)	Female (n=518)	
Height (cm)			0.180
Mean (SD)	133.2 (10.9)	134.0 (11.1)	
Range	111.4 – 166.4	113.1 – 159.1	
Weight (kg)			0.583
Mean (SD)	31.44 (10.35)	31.77 (9.85)	
Range	14.9 – 72.0	15.5 – 62.8	
Arm span (cm):			0.385
Mean (SD)	133.76 (12.0)	134.40 (12.46)	
Range	108.6 – 168.2	105.6 – 163.4	
Body Mass Index (kg/m^2)			0.672
Mean (SD)	17.40 (3.92)	17.31 (3.38)	
Range	11.08 – 50.07	11.27 – 31.02	

Table IV. Pearson bivariate analysis of height in correlation with arm span and age.

Characteristics	Height (cm)	
	R coefficient	p-value
Arm span (cm)	0.962	<0.001
Child age (year)	0.850	<0.001

In order to investigate the relationship between several variables (arm span, age, and gender) and height, a backward-type multiple regression analysis was performed. From the analysis, it was found that gender was not a statistically significant variable in predicting height; hence, it was opted out of the formula produced in this study. Table V shows the prediction formula of height based on arm span and age according to gender.

The equation of the male regression model (R^2 = 94%; Root Mean Square Error (RMSE) = 2.852; standard error of estimate (SEE)=2.66):

Height (cm)=21.8623+0.7634 × Arm Span(cm)+0.0791 × Age(month)

The equation of the female regression model (R^2 = 95.4%; RMSE = 2.402; SEE=2.39):

Height (cm)=21.2395+0.7779 × Arm Span(cm)+0.0701 × Age(month)

A concordance correlation test was performed in order to test the accuracy of the height prediction formula produced from this study when compared to the actual height. Table VI shows that the concordance correlation coefficient (CCC) of the male and female formula exhibited a high value of CCC (>0.95), precision (p> 0.95), and accuracy (Cb> 0.95).

Table VII demonstrates the average difference between the predicted height and actual height. It also shows that there was no significant difference between predicted height and actual height in the male and female formula (p>0.05). The differences in average values obtained were -0.003 cm in the male formula and -0.002 cm in the female formula.

Discussion

This study was conducted on 1,114 children aged 7-12 years. For optimum measurements,

Table V. Prediction formula of height based on arm span and age according to gender.

Gender	Independent Variable	Unstandardized Coefficients		t value	p-value
		B	Std. Error		
Male	Constant value	21.8623	1.4121	15.483	<0.001
	Arm span (cm)	0.7634	0.0162	47.173	<0.001
	Age (Month)	0.0791	0.0093	8.532	<0.001
Female	Constant value	21.2395	1.2902	16.463	<0.001
	Arm span (cm)	0.7779	0.0156	49.838	<0.001
	Age (Month)	0.0701	0.0099	7.079	<0.001

Dependent Variable: Height.

Table VI. Concordance correlation value of height prediction formula based on arm span in comparison to actual height.

This Study	N	Concordance correlation coefficient	Pearson ϱ (precision)	Bias correction factor Cb (accuracy)
Male Formula	596	0.9693 (0.9641 – 0.9738)	0.9698	0.9995
Female Formula	518	0.9764 (0.9721 – 0.9801)	0.9767	0.9997

Table VII. Difference between average height based on formula and actual height based on several prediction formula results.

	Average of Predicted Height (cm)	Difference in average (95% CI)	*p* value
Male			
(Actual Height Mean: 133.211 (10.898))			
Actual vs. this study (2020)	133.214 (10.569)	-0.003 (-0.217 – 0.211)	0.978
Female			
(Actual Height Mean: 134.012 (11.136))			
Actual vs. this study (2020)	134.014 (10.877)	-0.002 (-0.208 – 0.204)	0.986

we included only children who, based on their age, are expected to be capable of properly following measurement instructions. In addition, children aged 7-12 years old are elementary school children, and this eased the sample collection process in this study. The total number of subjects analyzed in this study exceeded the calculated minimum sample size as all students of every selected class were included as the subjects of this study. From a statistical point of view, larger samples are known to produce a greater power with a smaller standard error.[19] The average height and arm span of male subjects were found to be lower than those of female subjects even though no significant difference was found in this study ($p>0.05$). This was probably caused by earlier puberty in girls compared to boys.[20]

Several factors were found to affect height, including age and arm span. Strong correlations were found between height and arm span ($r=0.962$) and between age and arm span ($r=0.850$). The results of this study were in line with the study by Forman et al.[5], which reported a strong correlation between height and arm span ($r=0.97$), as well as the study by Maziciouglu et al.[10] ($r=0.95$).

Height was found to be the same as arm span in male subjects aged 7-10 years, but the arm span was found to exceed the height for the other age groups with a maximum difference of 1.6 cm. Whereas in female subjects, height was found to exceed the arm span at the age of 7 years, equal to arm span at age 8 to 10 years, but subsequently, arm span was found to exceed height with maximum difference of 2.43 cm. This result is different from the study by Zverev et al.[21] in Malawi, in which arm span was found to exceed height in all age groups between 6-15 years. The difference between arm span and height was about 2.9 cm in boys aged 6 years and 10.5 cm in boys aged 15 years. Whereas in girls, the difference was 10.3 cm at younger ages and 7.7 cm at the ages of 14 and 15 years. Turan et al.[22] in Turkey reported that the difference between arm span and height was about 2 cm in girls aged 4 years and later became the same at the age of 9 years. Whereas in boys, the difference was about -1.1 cm and gradually increased by about 2 cm after puberty.

The ratio of height to arm span in this study ranged between 0.98-1.01 in all age groups. The CDC reported that the height-to-arm-span ratio is 1:1 with an accurate measurement and normal growth.[14] Lee et al.[13] in Taipei found the results of the height-and-arm-span ratio varied from 0.98-1.03 in boys and from 0.99-1.03 in girls. A study by Alam et al.[23] in Uttar Pradesh, India demonstrated that the height-to-arm-span ratio varied from 0.98-0.99. The possible reason regarding the difference found in the height-to-arm span ratio and the differences among the studies is that the above studies were conducted locally with many different ethnicities, which can affect the children's growth. Several factors known to affect growth include genetic, hormonal and environmental factors (nutritional factors, physical activity, family factors, psychological factors).[14,22] This

reasoning is also in line with the study by Quanjer et al.[17], which found that the height-to-arm-span ratio might vary based on gender, age and race.

The results of this study do not indicate that the arm span ratio is equal to height as 1:1, thus arm span should not be used as a direct substitute for height. A study by Chhabra[24] compared the three estimates of height obtained from arm span: (1) by direct substitution using arm span, (2) the ratio of mean arm span-to-standing height, and (3) the regression equations. The study found that the error rates of ratios and regression equations were smaller (5-6%) than those of direct substitution (23.7%). Aggarwal et al.[25] also showed that the error rate was higher when the arm span was used as a direct substitute to height. The use of arm span directly to substitute height was found to produce an error of 16% compared to the use of the ratio (14%). The use of arm span in a prediction equation to calculate height leads to a smaller error rate compared to direct substitution. Error rates were found to be even smaller if height is predicted based on arm span and age.[17] A study by Mishra et al.[26] also showed that the regression equation provides a better estimation of height compared to the use of height-to-arm-span ratio.

The resulting regression equations, both in male and female subjects, provide a very high coefficient of determination (R^2> 94%) and a low SEE value (SEE=2.53). Zverev et al.[21] studied 626 children aged 6-15 years in Malawi and found the R^2=0.988, SEE=0.76. Mazicioglu et al.[10] in Turkey studied 5,358 children aged 6-17 years and found a correlation of R = 0.8310. Meanwhile, Mishra et al.[26] studied 1,465 children aged 6-11 years in India and found R^2=0.91 and SEE=2,96. The aforementioned studies showed a strong correlation between height and arm span, as well as a low SEE value. By conducting a correlation test comparing the actual height and the predictive height obtained from various existing regression equations, it was found that by using the regression equation obtained in this study, there was no significant difference between the predicted height and actual height (p> 0.05). The result of this study also showed that the average differences between the actual height and predicted height were of low values, which were -0.003 for male's height and -0.002 for female's height. The result of this study was also tested by using concordance correlation to see the level of accuracy and precision of the prediction formula on the actual height. The results obtained consecutively in male and female subjects were CCC=0.9693, p=0.9698 and Cb=0.9995 and CCC=0.9764, p=0.9767, Cb=0.9997, respectively. This might be due to the use of the "month" as the measurement of age. Age as an additional variable would strengthen the correlation between height and arm span. The regression equation will be specific for a certain age group and ethnicity.[16]

Studies in Indonesia are still limited. This study included a large number of subjects, 1,114 in total. This study also used "month" as the measurement of age, thus the results are expected to be more accurate. The limitation of the study is that the results of the study could not cover all ages, only for children aged 7-12 years. Therefore, the existing formula can not be used to estimate the alternative height in children aged younger than 7 years or older than 12 years. In addition, we did not asses the status of puberty of the subjects in this study.

To conclude, arm span and height are strongly correlated. Arm span can predict the actual height of children aged 7-12 years; thus, it can be used as an alternative measurement for growth.

Acknowledgements

We extend our gratitude to the headmasters, teachers and staffs of the elementary schools in Bandung for supporting our efforts throughout data collection. We heartily thank the children for their commitment and participation. The abstract of this manuscript has been published as preprints with The Lancet on 14 September 2020 at http://dx.doi.org/10.2139/ssrn.3667619.

Ethical approval

This study has been approved by the Research Ethics Committee of the Faculty of Medicine Universitas Padjadjaran (approval number 1171/UN6.KEP/EC/2019).

Author contribution

The authors confirm contribution to the paper as follows: study conception and design: RR; data collection: RR, FR; analysis and interpretation of results: RR; draft manuscript preparation: RR, EF, MD, KR, RT. All authors reviewed the results and approved the final version of the manuscript.

Source of funding

The authors declare the study received no funding.

Conflict of interest

The authors declare that there is no conflict of interest.

REFERENCES

1. Beker L. Principles of growth assessment. Pediatr Rev 2006; 27: 196-198. https://doi.org/10.1542/pir.27-5-196
2. Nichols J. Normal growth patterns in infants and prepubertal children. UpToDate 2018. Available at: https://www.uptodate.com/contents/normal-growth-patterns-in-infants-and-prepubertal-children (Accessed on July 26, 2020).
3. National Health and Nutrition Examination Survey. Anthropometry procedures manual. 2007. Available at: https://www.cdc.gov/nchs/data/nhanes/nhanes_13_14/2013_Anthropometry.pdf (Accessed on July 26, 2020).
4. Soetjiningsih. Monitoring of children's physical growth. In: Soetjiningsih, editor. Children's growth and development. 2nd ed. Jakarta: Sagung Seto; 2002. p. 131-141.
5. Forman MR, Zhu Y, Hernandez LM, et al. Arm span and ulnar length are reliable and accurate estimates of recumbent length and height in a multiethnic population of infants and children under 6 years of age. J Nutr 2014; 144: 1480-1487. https://doi.org/10.3945/jn.114.194340
6. Chen WY, Lin YT, Chen Y, et al. Reference equations for predicting standing height of children by using arm span or forearm length as an index. J Chin Med Assoc 2018; 81: 649-656. https://doi.org/10.1016/j.jcma.2017.08.023
7. World Health Organization. Training course on child growth assessment. 2008. Available at: https://apps.who.int/iris/rest/bitstreams/51774/retrieve (Accessed on July 26, 2020).
8. Yabanci N, Kiliç S, Simşek I. The relationship between height and arm span, mid-upper arm and waist circumferences in children. Ann Hum Biol 2010; 37: 70-75. https://doi.org/10.3109/03014460903198517
9. Brown JK, Whittemore KT, Knapp TR. Is arm span an accurate measure of height in young and middle-age adults? Clin Nurs Res 2000; 9: 84-94. https://doi.org/10.1177/10547730022158456
10. Mazicioglu MM, Hatipoglu N, Ozturk A, Gun I, Ustunbas HB, Kurtoglu S. Age references for the arm span and stature of Turkish children and adolescents. Ann Hum Biol 2009; 36: 308-319. https://doi.org/10.1080/03014460902740954
11. Arifi F, Bjelica D, Sermaxhaj S, Gardasevic J, Kezunovic M, Popovic S. Stature and its estimation utilizing arm span measurements in Kosovan adults: National survey. Int J Morphol 2017; 35: 1161-1167. https://doi.org/10.4067/s0717-95022017000300055
12. Arlappa N, Qureshi IA, Ravikumar BP, Balakrishna N, Arbaab M. Arm span is an alternative to standing height for calculation of body mass index (BMI) amongst older adults. International Journal of Nutrition 2016; 2: 12-24. https://doi.org/10.14302/issn.2379-7835.ijn-15-903
13. Lee TS, Chao T, Tang RB, Hsieh CC, Chen SJ, Ho LT. A longitudinal study of growth patterns in schoolchildren in one Taipei District. II: Sitting height, arm span, body mass index and skinfold thickness. J Chin Med Assoc 2005; 68: 16-20. https://doi.org/10.1016/S1726-4901(09)70126-1
14. Centers for Disease Control and Prevention. The CDC growth charts for children with special health care needs. 2018. Available at: https://www.medicalhomeportal.org/link/5550 (Accessed on July 26, 2020).

15. Ismail H, Ness K. Evaluation of short stature in children. Pediatr Ann 2013; 42: 217-222. https://doi.org/10.3928/00904481-20131022-08

16. Yousafzai AK, Filteau SM, Wirz SL, Cole TJ. Comparison of armspan, arm length and tibia length as predictors of actual height of disabled and nondisabled children in Dharavi, Mumbai, India. Eur J Clin Nutr 2003; 57: 1230-1234. https://doi.org/10.1038/sj.ejcn.1601705

17. Quanjer PH, Capderou A, Mazicioglu MM, et al. All-age relationship between arm span and height in different ethnic groups. Eur Respir J 2014; 44: 905-912. https://doi.org/10.1183/09031936.00054014

18. Statistics Indonesia. Profile of Indonesian children 2019. 2019. Available at: https://www.kemenpppa.go.id/lib/uploads/slider/e56dc-15242-profil-anak-indonesia_-2019.pdf (accessed July 26, 2020).

19. McDonald JH. Standard error of the mean - handbook of biological statistics. 2014. Available at: http://www.biostathandbook.com/standarderror.html (Accessed on July 26, 2020).

20. Soetjiningsih. Somatic growth in adolescence. In: Soetjiningsih, editor. Adolescent growth and development and its problems. 3rd ed. Jakarta: Sagung Seto; 2010. p. 1-16.

21. Zverev Y, Chisi J. Estimating height from arm span measurement in Malawian children. Coll Antropol 2005; 29: 469-473.

22. Turan S, Bereket A, Omar A, Berber M, Ozen A, Bekiroglu N. Upper segment/lower segment ratio and armspan-height difference in healthy Turkish children. Acta Paediatr 2005; 94: 407-413. https://doi.org/10.1111/j.1651-2227.2005.tb01909.x

23. Alam MT, Singh S, Rai R, Shaheen S. Correlation between stature and arm span: a prospective regional study in eastern Uttar Pradesh. Ann Int Med Dent Res 2016; 2: 56-60. https://doi.org/10.21276/aimdr.2016.2.3.15

24. Chhabra SK. Using arm span to derive height: impact of three estimates of height on interpretation of spirometry. Ann Thorac Med 2008; 3: 94-99. https://doi.org/10.4103/1817-1737.39574

25. Aggarwal AN, Gupta D, Jindal SK. Interpreting spirometric data: impact of substitution of arm span for standing height in adults from North India. Chest 1999; 115: 557-562. https://doi.org/10.1378/chest.115.2.557

26. Mishra SP, Mondal H, Mondal S. Estimation of height from arm span in 6-11 years in Odisha, India. J Clin Diagn Res 2017; 11: 1-4. https://doi.org/10.7860/JCDR/2017/29256.10687