Paediatrica Indonesiana

p-ISSN 0030-9311; e-ISSN 2338-476X; Vol.58, No.3(2018). p. 138-45; doi: http://dx.doi.org/10.14238/pi58.3.2018.138-45

Original Article

Sitting height, sitting height/height ratio, arm span, and arm span-height differences of healthy adolescents

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Abstract

Background Sitting height, sitting height/height ratio (SHR), arm span, and arm span-height difference (AHD) are indices to diagnose conditions of disproportion. Reference data on sitting height, SHR, arm span, and AHD for Indonesian children are limited.

Objective To compile reference data on sitting height, SHR, arm span, and AHD in Indonesian adolescents, and to compare these indices for boys and girls at various ages.

Methods A population-based survey was conducted from August 2016 to November 2017 in three high schools in Surakarta, Central Java, Indonesia. A convenience sampling method was employed to recruit healthy adolescents without history of chronic disease, history of physical trauma, and/or physical disabilities. All subjects underwent anthropometric measurements (height, weight, sitting height, and arm span), and their ethnic origins were noted. The lambda-mu-sigma (LMS) method was used for reference construction.

Results Of 639 subjects, 42% were male. Body mass index (BMI) values were similar between males and females. Mean height, weight, sitting height, and arm span of males were greater than those of females. The mean male and female SHRs were 51.1 (SD 1.6) % and 51.0 (SD 1.6) %, respectively (P=0.36), while the mean AHDs were 4.2 (SD 4.5) cm and 3.4 (SD 4.1) cm, respectively (P=0.02). The formula to estimate height based on arm span in males was [height = (0.78 x arm span) + 32.14] in cm. The formula in females was [height = (0.66 x arm span) + 50.59] in cm.

Conclusion There was no significant difference in SHR between male and female adolescents. However, males have significantly larger mean AHD than females. We provide references on sitting height, SHR, arm span, and AHD in male and female adolescents. **[Paediatr Indones. 2018;58:138-45; doi: http://dx.doi.org/10.14238/pi58.3.2018.138-45]**.

Keywords: *sitting height; sitting height/height ratio; arm span; arm span-height difference; adolescent*

Normal growth is essential for children. The routine anthropometric indices used to evaluate growth are height, weight, and head circumference. Subsequent advanced measurements are done when an abnormal result, e.g., short or tall stature, is found. These advanced measurements include upper-lower segment ratio, arm span, and other investigations into possibilities of organic diseases or dysmorphology.[1]

To assess for growth disorders, reference data on body proportion, such as sitting height, sitting height/height ratio (SHR), and arm span-height difference (AHD) are needed. The SHR varies among children of different ethnicities, ages, and sex. Body disproportion may be due to genetic disease or syndrome, such as short stature homeobox (SHOX) defects, Turner syndrome, idiopathic short stature, and achondroplasia.[2] Body proportion has also been correlated with some environmental factors, such as nutrition, lifestyle, and chronic disease. In addition, past studies have found a correlation between SHR and body mass index (BMI), a marker of obesity.[3,4] There

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is also evidence that adults with disproportionate body measurements are at risk for cardiovascular disease and impaired glucose metabolism.[5] Arm span measurement is useful for some syndromes, such as Marfan syndrome and achondroplasia. Both short and long extremities may lead to an abnormal AHD. A positive correlation between arm span and stature is helpful for predicting height in disabled individuals.[1,2]

Reference data for SHR, arm span, and AHD are needed for diagnosing growth disorders.[1] To date, we have limited national reference data for Indonesian children. Hence, we aimed to compile reference data on SHR and AHD among healthy adolescents in Surakarta, Indonesia.

Methods

This survey was conducted in three high schools (2 senior high schools and 1 junior high school) from August 2016 to November 2017 in Surakarta, Central Java, Indonesia. We asked for students who presented at their schools during study periods, to enroll this study (soliciting subjects). We obtained parental written informed consent for all participants. Inclusion criteria were male and female students aged 11 to 19 years. We excluded children with a history of chronic disease, physical trauma (from interview), or physical disability (from physical examination).

Subject characteristics were collected from school data records, including birth date, sex, and parents' ethnicities. If the data were incomplete, subjects were interviewed. If both parents were of the same ethnicity, subjects were categorized as being of Javanese, Chinese, or Arab ethnicity; otherwise, they were categorized as mixed/others.

All subjects underwent anthropometric measurements (height, weight, sitting height, and arm span) in triplicate by trained personnel. Each subject was measured three times by the same person and the mean of the three measurements was calculated. Height and sitting height were measured using a wall stadiometer (*Stature Meter 2M GEA*) to the nearest 0.1 cm with the subject facing the examiner. Subjects were asked to stand without shoes for height measurement and to sit for sitting height measurement. Body weight was measured using a digital scale (*Seca Clara 803*, Germany) to the nearest 0.1 kg. The SHR was calculated by dividing sitting height by height and expressed as percentage. The AHD was calculated by subtracting height from arm span in centimeters.

We reported means, standard deviations (SD) and percentages for descriptive data. Males and females were reported separately. We extrapolated the formula for height based on arm span by linear regression analysis. Reference charts were constructed using the the lambda-mu-sigma (LMS) method by *Cole6* with the help of *LMS Chartmaker Light version 2.54* software (Harlow Healthcare, Tyne & Wear, United Kingdom) for fitting and smoothing. Lambda, mu, and sigma represent the skewness (power transformation), median, and coefficient of variation from the Box-Cox transformation. We hypothesized that SHR and AHD were different between male and female. This study was approved by the Health Research Ethics Committee of Dr. Moewardi General Hospital/Sebelas Maret University Medical School, Surakarta.

Results

Six hundred and thirty-nine subjects were enrolled in this study. Subject characteristics are summarized in **Table 1**. The comparison of mean SHR and mean AHD between male and female subjects can be seen in **Table 2**.

The formulae for predicting male and female height based on arm span are described in **Table 3**. There is a strong correlation between height and arm span in both sexes (P=0.00). Charts depicting height, sitting height, SHR, body mass index, arm span, and AHD in males and females are shown in **Figure 1**. SHR patterns are similar in males and females, peaking in mid-adolescence, then decreasing. Male and female AHD patterns are also similar to each other, with the lowest values seen in mid-adolescence. The LMS parameters and SDs (-2SD and +2SD) for height, sitting height, SHR, and arm span in males and females are shown in **Tables 4** and **Table 5**. In males, some age groups had negative skewness values for SHR of <-2, while in females, the skewness in many age groups were <-2 or >2. **Table 6** describes the results from ethnic Chinese' subjects.

Table 1. Baseline characteristics of subjects

Characteristics	Total (N=639)	Male (n=266)	Female (n=373)
Mean age (SD), years	15.7 (1.6)	15.3 (1.7)	16.0 (1.5)
Mean height (SD), cm	157.7 (8.5)	162.8 (9.0)	154.1 (5.8)
Mean weight (SD), kg	53.4 (13.5)	56.7 (15.0)	51.1 (11.7)
Mean BMI (SD), kg/m^2	21.4 (4.6)	21.3 (4.9)	21.5 (4.5)
Mean sitting height (SD), cm	80.4 (4.5)	83.0 (4.5)	78.5 (3.5)
Mean arm span (SD), cm	161.4 (9.9)	166.9 (10.3)	157.5 (7.4)
Ethnicity, n (%)			
Javanese	481 (75.3)	213 (80.1)	268 (71.8)
Chinese	48 (7.5)	21 (7.9)	27 (7.2)
Arab	60 (9.4)	1 (0.4)	59 (15.8)
Others	50 (7.8)	31 (11.7)	19 (5.1)

Table 2. Sitting height/height ratio and arm span-height difference comparisons between male and female subjects

	Male (n=266)	Female (n=373)	P value
Mean SHR (SD), %	51.1 (1.6)	51.0 (1.6)	0.36
Mean AHD (SD), cm	4.2 (4.5)	3.4 (4.1)	0.02

greater than mean female corresponding values, although the mean age of the male group was lower. However, mean BMI and SHR were not significantly different between males and females. The mean heights of both male and female subjects in our study were within -2SD to +2SD of those found in an earlier study in Indonesian children,[7] but were below

Table 3. Formulae to predict height based on arm span in males and females

	Formula	r	R^2	P value
Male	Height = (0.78 x Arm span) +32.14	0.90	0.81	0.00
Female	Height = (0.66x Arm span) +50.59	0.84	0.70	0.00

Table 4. LMS parameters and SDs for height, sitting height, SHR, and arm span in males

Age	Height					Sitting Height					Sitting Height/Height Ratio					Armspan				
(years)	L	S	M	-25D	25D	L	S	M	-25D	25D	L	S	M	-25D	25D	L	S	M	-25D	25D
12	2,52	0,05	144,78	129,83	157,70	1,15	0,04	73,92	67,27	80,48	-0 52	0,02	0,51	0,50	0,54	0,35	0,04	147,56	136,36	159,35
12,5	1,15	0,05	150,59	134,68	166,25	0,24	0,06	77,76	68,88	87,49	-198	0,03	0,52	0,49	0,54	0,75	0,06	153,30	136,44	170,64
13	0,04	0,05	154,06	138,60	171,16	0,14	0,06	79,83	70,83	89,80	-2 76	0,03	0,52	0,49	0,55	1,13	0,06	157,15	137,95	176,05
13,5	-0,71	0,05	156,88	142,31	174,19	0,75	0,05	81,43	72,78	90,30	-2 26	0,03	0,52	0,49	0,55	1,58	0,06	160,46	141,05	178,59
14	-1,38	0,05	159,43	145,97	176,26	1,11	0,05	82,28	74,19	90,28	-0 71	0,03	0,52	0,48	0,55	1,93	0,05	162,93	144,56	179,55
14,5	-1,95	0,04	161,63	149,35	177,46	1,10	0,04	82,96	75,52	90,33	0,76	0,03	0,51	0,48	0,55	2,14	0,05	164,91	148,19	179,89
15	-2,31	0,04	163,67	152,30	178,45	0,90	0,04	83,52	76,55	90,56	1,56	0,03	0,51	0,48	0,54	2,28	0,04	166,95	151,92	180,42
15,5	-2,36	0,04	165,51	154,60	179,53	0,62	0,04	84,22	77,54	91,09	1,56	0,03	0,51	0,48	0,54	2,29	0,04	169,57	155,93	181,92
16	-2,18	0,04	166,45	155,76	179,90	0,46	0,04	84,59	78,06	91,41	0,89	0,03	0,51	0,48	0,54	2,14	0,04	171,65	158,44	183,79
16,5	-2,03	0,04	166,85	156,24	179,99	0,44	0,04	84,63	78,12	91,44	-010	0,03	0,51	0,48	0,54	1,96	0,04	172,78	159,37	185,26
17	-182	0,03	167,26	156,73	180,06	0,40	0,04	84,74	78,26	91,53	-112	0,03	0,51	0,48	0,54	1,65	0,04	173,80	160,20	186,73
17,5	-174	0,03	167,38	156,88	180,06	0,36	0,04	84,84	78,40	91,62	-2 09	0,03	0,51	0,48	0,53	1,50	0,04	173,85	160,37	186,83
18	-148	0,03	167,68	157,28	179,96	0,28	0,04	85,03	78,65	91,78	-2 97	0,03	0,50	0,48	0,53	1,04	0,04	172,94	160,30	185,55

L= lambda= skewness (power transformation); S= sigma= coefficient of variation; M= mu=median

Discussion

We present anthropometric data of adolescents in Surakarta, Central Java, Indonesia. Mean male body height, weight, sitting height, and arm span were

the WHO growth reference means.[8] We found mean SHRs of 51.1% in males and 51.0% in females. This ratio was slightly lower than that found in Dutch, Turkish, Chinese, and Spanish adolescents, which ranged from 52% to 53%.[1,9-11] Our ethnic Chinese subjects had mean SHRs similar to the overall mean

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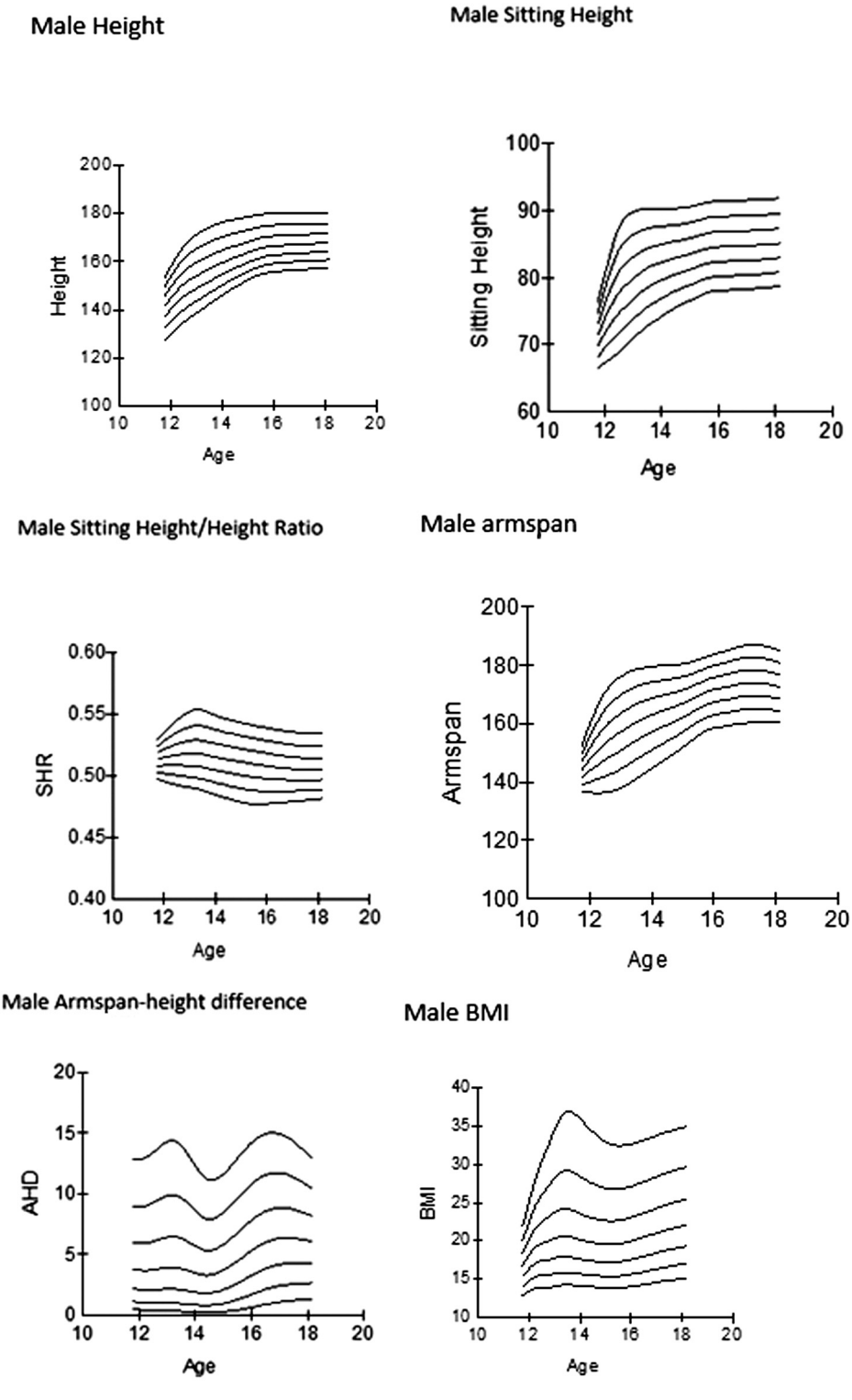
Male Height
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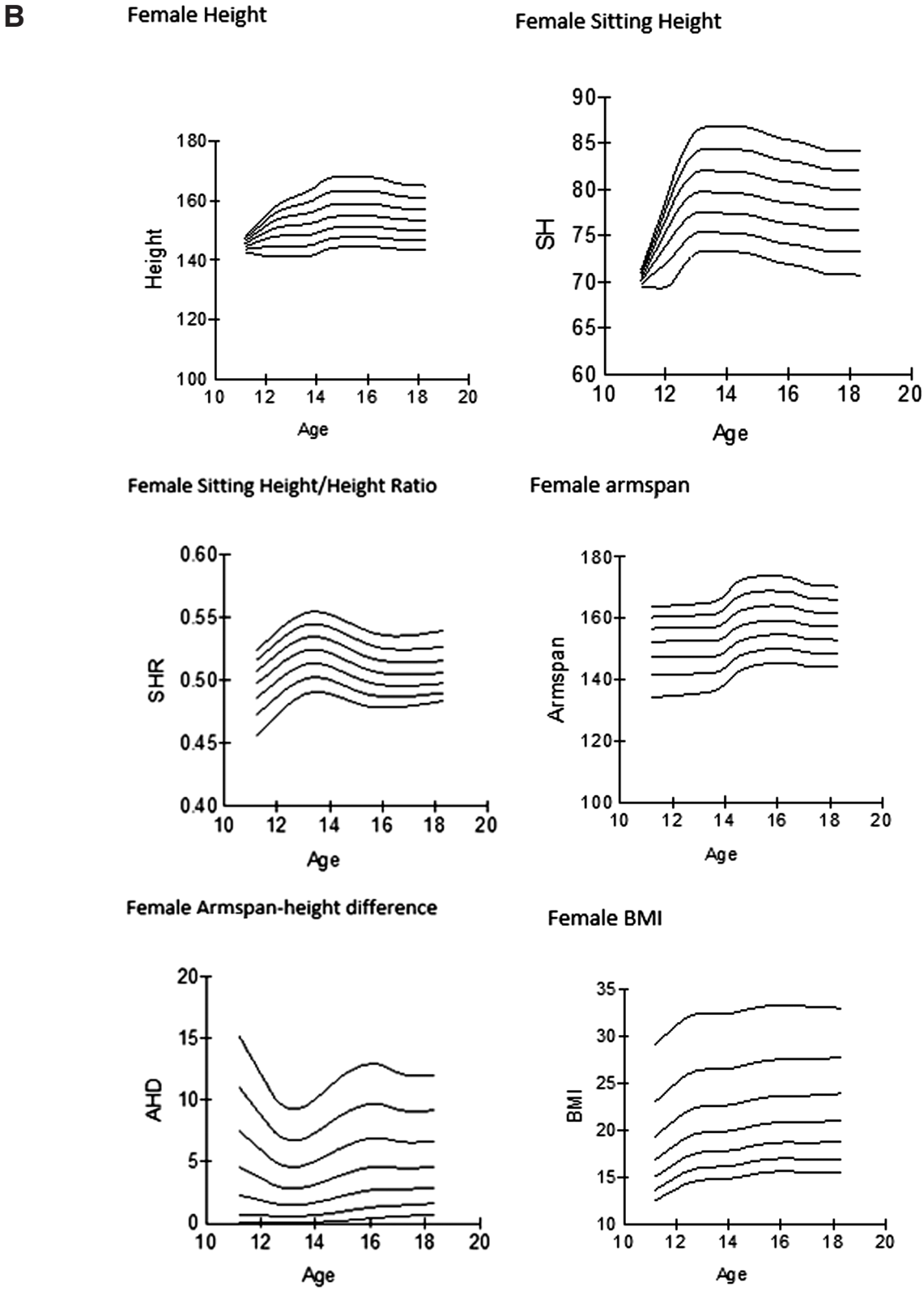

Figure 1. Charts for height, sitting height, SHR, arm span, AHD, and BMI in males (A) and females (B)

Table 5. LMS parameters and SDs for height, sitting height, SHR, and arm span in females

Age	Height					Sitting Height					Sitting Height/Height Ratio					Armspan				
(years)	L	S	M	-25D	25D	L	S	M	-25D	25D	L	S	M	-25D	25D	L	S	M	-25D	25D
11,5	11,83	0,01	147,24	142,23	150,88	17,06	0,02	72,38	69,20	74,22	6,80	0,03	0,50	0,46	0,53	5,75	0,04	152,46	134,46	163,87
12	8,57	0,02	149,56	141,56	155,23	10,44	0,03	75,53	69,09	79,03	5,71	0,03	0,51	0,47	0,54	5,38	0,05	152,47	134,79	164,10
12,5	5,59	0,03	151,07	141,14	158,68	4,43	0,04	78,24	71,35	83,52	4,60	0,03	0,52	0,48	0,55	4,95	0,05	152,49	135,15	164,37
13	3,36	0,03	151,69	141,02	160,84	0,78	0,04	79,66	73,12	86,31	3,50	0,03	0,52	0,49	0,55	4,42	0,05	152,49	135,57	164,70
13,5	1,53	0,03	151,96	141,12	162,40	-0,21	0,04	79,71	73,31	86,81	2,58	0,03	0,52	0,49	0,55	3,63	0,05	152,51	136,22	165,20
14	-0,56	0104	152,83	142,12	164,85	-0,38	0,04	79,62	73,24	86,80	1,85	0,03	0,52	0,49	0,55	2,29	0,05	153,98	138,62	167,59
14,5	-198	0,04	154,33	143,83	167,51	-0,42	0,04	79,56	73,18	86,76	1,21	0,03	0,52	0,49	0,55	0,94	0,05	157,19	142,61	171,86
15	-2,20	0,04	154,77	144,38	168,00	-0,33	0,04	79,24	72,84	86,41	0,58	0,03	0,51	0,48	0,54	0,46	0,05	158,52	144,36	173,40
15,5	-2,13	0,04	154,77	144,44	167,83	0,23	0,04	78,78	72,26	85,75	-0,03	0,03	0,51	0,48	0,54	0,56	0,04	159,19	145,19	173,76
16	-2,10	0,04	154,73	144,43	167,72	0,75	0,04	78,55	71,90	85,34	-0,70	0,03	0,51	0,48	0,54	0,69	0,04	159,33	145,42	173,62
16,5	-2,00	0,04	154,57	144,33	167,36	1,21	0,04	78,37	71,60	85,02	-1,59	0,03	0,51	0,48	0,54	0,76	0,04	159,19	145,36	173,31
17	-165	0,04	153,94	143,86	166,14	1,97	0,04	78,04	71,07	84,45	-2,74	0,03	0,50	0,48	0,54	0,97	0,04	158,06	144,62	171,54
17,5	-137	0,04	153,58	143,60	165,38	2,35	0,04	77,86	70,79	84,16	-4,10	0,03	0,51	0,48	0,54	1,08	0,04	157,54	144,31	170,69
18	-125	0,03	153,43	143,50	165,06	2,40	0,04	77,84	70,75	84,13	-5,54	0,03	0,51	0,48	0,54	1,10	0,04	157,45	144,26	170,53

L=lambda=skewness (power transformation); S=sigma=coefficient of variation; M=mu=median

Table 6. Anthropometric measurements on subjects of Chinese ethnicity

	Total (n=48)	Male (n=21)	Female (n=27)	P value
Mean age (SD), years	16.0 (1.4)	15.8 (1.6)	16.2 (1.1)	0.35
Mean height (SD), cm	159.1 (9.1)	164.0 (9.0)	155.3 (7.2)	0.00
Mean weight (SD), kg	55.4 (13.2)	58.4 (15.1)	53.0 (11.2)	0.16
Mean body mass index (SD), kg/m2	21.8 (4.5)	21.6 (4.9)	21.9 (4.2)	0.81
Mean sitting height (SD), cm	80.8 (4.0)	83.0 (3.9)	79.1 (3.2)	0.00
Mean sitting height/height ratio (SD), %	50.8 (1.1)	50.6 (0.9)	51.0 (1.2)	0.24
Mean arm span (SD), cm	162.8 (11.4)	168.4 (11.9)	158.5 (8.9)	0.00
Mean arm height difference (SD), cm	3.7 (4.6)	4.4 (5.0)	3.2 (4.3)	0.39

SHRs (**Table 6**), but lower than the mean SHR of Chinese adolescents in China.[12] The mean SHR in late adolescence in our study was 50% to 51%. Our population had lower SHRs than that in a study by Galloway, who reported that the mean SHR in early adults (18 years old) was 53.4% in males and 53.8% in females.[3]

Other studies have noted that the SHR nadir occurred at an earlier age in females than in males.[1,10] This observation may be due to the earlier onset of puberty in females.[1,10] We did not assess the lowest SHR in our study, since we did not include subjects less than 11 years. Our findings were similar to reports from Turkish, Japanese, and Dutch studies that SHR was slightly increased in mid-pubertal age.[1,10,13] We observed peak median SHR at mid-pubertal age (age of 12.5-14.0 years old) for both males and females (52%); after this period SHR declined to 51% by the end of puberty. We can assume that at mid-pubertal age, growth in trunk length exceeds that of limb length; the opposite happens in late puberty. A similar pattern was observed in a Japanese study,[13] but not in Dutch and Turkish studies.[1,10] On the other hand, the SHR of Mozambique adolescents was relatively constant from early to late puberty, i.e., there was no peak SHR.[14] We also found that SHRs were similar between male and female adolescents. However, this was not the case in Turkish and Chinese studies.[10,12]

Linear regression analysis revealed a strong correlation between arm span and stature in both males and females. A previous study by Wongsodjaja *et al.* on children in the nearby city of Semarang, Indonesia, also found strong correlations, with correlation coefficients (r) of 0.956 in boys and 0.972 in girls ($P < 0.001$ in both sexes).[15] Strong correlations between height and arm span were also found in adult males

and females in Nigeria, Montenegro, and India.[16-18] In the Indonesian elderly, Fatmah obtained an r of 0.765 in elderly men and 0.609 on elderly women ($P<0.05$ in male and female).[19] These results indicate that height and arm span strongly correlate at almost all ages, from children to the elderly. Wongsodjaja et al. obtained the following formulae in 12-year-olds: [height=31.881 + (0.773 x arm span)] for males and [height=50.476 + (0.648 x arm span)] for females.[15] These formulae are similar to those we have obtained. In the elderly in Jakarta, Indonesia, Fatmah obtained the following equations: [height=60.16 + (0.603 x arm span)] for men and [height=75.23 + (0.47 x arm span)] for women.[19]

In our study, subjects had longer mean arm span than height. However, this comparison differed between countries. Similar results were reported by Brown *et al.* in adults in New York,[20] Zverev *et al.* in Malawi,[21] Rai *et al.* in Ellisras rural children in Rajasthan,[22] and Goon *et al.* in Nigerian young adults.[16] In contrast, South African and Turkish children had longer height than arm span.[22,23]

In our study, mean arm span and AHD in females were lower than in males. The mean AHDs in our study were longer than those reported in another Indonesian study (less than 2 cm in both sexes) and in Turkish adolescents (less than 3 cm in both sexes).[15,24]

A limitation of our study was that subjects may not have been representative of all Indonesian adolescents because of the convenience sampling method, although we had a variety of ethnic origins (Javanese, Chinese, and Arab). We need more subjects from different geographical locations and ethnicities to obtain nationwide Indonesian references for sitting height, SHR, and AHD. Data from children of different socio-economic backgrounds are also needed, as all our subjects were from an urban area. Furthermore, our data was limited to mid-pubertal adolescent ages, so we were unable to assess for changes in SHR during early puberty. We did not perform Tanner staging; this might have biased our results. In addition, arm span measurements from prepubertal age are needed to determine the AHD from childhood.

In conclusion, we have obtained references for sitting height, SHR, and arm span in adolescents. The LMS parameters and SD values for sitting height, SHR, and arm span found in our study can be used to evaluate body disproportions in Surakarta adolescents. In our study population, there is no significant difference in SHR between male and female adolescents, but the mean AHD of males is longer than that of females. Further studies with a larger sample size involving a more diverse geographical and ethnic population, as well as inclusion of prepubertal and early pubertal children is needed, in order to provide more inclusive references for SHR and AHD in prepubertal and early pubertal children.

Conflict of Interest

None declared.

Acknowledgements

We would like to thank Hari Wahyu Nugroho and Diah Lintang Kawuryan for manuscript editing; Imasari Aryani, Ulfa Puspita Rachma, Jonathan Billy Christian Tjiayadi, Nurul Hidayah, and Dinda Ariesta for research assistance; and Tatsuhiko Urakami for advice on this manuscript.

Funding Acknowledgment

The authors received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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