Original Article

Knee height and knee height/height ratio of healthy schoolchildren

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Abstract

Background Knee height (KH) is rarely used to estimate stature in children, although its measurement might have benefit because not influenced by some musculoskeletal disorder in spinal region. Knee height and knee height/height ratio are typical in children due to different in pubertal timing of each child.

Objective To derive a formula to estimate body height using knee height and to analyze the patterns of knee height and knee height/height ratio of healthy schoolchildren.

Methods This cross-sectional study involved healthy children in one elementary school and one junior high school in Surakarta, Central Java. Demographic data were collected (sex, age, and ethnicity). All anthropometric measurements (height, weight, sitting height, and knee height) were taken three times, and their means were calculated. Linear regression analysis was used to compare height from knee height and sitting height. Non-parametric analysis through locally weighted scatterplot smoothing (LOWESS) was used to analyze the growth patterns of knee height, knee height/height ratio, and sitting height/height ratio.

Results There were 633 children (328 boys and 305 girls) in this study. The formulas for the estimation of height were as follows: for boys, $2.40 \times$ KH (cm) $+ 1.36 \times$ age (years) $+ 20.31$; and for girls, $2.48 \times$ KH (cm) $+ 1.15 \times$ age (years) $+ 19.58$ (adjusted $R2=0.97$). Knee height increased earlier than sitting height in both boys and girls during childhood to adolescent period. Boys had a longer period of knee height increment than girls.

Conclusion Knee height may be a useful alternative to estimate height in children. Knee height increases faster than height and sitting height in both boys and girls. **[Paediatr Indones. 2020;60:233-8; DOI: 10.14238/pi60.5.2020.233-8].**

Keywords: *knee height; knee height/height ratio; schoolchildren*

Shorter leg length, including knee height, has been associated with risks of metabolic syndrome (obesity, coronary heart disease, and diabetes), liver dysfunction, and certain cancers in adulthood.[1] Leg length is also an indicator of environmental quality for growth during childhood.[1]

Knee height, a part of leg length, has been used as a measurement to estimate stature, especially in elderly or critically ill patients; other such measurements include leg length, sitting height, arm span, and upper-to-lower segment ratio.[2-4] Knee height or leg length assessment in children changes with age, especially during puberty. In clinical practice, knee height is rarely used to estimate body height in children. However, because of difficulties in measuring the body height in some conditions such as scoliosis and cerebral palsy, children's body height could be estimated using other measurements, such as sitting height or knee height.[5,6]

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We aimed to develop a formula using knee height to predict height in children, and compared that formula to equations using sitting height. We also analyzed knee height and knee height/height ratio patterns among schoolchildren in Surakarta, Central Java, Indonesia.

Methods

This study was conducted on healthy children in one elementary school and one junior high school from September 2017 to September 2018 in Surakarta, Central Java, Indonesia. Ethical approval was obtained from the Health Research Committee, Dr. Moewardi General Hospital, Universitas Sebelas Maret Medical School. Parental written informed consent was obtained. Students who were present at their school during the study periods were included.

Subjects' demographic data were collected (gender, birth date, and parents' ethnicity) from school records. We interviewed the children for any incomplete data. If both parents were Javanese or Chinese, we categorized the children as Javanese or Chinese, respectively; "other" was used for other or mixed ethnicities.

Anthropometric measurements (height, weight, sitting height, and knee height) were taken three times by trained personnel, then the means were calculated. Height and sitting height were measured using a wall stadiometer (*Stature Meter 2M GEA*) to the nearest 0.1 cm with the child facing the examiner. Knee height was measured to the nearest 0.1 cm on the right lower leg using a knee height caliper belonging to the Department of Child Health, Universitas Sebelas Maret Medical School, with the child sitting upright in a chair facing forward and hands at sides, and both the knee and ankle at 90°.1 Bodyweight was measured using a digital scale (*Seca Clara 803*, Germany) to the nearest 0.1 kg. The sitting height/height ratio was calculated by dividing the sitting height by total height; the knee height/height ratio was calculated by dividing knee height by total height.

The *WHO* classification was used to define overweight/obesity (body mass index > 2 SD), short stature (height-for-age Z-score (HAZ) < -2 SD), normostature ($-2 \leq HAZ \leq 2$), and tall stature (HAZ>2 SD). Non-parametric analysis through locally weighted scatterplot smoothing (*LOWESS*) was used to analyze growth increment and growth patterns of height, knee height, and knee height/height ratio. All statistics were analyzed using Stata software 14.0.

Results

We recruited 633 children (328 boys, 305 girls) into this study. Their characteristics are described in **Table 1**. The equations for height estimation from knee height and sitting height for boys and girls are described in **Table 2**.

Table 3 shows the height increment and KH increment in boys and girls. The mean height increment > 6 cm/year was seen in boys aged 9-11 years and girls aged 9-10 years. The mean knee height increment > 2 cm/year was seen in boys aged 7-10 years and girls aged 9-10 years. The mean knee heights

Table 1. Baseline characteristics of subjects

Characteristics	Males (n=328)	Females (n=305)	Total (N=633)
Ethnicity, n(%)			
Chinese	16 (4.9)	17 (5.6)	33 (5.2)
Javanese	246 (75.0)	228 (74.8)	474 (74.9)
Other	66 (20.1)	60 (19.7)	126 (19.9)
Age, years			
Mean (SD)	11.1 (3.0)	10.4 (2.6)	10.8 (2.8)
Range	5.8-16.4	5.8-16.6	5.8-16.6
Overweight-obese, n (%)	77 (23.45)	40 (13.1)	117 (18.5)
Stature, n (%)			
Short	23 (7)	35 (12)	58 (9)
Normal	302 (92)	265 (86)	567 (90)
Tall	3 (1)	5 (2)	8 (1)

Table 2. Formulas using KH and sitting height to predict body height

Variables	Male		Female	
	Equation	Adj. R^2	Equation	Adj. R^2
Knee height	Height = 2.40*knee (cm) + 1.36*age (yrs) + 20.31	0.97	Height = 2.48*knee (cm) + 1.15*age (yrs) + 19.58	0.97
Sitting-height	Height = 1.34*sitting (cm) + 2.39*age (yrs) +15.95	0.95	Height = 1.60*sitting (cm) + 1.27*age (yrs) + 7.25	0.95

Table 3. Mean height, knee height, and their increment by yearly age

		Boys						Girls			
Age	n	Height, cm	Δ height, cm	KH, cm	Δ KH, cm	Age	n	Height, cm	Δ height, cm	KH, cm	Δ KH, cm
5-<6	3	110.69	~	33.47	~	5-<6	4	112.94	-	34.37	-
6-<7	34	114.27	+3.58	34.78	+1.31	6-<7	33	115.34	+2.41	35.23	+0.86
7-<8	29	119.99	+5.72	36.94	+2.16	7-<8	34	119.81	+4.47	36.83	+1.60
8-<9	32	125.52	+5.53	39.01	+2.07	8-<9	29	124.65	+4.84	38.58	+1.74
9-<10	36	131.61	+6.10	41.23	+2.21	9-<10	35	131.61	+6.95	41.00	+2.42
10-<11	30	137.93	+6.32	43.42	+2.20	10-<11	39	137.75	+6.14	43.04	+2.04
11-<12	19	143.97	+6.05	45.35	+1.93	11-<12	44	142.43	+4.68	44.37	+1.33
12-<13	35	149.81	+5.84	47.08	+1.73	12-<13	16	147.92	+5.49	45.92	+1.56
13-<14	36	155.79	+5.98	48.75	+1.66	13-<14	34	151.19	+3.27	46.72	+0.80
14-<15	47	160.66	+4.87	49.93	+1.19	14-<15	30	153.55	+2.35	47.19	+0.48
15-<16	19	164.26	+3.59	50.54	+0.60	15-<16	6	155.13	+1.58	47.47	+0.27
16-17	8	166.90	+2.64	50.82	+0.28	16-17	1	156.88	+1.76	47.74	+0.27

among short, normal, and tall stature groups were significantly different (**Table 4**).

Table 4. Mean knee heights among subjects with short, normal, and tall stature

| Variables	n (%)	Mean age* (SD)	Mean KH** (SD)
Short stature	58 (9)	10.34 (2.89)	38.74 (4.90)
Normal stature	567 (90)	10.79 (2.82)	43.45 (5.50)
Tall stature	8 (1)	11.73 (2.38)	50.52 (4.54)

*Anova test (P>0.05); **Anova test (P<0.05)

Figure 1 describes the patterns of height, knee height/height ratio, sitting height/height ratio in boys and girls according to age. Knee height/height ratio increased until peaking around age 11 for both boys and girls. However, sitting height/height ratio patterns decreased during the increment of knee height/height ratio for boys and girls aged 6-11 years. **Figure 2** illustrates the patterns of knee height/height ratio by age in short stature and overweight-obese children compared to normal stature and normoweight subjects. The patterns of short stature and/or obese were similar to normal subjects, for boys and girls.
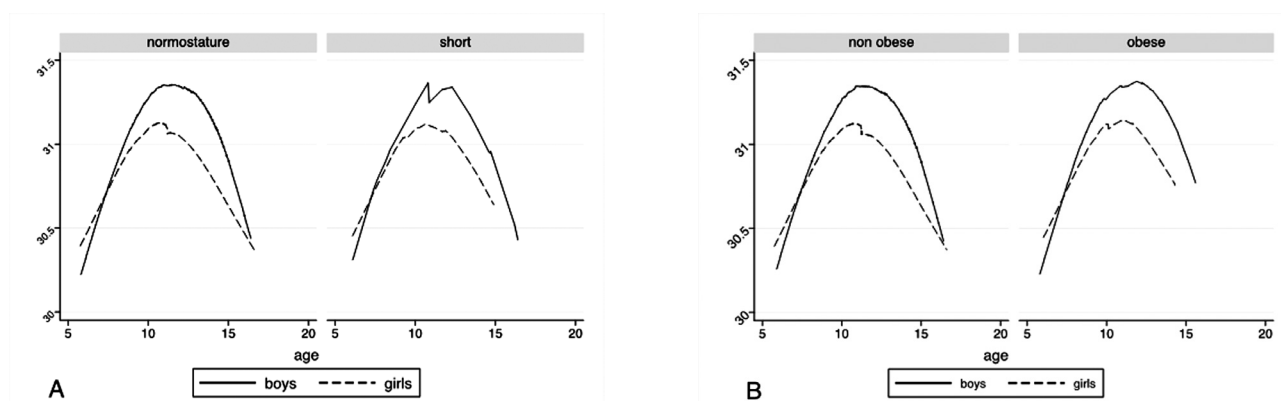
Figure 3 shows the patterns of knee height/height ratio in children stratified by ethnicity, according to age and sex. The Chinese, and also others' ethnicity, growth patterns were similar to Javanese one.

Discussion

Knee height measurement is rarely used in children, although leg length is associated with the quality of the environment in children's growth. Our study demonstrated a positive correlation between knee height and body height. The formula of knee height were concordant to sitting height (adjusted R^2 were 0.97 *vs.* 0.95, respectively). The formulas of knee height were different with an adult study in Indonesia {height = (1.647 x kneeheight) + 80.08 (male), height = (1.807 x kneeheight) + 66.54 (female)}.[4] The adjusted R^2 of knee height (male/female) in our pediatric study was larger than that in the study involving elderly individuals (0.97/0.97 *vs.* 0.512/0.579, respectively).[4] Hence, this formula can be used to estimate body height in schoolchildren, although the knee height/height ratio is dynamic by age. We still need to verify the accuracy of the
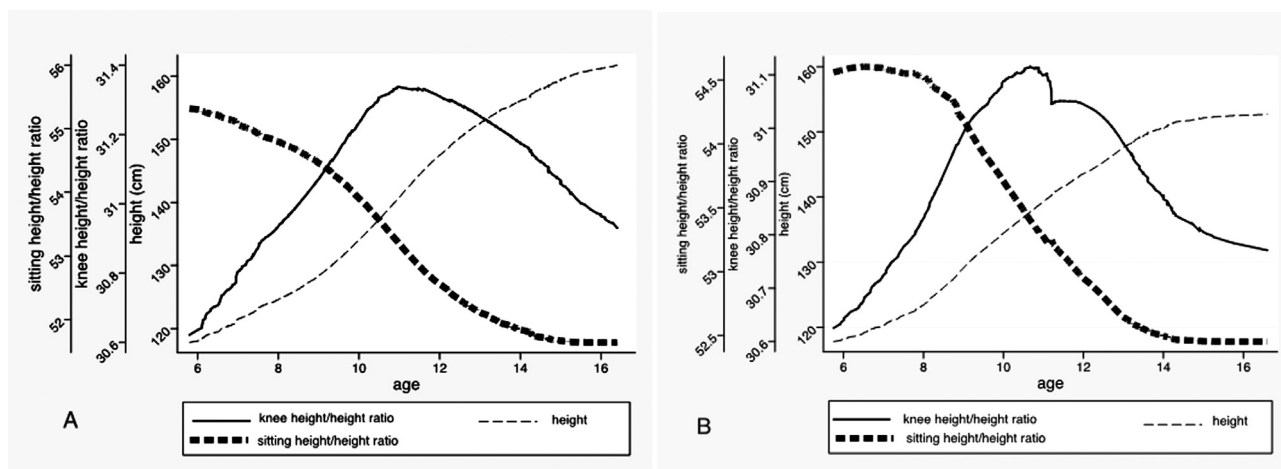
Figure 1. Patterns of height, knee height/height ratio, sitting height/height ratio of subjects [knee height/height ratio = (knee height/body height x 100); sitting height/height ratio=(sitting height/body height x 100)]. (A) Boys (B) Girls

Figure 2. Patterns of knee height/height ratio in short stature and overweight-obese subjects by age and sex; (A) stature and (B) weight status
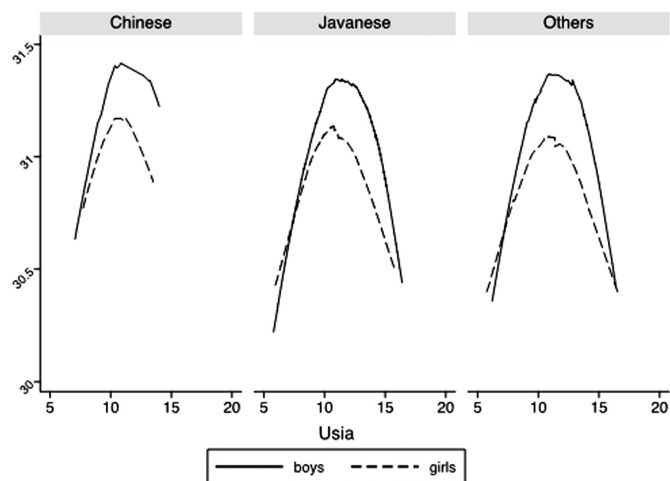
Figure 3. Patterns of knee height/height ratio according to ethnicity, age, and sex

equations to estimate body height compared to actual height in other schoolchildren.

The knee height in schoolchildren in our study was comparable to that in a 2015 Jakarta study.[5] A previous study recommended re-evaluating the Indonesian National Standard for elementary school furniture because of the mismatch between standard and anthropometric data. We also noted this mismatch, hence, we agree with their recommendation.[5] For this purpose, a much larger dataset on knee height measurements in schoolchildren will be needed.

The human body has characteristically longer legs compared to other species.[1,7] The differences between the lowest and highest values of the knee height/height ratio in our study were not large (30.2-31.5 in boys and 30.4-31.2 in girls). A previous study showed a similar ratio in the same age range, but the peak knee height/height ratio in our study was smaller (31.5/31.2 *vs.* 32.3, respectively).[6] The increase in the knee height/height ratio with age was concurrent with the decrease in sitting height/height ratio with age (**Figure 1**). We noted that knee height grew faster than sitting height (i.e., the lower segment grew faster than the upper segment of the body). More precise data are needed on puberty or maturity in schoolchildren to analyze for an association between early growth of knee height and pubertal stage.

The patterns of the knee height/height ratio between boys and girls were different. Knee height increment and knee height/height ratio patterns in girls were steeper and narrower than those in boys, thus lowering the peak of the ratio in girls. Our previous study on the sitting height/height ratio in adolescents showed similar values between boys and girls.[8] The knee height of children with short stature was smaller than that of children with normal stature, but there were no differences in the patterns of knee height/height ratio with respect to stature in our subjects. The peak knee height/height ratios in children with short or normal stature were similar. Thus, people with short stature had short legs, but their body proportion between upper and lower segment remained unchanged. Overweight/obesity did not affect the knee height/height ratio patterns, even though it is evident that obese children mature earlier. Additional data on the patterns of knee height growth in children less than 5 years of age are required to analyze for conditions such as short stature and obesity.

Regarding the influence of ethnicity, Chinese subjects had the same patterns of knee height/height ratio as Javanese children, who comprised the majority of our cohort. These results were in agreement with those of our previous study on sitting height/height ratio and another study involving an Asian population with similar proportions.[8,9]

There were some limitations to our study. Since we conducted a study of urban schoolchildren from one elementary and one junior high school in Surakarta, Central Java, our sample might not be representative of all schoolchildren in Indonesia. Follow-up studies on the same cohort are needed to elucidate the change in patterns of height, knee height, and knee height/height ratio with respect to the growth of the schoolchildren. Future studies should analyze for pubertal or maturity factors. The Preece-Baines growth model is useful to assess the peak height or knee height velocity. However, this model needs longitudinal data and does not work well with cross-sectional data, which was used in our study.[10,11] To comment on whether short legs were associated with the quality of the environment during growth, data on family socioeconomic backgrounds are needed, which were unavailable in our study.[7] We also did not assess the cause of short stature as to whether it was a normal variation (e.g., familial short stature, constitutional delay of growth) or an underlying pathology (caused by inadequate nutrition or infection). Additional study is needed to further analyze for links among environment quality, knee height, and body height. Measurement of knee height, compared to sitting height, was more difficult to conduct in schoolchildren.[6] For clinical practice, we can use knee height to estimate body height whenever sitting height cannot be measured.

In conclusion, knee height may be used to estimate height in children. Knee height increases faster than height and sitting height during puberty in male and female children. Boys have a longer period of knee height increment than girls. Short stature, overweight/obesity, and ethnicity do not affect the knee height patterns.

Conflict of interest

None declared.

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