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Original Article

Patterns of Body Mass Index, Percentage Body Fat, and Skinfold Thicknesses in 7- to 18-Year-Old Children and Adolescents from Indonesia

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Abstract

Background: Body mass index (BMI) and skinfold thickness are widely used to evaluate body composition. Information on patterns of skinfold thickness may help to understand changes in body composition during growth. The objectives of this study were to observe patterns of BMI, percentage body fat (%BF), and skinfold thicknesses of Indonesian children and adolescents aged 7–18 years. **Methods:** Weight, height, and four skinfold thicknesses were measured in 2104 school children (924 boys, 1,180 girls) aged 7–18 years from Yogyakarta between 2015 and 2018. BMI and ratios between central and peripheral skinfold thicknesses were determined. %BF was predicted using the equation of Slaughter *et al*. Data were analyzed using analysis variance (ANOVA), independent sample *t*-test, and partial correlation (SPSS version 20.0). **Results:** At 7–18 years, boys and girls showed a comparable gain in BMI. The comparable gain in %BF between boys and girls only occurred till age 10 and total skinfolds till age 11 years. While, %BF and skinfold thicknesses were higher in girls at 12–17 years, central to peripheral skinfold ratio were higher in boys. Partial correlation analyses showed that all skinfold thickness parameters and %BF were significantly correlated with BMI ($P < 0.001$; $r = 0.19–0.87$). **Conclusions:** The gain in BMI and skinfold thickness between the ages of 7 and 18 years occurred in age- and sex-specific patterns. Instead of comparable BMI, girls showed higher means of total skinfold thickness from age 12 years, while boys had higher central to peripheral adiposity ratio.

Keywords: *Body mass index, children, growth patterns, percentage body fat, skinfold thickness*

Introduction

Childhood and adolescent obesity is known to persist into adulthood and is associated with many chronic diseases and premature death.[1,2] Body mass index (BMI) is commonly used to assess obesity. However, BMI does not always accurately estimate adiposity as it cannot assess body composition and its relation with body fat (BF) is influenced by race or ethnicity.[3] Applications of the available international BMI cutoffs for children have also resulted in different obesity rates in a population.[4]

Skinfold thicknesses as measures of subcutaneous fat have also long been used in nutrition-related studies, such as nutritional status, body composition, and subcutaneous fat distribution.[5-7] The skinfold technique is noninvasive, relatively easy to administer, and inexpensive, therefore, suitable for use in large field studies. Skinfold thickness measures represent an indirect measure of subcutaneous adipose tissue and are used to estimate total body density to derive %BF.[5] Depending on the sites of the body, skinfold thickness can be distinguished into peripheral (e.g., skinfold thickness at triceps, biceps, calf, and thigh) and central (e.g., skinfold thickness at suprailiac, supraspinal, abdominal, and subscapular). Skinfold thickness is more strongly correlated and more accurately predicts %BF than BMI.[8] However, there was variation among different sites of skinfolds in predicting later cardiometabolic risk, that is, subscapular skinfold thickness had high accuracy in predicting cardiometabolic risk in children and adolescents, but not triceps skinfold thickness.[9] High subscapular to triceps skinfold thickness ratio was associated with elevated blood pressure.[10,11]

Assessment of skinfold patterns during growth is substantial to gain an understanding of changes in the body

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composition in children and adolescents.[12] So far, compared to information from the Caucasian population, information on the skinfold pattern of Asian children and adolescents are relatively few.[13,14] The present study aimed to observe patterns of BMI, %BF, and skinfold thicknesses of Indonesian children and adolescents aged 7–18 years.

Methods

This was a cross-sectional study involving 2,104 children and adolescents (924 boys, 1,180 girls) aged 7–18 years in Bantul and Kulonprogo Regencies, Yogyakarta Province, Indonesia. Data were collected from 2015 to 2018 by consecutive sampling in one primary, two secondary, and one high schools in Yogyakarta Province.

This study has been approved by the Medical and Health Research Ethics Committee of Faculty of Medicine, Public Health, and Nursing Universitas Gadjah Mada. Written consent was obtained from the parents of each child. Besides informed consent, assents were obtained from teenage students aged 12–18 years old. To ensure that children and adolescents in the selected schools were treated fairly, all children were measured, including those whose data were not subsequently used because of the exclusion criteria, for example, children with physical disabilities.

Students who are apparently healthy, of any gender, and aged 7–18 years were eligible to be included in the study, while, those who have physical disabilities were excluded. Measurements were taken on their weight, height, and skinfold thickness at triceps, subscapular, suprailiac, and calf following the protocols of the International Society for the Advancement of Kinanthropometry.[15] Weight was measured with a Seca weight scale (Seca 803, Seca Deutschland) to the nearest 0.1 kg while subjects were wearing light clothing. Height was measured using an anthropometric set (GPM, Swiss, Ltd) to the nearest 0.1 cm. BMI was calculated as weight/height^2 (kg/m^2).

A Harpenden skinfold caliper was used to measure skinfold thickness to the nearest 0.2 mm at triceps, subscapular, suprailiac, and calf. Comparison between central (subscapular, suprailiac) and peripheral (triceps, calf) skinfolds was observed using ratios of subscapular + suprailiac/triceps + calf skinfolds (SbSp/TC). %BF was estimated using skinfold sex-specific equations provided by Slaughter *et al*.[16] based on triceps and subscapular skinfold thicknesses in boys and girls.

Two-way ANOVA was performed to compare the variation between groups. Mean differences between age groups, that is, age groups of 7, 8, 9 … until 18 years old, stratified by gender, were assessed. Dunnett's post hoc analysis was used to compare all other age groups to the youngest age group. All groups have been checked for the normality of the distributions and homogeneity of variances. Correlation between skinfold thickness, %BF, and BMI was evaluated using partial correlation analysis adjusted for age and gender-age. All statistical analyses were performed using SPSS (version 20.0, SPSS Inc, 2011, Chicago, IL) and a $P < 0.05$ was considered statistically significant.

Results

Two way ANOVA indicated that there were significant differences in most of the anthropometric parameters and %BF, i.e., between gender, age groups, and gender-age groups (mostly $P = 0.000$), except for BMI [Table 1]. Partial correlation analysis showed that skinfold thickness in all sites, a total of skinfold thicknesses, and ratios of central and peripheral adiposity were significantly correlated with BMI, even after adjustment for age and gender ($P = 0.000$) with r ranged from 0.19 to 0.87 [Table 1].

Figure 1 demonstrates a similar pattern and comparable mean values of BMI in most of the ages which exhibited a rapid increase at age 10 years followed by a gentle rise until age 18 years. Total skinfold thickness and %BF increases only until the age of 10 and 11 years, respectively, in boys; however, girls showed a rapid increase to age 18 years. Boys had a slight increase in their central skinfold sites, but not in their peripheral skinfold sites. In the end, boys had a higher ratio of central to peripheral skinfold thicknesses.

Table 1: ANOVA and partial correlation analysis between skinfold thickness parameters and BMI in boys, girls, and all subjects, adjusted for age and gender*age

Skinfold site	Correlation (*r*)				ANOVA (*P*)		
	Boys	Girls	All-age†	All-age- gender‡	Gender	Age groups	Gender*age groups
BMI (kg/m^2)					0.989	<0.001	0.534
%BF	0.85**	0.74**	0.70**	0.78**	<0.001	<0.001	<0.001
Triceps	0.75**	0.80**	0.74**	0.77**	<0.001	<0.001	<0.001
Subscapular	0.87**	0.82**	0.83**	0.84**	<0.001	<0.001	0.001
Suprailiac	0.85**	0.79**	0.82**	0.82**	<0.001	<0.001	0.006
Calf	0.71**	0.65**	0.66**	0.68**	<0.001	<0.001	<0.001
Total SFT	0.87**	0.85**	0.83**	0.85**	<0.001	<0.001	<0.001
SbSp/TC	0.50**	0.45**	0.44**	0.47**	<0.001	<0.001	<0.001

**P=0.000. †All samples adjusted for age; ‡all samples adjusted for age and gender; r: Pearson correlation coefficient; %BF: percentage body fat; SFT: Skinfold thicknesses; SbSp/TC: (subscapular + suprailiac)/(triceps + calf) skinfolds

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Patterns of skinfold thickness growth at each site were illustrated in Figure 2. A steady increase in all skinfold sites was observed in both genders until the age of around 10 years. After that, a steady increase followed by a

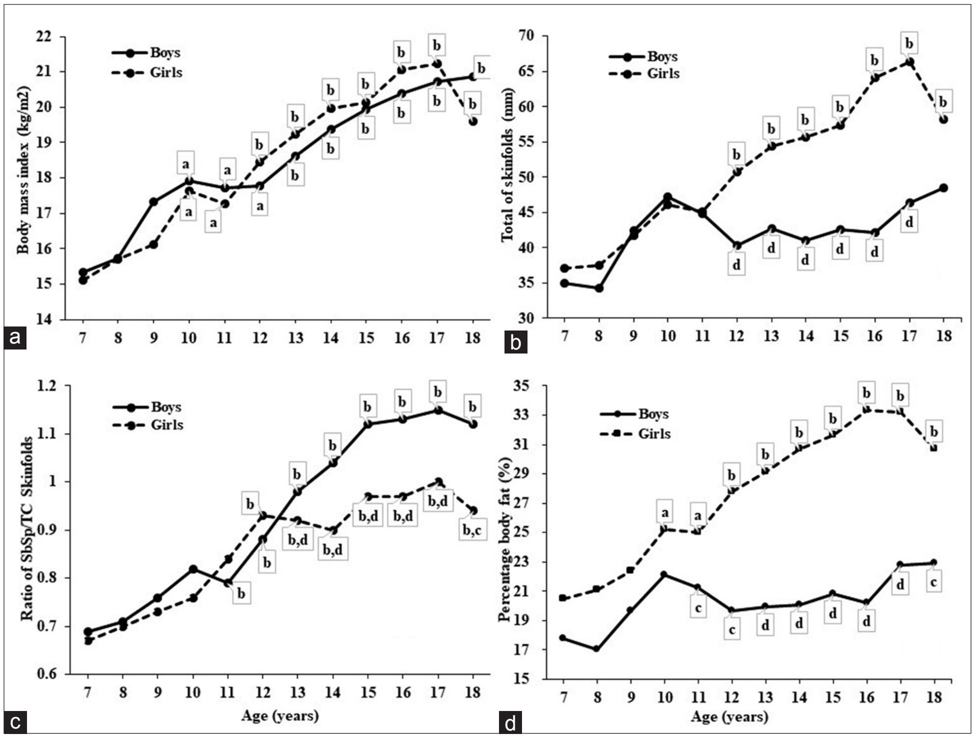

Figure 1: (a) Growth patterns of body mass index (BMI) in boys and girls aged 7–18 years; (b) total of skinfold thicknesses: raised at maximum 79% in girls and 41% in boys; (c) subscapular + suprailiac/triceps + calf skinfolds (SbSp/TC) skinfold thicknesses: raised at maximum 67% in boys and 49% in girls; and (d) %BF: raised at maximum 63% in girls and 29% in boys; a: *P* <0.05; b: *P* <0.001, significantly difference from the value at 7 years old, of the same gender; c: *P* <0.05; d: *P* <0.001, significantly difference from the value of the opposite gender

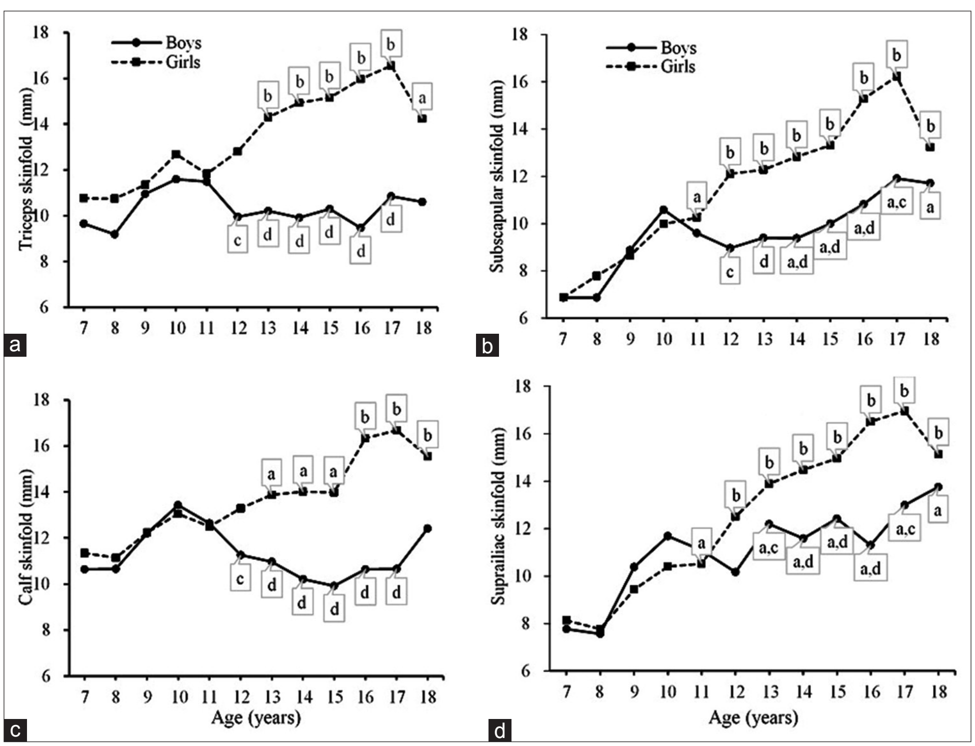

Figure 2: Growth patterns skinfold thicknesses at triceps (a), subscapular (b), Calf (c), and suprailiac (d) in boys and girls aged 7–18 years; a: *P* <0.05; b: *P* <0.001, significantly different from the value at 7 years, of the same gender (one-way ANOVA, Dunnett's post hoc test; c: *P* <0.05; d: *P* <0.001, significantly different from the value of the opposite gender, of the same age groups (independent sample *t*-test)

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small decrease at the end of puberty in all skinfold sites was only observed in girls. The age of puberty was not assessed in this study but the mean age of menarche was 12.26 ± 1.01 years with a median of 12.10 years.

Discussion

Our results indicated that the gain in BMI, %BF, and skinfold thickness between the age of 7 and 18 years occurred in age- and sex-specific patterns. Despite having a comparable pattern of BMI increase, the girls showed a higher gain in %BF and overall skinfold thicknesses than the boys. However, the boys gained less central subcutaneous adiposity than the girls as they did not gain nearly any peripheral subcutaneous adiposity, the central to peripheral adiposity ratio of the boys were higher than the girls. These findings imply that the increase in BMI in adolescents, especially in girls, was more likely related to the gain in fat mass, not the gain in lean body mass. This contrast in the gain of %BF and skinfold thicknesses confirms the sexual dimorphism in BF accumulation and patterns of skinfold thickness which had been described elsewhere.[13,14,17]

We observed that boys and girls had a similar pattern of gain in BMI in all ages. Rapid growth was observed at the age of 10 years, followed by a steady increase to the age of 18 years. The observed surge of BMI occurring at 10 in both boys and girls in our samples was consistent with some previous studies.[7,17] The onset of puberty is believed to be responsible for the rapid growth of BMI and some anthropometric variables in adolescents.[18] We did not evaluate the pubertal onset in our samples; however, we did collect the age of menarche in the girls and the mean age of menarche was 12.26 ± 1.01 years with the median of 12.10 years. As earlier studies had shown that pubertal onset occurred around 2 years before the menarche, the gain in BF seemed to occur at the onset of puberty.[19] A relatively low value of the BMI and skinfold thickness were associated with menarche at a later age and relatively high value at an earlier age at menarche.[20-22]

Pubertal onset in boys was reported to be around 1 year later than the girls.[19] As pubertal onset in boys was not investigated in our study, the surge of BMI in boys attained in the same age as the girls were not easy to explain. Mechanism of the rapid growth may involve the hormonal aspect of pubertal development[23] and the ovarian function associated with energy balance[24]; however, a strong association has been conveyed in the literature about the pubertal onset and body composition parameters.[12,24,25] The difference in the amount of BF between girls and boys might be associated with the difference in their sex-steroid hormone profiles after puberty.[19] Studies in adult males have also observed inverse associations between testosterone (T) levels and percent BF. In the adult male, higher BF is associated with lower T level and higher estradiol (E2) level, as well as a higher E2/T ratio.[26] Unfortunately, the hormonal level was not measured in our study.

Instead of the proportional BMI from the lowest to the highest increase between 7 and 18 years which was about 40%, skinfold thickness raised over twice in girls (79%) while only 41% in boys. Similarly, %BF was 63% in girls, while only 29% in boys. The point was indicating that boys may grow more on body lean despite adiposity as seen in the girls. However, boys had, to some extent, more increased adiposity stored in the central than the peripheral body (67%) compared with the girls (49%). While skinfold thicknesses grew progressively and proportionally between central and peripheral adiposity in girls. Although boys are supposed to grow more body lean during the adolescent period than the girls, gaining more on the central body adiposity should get more attention.[27] Abnormal increases in fat during puberty may also reflect an increased risk of developing cardiovascular disease.[28] Therefore, it is important to establish normal patterns of change in adiposity.

The strength of the current study was involving a large number of sample size. Nonetheless, the number of samples in each age may not distribute proportionally. The generalizability of our results to the national representation is also limited since samples are taken from one province, however, samples are of the Javanese population, which is the largest ethnicity. Moreover, the cross-sectional design cannot describe the process of growth increment.

In conclusion, BMI, BF, and skinfold thickness increased between 7 and 18 years in age- and sex-specific patterns with higher mean values for %BF and skinfold thicknesses in girls obtained at 12 years instead of comparable BMI. This study confirms the sexual dimorphism in BF accumulation. Despite the similar age of the BMI and skinfold thickness spurt, compared with the girls, boys seem to gain more body lean but store more adiposity in the central than peripheral body during the adolescent period. Public health concerns should design a program that targets these boys since they may pose in danger of risk for health problems associated with central obesity. Accordingly, the inclusion of skinfold thickness measurement in addition to BMI offers worthy information in the assessment of growth.

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Conflicts of interest

There are no conflicts of interest.

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