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Original Article

Age at menarche and body fat in adolescent girls

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Abstract

Background Menarcheal age is important in adolescent girls due to its associations with health outcomes at adulthood. Modifiable factors that may influence menarcheal age include body fat mass and fat distribution.

Objective To investigate possible correlations between body fat mass and fat distribution with age at menarche in adolescent girls.

Methods This study was a cross-sectional study on 32 girls aged 10-15 years in Central Jakarta, who experienced menarche within the time period of July to September 2019. Data on menarcheal age was collected by recall. Body fat mass and distribution were calculated using anthropometric measurements and bioelectrical impedance analyzer (BIA) results.

Results The mean age of study subjects was 12.06 (SD 0.82) years and the mean age at menarche was 11.91 (SD 0.83) years. Correlation tests revealed a moderate negative correlation between body mass index-for-age and menarcheal age (r=-0.45; P=0.01) and weak negative correlation between waist-height ratio and menarcheal age (r=-0.37; P=0.03).

Conclusion Menarcheal age is correlated with body mass index-for-age and waist-height ratio. However, no significant correlations between menarcheal age and body fat mass or distribution are found. **[Paediatr Indones. 2020;60:269-76; DOI: 10.14238/pi60.5.2020.269-76]**.

Keywords: *menarcheal age; age at menarche; body fat mass; body fat distribution*

Menarche is defined as the first menstrual period experienced by an adolescent girl. It is considered to be the most recognizable feature of puberty in girls, generally in the mean age of 12.88 (SD 1.27) years.[1,2] Age at menarche is important to the overall clinical patient history, because it is known to influence health in adulthood. Girls with younger menarcheal age (<12 years) tend to have higher blood pressure, glucose intolerance, cardiovascular disease, and higher mortality due to cancer.[3,4] Older menarcheal age (>14 years) is associated with lower bone density which increases the risk for osteoporosis.[5] *The 2010 Indonesian Basic Health Research Report* showed that 22.5% of Indonesian girls underwent early menarche and 24.3% underwent late menarche.[6] Throughout the world, especially in low-to-middle income countries, menarche is associated with taboos and sanitation problems, which can lead to missed school

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days, isolation, and gender inequality, as well as barriers to adequate sexual and reproductive health education. Recognizing and addressing the problems related to menstruation can promote attainment of the *Sustainable Development Goals*, including, but not limited to, SDG 3 (Good Health), SDG 4 (Quality Education), and SDG 5 (Gender Equality).[7]

The advancement of socioeconomic and health conditions in the 20th century led to a shift to earlier menarcheal age. This shift is known as a secular trend, observed worldwide,[8-10] including in Indonesia, a low-middle income country with diverse socioeconomic and environmental conditions. A systematic review described the secular trend in menarcheal age in Indonesia in 1970-2010, which decreased from 14.43 years to 13.63 years, and was predicted to continue to decrease by 0.0245 years (8-9 days) per year.[11]

Age at menarche is influenced by genetic and non-genetic factors, including body fat mass. Body fat can affect menarcheal age through leptin, a protein produced by adipocytes, which increases with the amount of body fat. Leptin stimulates the hypothalamus to secrete gonadotropin-releasing hormone (GnRH), which in turn stimulates the pituitary gland-ovarium axis and accelerates puberty. Fat distribution also plays a role in menarcheal age; leptin levels have stronger associations with gluteofemoral fat compared to upper body fat.[3]

Body fat can be measured through anthropometric measurements, skinfold thickness (SFT), or body composition measurement tools. Anthropometric and SFT measurements are easier and less expensive to perform, but may be affected by intraobserver and interobserver errors, due to their subjective nature. Body composition measurement tools and machines have better accuracy, but are more expensive and their usage is mostly limited to research purposes.[12,13] In addition, bioelectrical impedance analysis (BIA), a body composition measurement tool to assess fat distribution, is accurate, easy to use, comfortable for subjects, and relatively affordable.[13]

Body fat and fat distribution are determining factors of menarcheal age that can be modified through lifestyle changes. Investigating the influence of these factors on menarcheal age can help improve morbidity risk due to early or late menarche, in line with the third goal of the *Sustainable Development Goals* (SDGs) to reduce mortality due to non-communicable diseases (type 2 diabetes mellitus, cardiovascular diseases, and cancer) through prevention.[14] This study was aimed to investigate possible correlations between body fat mass and fat distribution with age at menarche in adolescent girls.

Methods

This cross-sectional study was performed in July-September 2019 in Central Jakarta, Indonesia. We visited primary and junior high schools closest to the Universitas Indonesia Medical School, which was the location of measurement. We recruited 32 girls aged 10-15 years who experienced menarche in the last 3 months from 10 primary schools (SDN Cikini 01, SDN Cikini 02, SDN Paseban 03, SDN Paseban 05, SDN Paseban 07, SDN Kramat 06 pagi, SDN Kramat 08 pagi, SDN Johar Baru 01, SDN Pegangsaan 01, and SDN Kenari 07) and seven junior high schools (SLTPN 2 Jakarta, SLTPN 8 Jakarta, SLTPN 28 Jakarta, SLTPN 71 Jakarta, SLTPN 216 Jakarta, SLTP Muhammadiyah 3, and SLTP Muhammadiyah 16).

Our inclusion criteria were girls aged 10-15 years who experienced menarche in the previous 3 months, had no changes in body weight greater than 5% in the previous 3 months, signed an informed assent form, and whose parents or guardians signed informed consent forms. We excluded girls who had precocious puberty, were absent during data collection, or had other conditions that may affect anthropometric measurements (organomegaly, edema, scoliosis, musculoskeletal problems, and other syndromes or congenital defects with growth disorders).

Subjects were asked to fill questionnaires on menarcheal age and socioeconomic characteristics. Menarcheal age was obtained through recall, by calculating the time period between the day the subject menstruated for the first time and her date of birth (in years and months with two decimal points). Parental education level was divided into three groups: low (primary school or the equivalent), intermediate (junior high, high school, or the equivalent), and high (diploma, bachelor's degree, master's degree, or the equivalent). Parental income was divided into two groups based on the Jakarta Regional Minimum Wage in 2019 (IDR 3,900,000/month or around USD 247/month): low (below minimum wage) and high (equal to or above minimum wage).

The investigating team and other trained staff measured body fat mass and distribution using anthropometric measurements and BIA at IMERI, Universitas Indonesia Medical School. The anthropometric measurements were body mass index (BMI), waist circumference, hip circumference, waist-hip ratio, and waist-height ratio. The BMI was calculated by dividing weight (kg) by height-squared (m2), stated in kg/m^2. We measured BMI-for-age using the CDC BMI-for-age chart, stated in *z*-score with 2 decimal points.[15] During measurements, subjects wore their school uniforms and no shoes. Body weight and body fat mass were measured once each using a *Tanita MC 780 BIA* (*Tanita Corporation*, Tokyo, Japan), with 0.1 kg precision. Body height was measured twice using a stadiometer with 0.1 cm precision and an mean of the two measurements was recorded.

Waist circumference was measured with the subject standing upright and the measuring tape placed between the lowest rib and the iliac crest; a mean of two measurements at the end of expiration was recorded (cm). Hip circumference was measured with the subject standing upright and the measuring tape placed on the largest circumference of the hip area; a mean of two measurements was recorded (cm). The waist-hip ratio was calculated by dividing waist circumference by hip circumference. The waist-height ratio was calculated by dividing waist circumference by body height.

The BIA measurements obtained for this study included total body fat mass (TBFM), body fat mass of the upper extremities (BFMUE), body fat mass of the lower extremities (BFMLE), body fat mass of the trunk (BFMT), ratio of body fat mass of the extremities and the trunk (BFMET ratio), percentage of total body fat (%BF), percentage of fat in the upper extremities (%BFUE), percentage of fat in the lower extremities (%BFLE), and percentage of fat in the trunk (%BFT). Measurements were done once per subject.

The data were analyzed using *SPSS version 22* for *Windows*. Descriptive data for categorical variables (name of school, parental education and socioeconomic levels) are stated in frequency (n) and percentage (%). Descriptive data for numerical variables (age, menarcheal age, weight-for-age, height-for-age, BMI, BMI-for-age, waist circumference, hip circumference, waist-hip ratio, waist-height ratio, TBFM, BFMUE, BFMLE, BFMT, BFMET ratio, %BF, %BFUE, %BFLE, and %BFT) were stated as mean, median, interquartile range, and standard deviation. Shapiro-Wilk test was done to assess data normality prior to hypothesis testing. Correlations between body fat measurements and menarcheal age were analyzed by Pearson's or Spearman's tests. Results with P values <0.05 were considered to be statistically significant. This study was approved by the Ethics Committee of the Faculty of Medicine, Universitas Indonesia.

Results

We recruited 102 girls who experienced menarche in the last three months, out of 1,498 girls enrolled in 10 primary schools and seven junior high schools. Parental informed consent and subject informed assent were requested from the 102 girls, however, only 32 subjects' parents consented to participation.

Most subjects were categorized as middle-to-low socioeconomic class. Subjects' mean age was 12.06 (SD 0.82) years and their mean age at menarche was 11.91 (SD 0.83) years. The characteristics of subjects are described in **Table 1**.

We analyzed for potential body fat mass and distribution correlations with menarcheal age. Pearson's correlation test was used for BMI, BMI-for-age, waist circumference, hip circumference, waist-hip ratio, and %BFUE. Spearman's correlation test was used for waist-height ratio, TBFM, BFMUE, BFMLE, BFMT, BFMET ratio, %BF, %BFLE, and %BFT. Two variables had statistically significant correlations with menarcheal age: BMI-for-age (moderate negative correlation; $r=-0.45$; $P=0.01$) and waist-height ratio (weak negative correlation; $r=-0.37$; $P=0.03$) (**Table 2**). The scatter plots for the correlation tests are shown in **Figure 2**.

Discussion

A multicenter study in Indonesia on menarcheal age in 1992-1995 showed the mean menarcheal age in Indonesia to be 12.96 years, with a mean BMI of 19.17 kg/m^2. The mean menarcheal age in Jakarta was 12.89 years, with a mean BMI of 19.54 kg/m^2.[10] A Surakarta, Central Java study on 835 healthy

Table 1. Characteristics of study subjects

Characteristics	Total (N = 32)
School, n (%)	
Primary school	18 (56)
Junior high school	14 (44)
Paternal education level, n (%)	
Low	7 (22)
Intermediate	17 (53)
High	8 (25)
Maternal education level, n (%)	
Low	2 (6)
Intermediate	26 (81)
High	4 (13)
Parental income, n (%)	
Low	21 (66)
High	11 (34)
Median body weight (IQR), kg	41.25 (9,88)
Mean body weight-for-age (SD), Z-score*	0.01 (1.09)
Mean body height (SD), cm	149.95 (4.72)
Mean body height-for-age (SD), (Z-score)*	-0.51 (0.93)
Mean BMI (SD), kg/m2	19.92 (3.56)
Mean BMI-for-age (SD), Z-score*	0.34 (0.98)
Mean waist circumference (SD), cm	68.54 (7.94)
Mean hip circumference (SD), cm	83.25 (6.01
Mean waist-hip ratio (SD)	0.82 (0.06)
Median waist-height ratio (IQR)	0.43 (0.06)
Median total body fat mass (IQR), kg	9.9 (5.65)
Median body fat mass of the upper extremities (IQR), kg	0.7 (0.53)
Median body fat mass of the lower extremities (IQR), kg	4.8 (2.15)
Median body fat mass of the trunk (IQR), kg	4.55 (3)
Median ratio of the body fat mass in the extremities and trunk (IQR)	1.2 (0.32)
Median body fat percentage (IQR), %	23.65 (7.32)
Mean percentage of fat in the upper extremities (SD), %	7.26 (1)
Median percentage of fat in the lower extremities (IQR), %	46.98 (6.26)
Median percentage of fat in the trunk (IQR), %	45.34 (6.59)

SD=standard deviation; IQR=interquartile range; *CDC growth chart (2000)

Table 2. Correlation analyses of body fat mass and fat distribution measurements with menarcheal age

Characteristics	Menarcheal age	
	R	P value
BMI, kg/m^2	-0.28	0.11[a]
BMI-for-age, Z-scores	-0.45	0.01[a]
Waist circumference, cm	-0.32	0.06[a]
Hip circumference, cm	-0.21	0.23[a]
Waist-hip ratio	-0.29	0.10[a]
Waist-height ratio	-0.37	0.03[b]
Total body fat mass, kg	-0.06	0.70[b]
Body fat mass of the upper extremities, kg	-0.12	0.48[b]
Body fat mass of the lower extremities, kg	-0.19	0.28[b]
Body fat mass of the trunk, kg	-0.03	0.87[b]
Body fat mass of the extremities and the trunk ratio	-0.07	0.68[b]
Body fat percentage,%	-0.04	0.78[b]
Percentage of body fat in the upper extremities, %	-0.24	0.17[a]
Percentage of body fat in the lower extremities, %	-0.01	0.94[b]
Percentage of body fat in the trunk, %	0.04	0.82[b]

a=Pearson's correlation test; b=Spearman's correlation test

adolescent girls in 2018 reported a mean age at menarche of 12 years, with a mean BMI of 20.7 kg/m^2. The majority (99.04%) of subjects had menarche by the age of 14 years.[16] *The 2010 Indonesian Basic Health Research Survey* reported the mean menarcheal age in Indonesia was 12.74 (SD 1.19) years, based on a survey on 1,418 girls.[17] In 2011, a study on 128 primary and junior high school students in Jakarta and two suburban settlements near Jakarta found a mean menarcheal age of 12.18 (SD 0.91) years, with a mean BMI OF 18.87 (SD 2.89) kg/m^2.[18] Another study in an Islamic school (equivalent to junior high school) in 2013 found a mean menarcheal age of 11.68 (SD 0.71), with a mean BMI of 20.05 (SD 4.23) kg/m^2.[19] These studies, done in different years, show a secular trend of decreasing menarcheal age in Indonesia, although not as precisely as previously predicted by Wahab *et al.*,[11] which was approximately 0.0245 years (8-9 days) per year.

The mean menarcheal age in our subjects was 11.91 (SD 0.83) years, with a mean BMI of 19.92 (SD 3.56) kg/m^2. Comparing study results is challenging due to differences in inclusion criterion age cut-offs. We used an age cut-off of 10-15 years, excluding girls who experienced menarche outside the age range. We also excluded girls with precocious puberty (puberty before 8 years of age).

We found menarche to happen mostly (75%) in adolescents with normal BMI. The Frisch and Revelle hypothesis stated that menarche in an adolescent

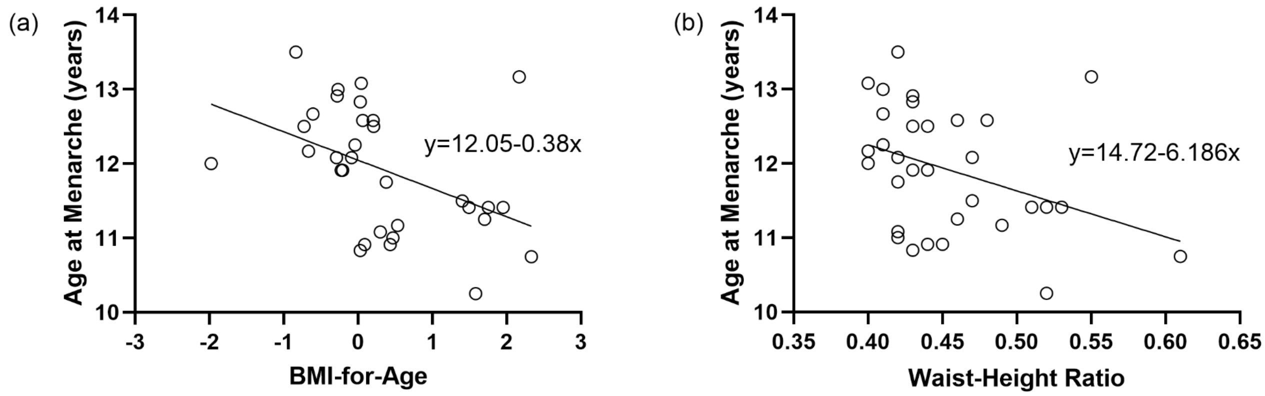

Figure 1. (a) Correlation between age at menarche and BMI-for-age, (b) Correlation between age at menarche and waist-height ratio.

girl can occur when her body weight reaches a minimum of 48 kg or 17% body fat percentage.[20] Our subjects median weight was 41.25 (range 29.8-68.6) kg and median body fat percentage was 23.65 (range 14.1-47.1)%. Our findings suggest that body weight and body fat percentage are not the only determining factors of menarche. Other factors such as fat distribution, nutrition, environment, and genetics may also play a role.

Correlation tests revealed statistically significant relationships between menarcheal age and BMI-for-age, as well as waist-height ratio. We found a moderate negative correlation between BMI-for-age and menarcheal age; girls with higher BMI-for-age Z-scores tended to undergo menarche earlier. Our finding was consistent with a study in Spain on girls aged 13-16 years, which found BMI-for-age to be weakly correlated with menarcheal age (r=-0.34).[21] Other Indonesian studies on the relationship between menarcheal age and BMI, not BMI-for-age, found varying degrees of negative correlations (r=-0.31, r=-0.33, and r=-0.98, respectively).[18,22,23]

We measured waist circumference, waist-hip ratio, and waist-height ratio to assess abdominal obesity, and found a weak correlation between waist-height ratio and menarcheal age (r=-0.37). A study in Tanzania found no statistically significant differences between waist-hip ratio and waist-height ratio of pre-menarche and post-menarche girls.20 In addition, another study found a strong positive correlation between waist-hip ratio and menarcheal age (r=0.95).[23] This difference may have been due to different study methods, especially with regards to sample size, age limitation of study subjects at recruitment, baseline characteristics of subjects, and the time period between data collection and menarche.

Body fat mass and fat distribution was measured by BIA. We found no correlation between body fat percentage and menarcheal age, which contradicted previous studies which found significant correlations of varying strengths. Sterling investigated body fat percentage measured by *Tanita BIA* and found a positive correlation coefficient of 0.09 for the relationship between body fat percentage and menarcheal age in 251 adolescent girls aged 12-19 years in California and Michigan, USA.[24] A prospective cohort study on 156 pre-menarche girls in primary school grades 4-6 found a positive correlation coefficient of 0.28 for such a relationship.[22] In addition, a strong positive correlation between body fat percentage and menarcheal age was reported by a previous study on 44 girls in Padang, West Sumatera, Indonesia, who experienced menarche within 12 months of the study (r=0.97).[23]

We found no significant correlation between segmental fat distribution and menarcheal age. Previous studies on menarcheal age generally used skinfold thickness or anthropometric measurements to assess fat distribution, with limited use of BIA. A previous study used the *Third National Health and Nutrition Examination Survey* (NHANES III) data of 10-14-year-old girls and found that increased hip circumference was positively correlated with menarche (OR 1.22; 95%CI 1.17 to 1.26; P<0.01), while the increase of waist circumference and triceps skinfold thickness was negatively associated with menarche [(OR 0.93; 95%CI 0.90 to 0.96; P<0.01) and (OR 0.91; 95%CI 0.88 to 0.94; P<0.01), respectively]. Menarche occurred in girls with low total body fat mass, but adequate gluteofemoral fat mass.[25] A previous study investigated subcutaneous fat distribution using skinfold thickness in pre- and post-menarche girls in India, and found no difference in the ratio of subcutaneous fat in the trunk and extremities in the two groups. Post-menarche girls had more fat mass in the upper trunk and upper extremities.[26]

Menarcheal age is influenced by genetic and non-genetic factors, such as environment, socioeconomic status, nutrition, and body fat.[3] Our study focused on how body fat affects menarcheal age, because the modifiable nature of body fat and body fat levels are easy to monitor. The relationship between body fat and puberty starts in infancy. Formula-feeding has been associated with rapid weight gain after birth and earlier menarche. This rapid weight gain in infancy and childhood may disrupt hormonal balance and growth velocity, as seen in the increase of androgen levels at 8 years of age. Insulin resistance and peripheral hyperinsulinemia are common in obese children, with effects on several organs (adrenal glands, liver, ovarium, and adipocytes), leading to increased bioavailability of sex hormones. This increase in sex hormones may activate the hypothalamus-pituitary axis to start puberty earlier.[27] A longitudinal study showed that high BMI at 3 years of age in conjunction with fast BMI increase at 3-6 years of age were associated with early puberty.[28] The study added to the body of evidence that shows the importance of BMI monitoring from the beginning of life, to avoid early puberty and its implications.

We limited our subject recruitment to girls who had their first menstrual period within the 3 months prior to recruitment, with the aim of a short time period between menarche and data collection, so that the data would reflect measurements at menarche more accurately. Because we relied on subjects to recall the date of their first menstrual period, the maximum 3-month recall period would also help to reduce recall bias.

We measured 15 fat mass variables, but only two variables (BMI-for-age and waist-height ratio) had significant relationships with menarcheal age. This may have been due to the heterogenous nature of subjects' characteristics, which led to a broad range of body fat measurements. This limitation could have been mitigated by stratifying the study sample into early menarche, normal menarche, and late menarche groups. As such, a larger sample size would be required depending on the number of stratification groups. But the study results would be more representative of actual conditions.

To our knowledge, our study is the first in Indonesia to investigate the relationships between menarcheal age and body fat mass as well as fat distribution using BIA. The BIA was chosen for its accuracy, ability to assess fat distribution, ease of use, comfort during use, and relatively affordable cost. To further ensure accuracy, anthropometric measurements were done by the authors, taking a mean of two measurements, to reduce interobserver and intraobserver errors.

During puberty, teenagers undergo changes in body composition, especially body fat. Body fat assessment is ideally performed several times to monitor pre- and post-menarche changes. The limitations of this study were that the body fat mass and fat distribution measurement was done only once, and it was not done immediately after menarche. In order to increase accuracy, we limited the subjects we recruited to girls who had just experienced menarche and did not have ≥ 5% change in body weight in the last 3 months. The relationship between body fat and menarcheal age is influenced by leptin and other reproductive hormones (gonadotropin-releasing hormone, follicle-stimulating hormone, luteinizing hormone, and estradiol). In order to investigate the molecular processes of these relationships, a prospective cohort study with hormone monitoring through the pre- and post-menarche period would be the ideal design for future studies. In conclusion, body fat mass and fat distribution are not correlated with menarcheal age. However, there are weak to moderate negative correlations between menarcheal age and BMI-for-age as well as waist-height ratio.

Conflict of Interest

None declared.

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