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Adiposity level, fat distribution and age at menarche in Bengali girls from Kolkata, India

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Abstract

Background The onset of menarche is influenced by various factors, including genetic, morphological and socioeconomic factors.

Objectives The study aimed to examine the differences in adiposity levels and fat distribution between early, average, and late maturing girls from Kolkata, India.

Sample and Methods 936 Bengali girls included in a cross-sectional study were categorized as early, average or late maturing. The examination was school-based and conducted from 2005 to 2011. Six skinfolds (biceps, triceps, subscapular, suprailiac, abdominal and calf) were measured. Trunk-to-limbs, trunk-to-total, abdominal-to-trunk skinfold ratios, and total adiposity were calculated. Statistical differences between all menarche categories were assessed using Student t-test or Mann-Whitney test.

Results Early maturing girls were characterized by greater overall (% BF: early=24.3; average=24.0; late=23.8; $p>0.05$) and abdominal adiposity (as represented by skinfold thicknesses and values of studied indicators), compared to those with late or average age at menarche.

Conclusions Early menarche was associated with a tendency towards central adiposity and thus, increased risk of abdominal obesity. Future research should explore the association between the age at menarche and metabolic characteristics in ethnically diverse populations. Longitudinal studies and studies conducted on large cohorts are particularly valuable. It would be beneficial to adjust the results for factors such as diet or physical activity, as well as for ethnic characteristics in relation to the body's tissue composition.

Take-home message for students In the examined group of Indian girls, early menarche was associated with a tendency towards central adiposity and an elevated probability of abdominal obesity. It is important for future research to explore the association between age at menarche and metabolic characteristics in ethnically and socioeconomically diverse populations.

Introduction

Menarche is influenced by a plethora of factors which can be divided into genetic, morphological and environmental/socioeconomic aspects. For instance, it has been suggested that up to 50–80 % of the variance in human pubertal timing is determined by genetic factors (Gajdos et al. 2010). High level of genetic control over the timing of menarche is also confirmed by its estimated heritability of ~50% (Demerath et al. 2013).

Is has been suggested that genes analyzed as regulatory candidate for the age at menarche (e.g., LIN28B, FTO, TNNI3K, GPRC5B) may also be linked to various anthropometric characteristics such as body height and mass suggesting a common genetic basis for these traits (Elks et al. 2010; Perry et al. 2014). Some alleles related to higher Body Mass Index (BMI) and Waist-to-Hips Ratio (WHR) show at least nominal associations with an earlier onset of menarche. This, in turn, suggests that menarche loci can generally have a pleiotropic effect on growth (Elks et al. 2010).

It should also be stressed, that the described genetic factors closely interact with environmental and socioeconomic aspects in regulating the timing of puberty (Gajdos et al. 2010). The acceleration of the biological maturation appears to be highly correlated with the economic development of a country, and consequently, the improvement of living conditions (Deardorff et al. 2014). Indian girls coming from more affluent families tend to experience menarche at an earlier age, compared to their fewer wealthy counterparts (Bagga and Kulkarni 2000; Żegleń et al. 2020). An analogous phenomenon was observed in Polish adolescents when the increasing expenses due to the rising food prices in the 1960s, became associated with later menarche (Gomula and Koziel 2018). On the other hand, studies exist that suggest the opposite: in the American population, a relatively poor financial situation was uniquely associated with earlier first menstruation (Deardorff et al. 2014).

Considering the influence of socioeconomic factors, it can be concluded that the age at menarche is an excellent indicator of environmental conditions of a given population (James-Todd et al. 2010; Kozieł et al. 2016).

It is well known, that both environmental and genetic factors have a significant influence on dimensions, proportions, and tissue composition of the human body. These in turn are among the factors that play an important role in the onset of menarche.

Also psychosocial factors may affect the age at menarche (Hermanussen et al. 2012). The psychosocial environment of an individual and the peer group, as well as the personal understanding of sexuality can be factors that delay or accelerate menarche.

Body height is associated with menarche. Girls who experienced menarche earlier achieve a lower final body height compared to maturing later girls (Onland-Moret et al. 2005). Body height itself, in particular the timing of the adolescent height spurt influences the onset of menarche (Chang et al. 2000).

Another anthropometric characteristic that was shown to significantly influence the age of the first menstruation is body mass. Similar to stature, girls with higher BMI tend to have early menarche. This association was noted in a plethora of studies both in the Indian population, and in other countries (Al-Awadhi et al. 2013; Bagga and Kulkarni 2000; Gupta et al. 1996). The average BMI of premenarcheal girls is significantly lower than that of menstruating girls of the same calendar age which was attributed to differences in the tempo of maturation (Mumm et al. 2014). Batubara et al. stressed that the nutritional status strongly influences menarche (Batubara et al. 2010).. The association between BMI and menarche appears independent of the socioeconomic status of the studied population (Al-Awadhi et al. 2013).

Another important aspect concerning the age at menarche is its influence on the future health of girls, as well as on body size, proportions and tissue composition, which includes both early and late maturation.

Early maturing girls tend to have higher BMI, body adiposity as well as greater waist circumference and indicators such as waist-to-hips ratio (WHR) and waist-to-height-ratio (WHtR) which mirror the deposition and distribution of the fat tissue (Mueller et al. 2014).

John et al. showed the link between menarche and body mass, adiposity, and body height in the Indian population (John et al. 2014).

These phenomena suggest that the age at menarche can be an excellent clinical and public health indicator of susceptibility to overweight and obesity, as well as diabetes and abnormalities of insulin-related metabolism (Harris et al. 2008; Lakshman et al. 2008).

Based on these data, we made the following research hypotheses:

- early maturing girls will be characterized by greater general body fat, compared to their counterparts who experienced menarche late;
- early maturing girls will be characterized by greater thickness of skinfolds, compared to their counterparts who experienced menarche late;
- early maturing girls will be characterized by greater central adiposity, compared to their counterparts who experienced menarche late.

The aim of this study was to examine the differences in adiposity level and fat distribution between early, average and late maturing girls from Kolkata, India

Sample and methods

Sample

This cross-sectional study comprised 2.195 Bengali girls aged 7–21 years from 37 schools and colleges in Kolkata. All individuals with menarcheal status marked as "occurred" were selected. If the date of menarche was specified to the day, it was left as it was. If the date of menarche was specified to the month, it was noted at the 15th day of that month. Individuals whose date of menarche was missing or unclear were excluded from the study. This resulted in a group of 936 girls.

The girls came predominantly from middle-class families, classified on the basis of:

- monthly family expenditure – ≥2200 INR;
- parental occupation – the majority of fathers working in the business field;
- parental education – the majority had at least a graduate degree;
- household assets and housing condition – included for example the area occupied by the household, number of rooms (in -the majority of the cases and bathrooms (at least 1) in the house as well as the source of drinking water (own tap/well in the majority of the households).

The qualification to the study group was based on the good overall health of the participants as well as the consent of their parents/legal guardians. All procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. The study has been approved by the Ethical Committee for Research Risks to Human Subjects, Indian Statistical Institute (Kolkata, India).

Age at menarche was determined using the retrospective recall method and expressed as a decimal fraction. All participants were categorized as early, average or late maturing (Table 1) with:

early: < -1SD,
average: X ± 1 SD,
late: > 1 SD,

X mean age at menarche, SD standard deviation.

Table 1 Number of girls according to menarcheal status.

Menarcheal status	n	%
Early	151	16.1
Average	647	69.1
Late	138	14.7
Total (N)	936	100

Measurement and analysis methods

The analyzed anthropometric characteristics included six skinfolds measured by Lange skinfold calliper.
The triceps skinfold (TRC) was measured with the arm muscles relaxed, in the middle part of the posterior surface of the upper arm, above the triceps. The biceps (BIC) skinfold was measured at the same site, around the biceps branchi (the arm resting relaxed and supine). The subscapular skinfold (SSC) was measured below the inferior angle of the scapula, at 45° to the vertical, along the natural crease lines of the skin. The suprailiac (SIL) skinfold was measured above the iliac crest, posterior to the mid-axillary line and parallel to the cleavage lines of the skin. The abdominal skinfold (ABD) was measured 5 cm adjacent and 1 cm below the umbilicus. Lastly, the calf skinfold (CL) was measured at the maximum girth, with the lower limb relaxed (Tanner 1962).

The study was performed by experienced anthropometrists who were specifically trained by the head researcher. Measurements were made according to the protocol of the International Biological Programme (Weiner and Lourie 1969) – all skinfolds were measured on the left side of the subjects.
The measurements were used to calculate:

- trunk-to-limbs skinfold ratio: [(ABD+SSC+SIL) / (TRC+BIC+CL)],
- trunk-to-total skinfold ratio: [(ABD+SSC+SIL) / (TRC+BIC+CL+ABD+SSC+SIL)],
- abdominal-to-trunk skinfold ratio: [(ABD / (ABD+SSC+SIL)],
- body fat percentage was calculated according to Slaughter formula (Slaughter et al. 1988).

Statistical differences between measurements and their ratios, and menarche category were calculated by Students t-test (level of significance $p<0.05$) or in the case of not-normal distribution by Mann-Whitney test. All calculations were performed using Microsoft Excel and MedCalc software.

Results

The mean age at menarche was 11.67 (±1.32) years. We used cut-offs for early and late menarche at 10.36 and 12.99 years. The majority (69.1%) of the girls experienced menarche at an average age, while 16.1% and 14.7% had their first menstruation earlier or later, respectively.
Early maturing girls were characterized by greater biceps and calf skinfolds compared to their counterparts who achieved menarche late or at average age (Table 2). Interestingly, the triceps skinfold was, on average, the thickest in late maturing girls. Yet, all differences in limbs adiposity were statistically not significant (Table 2-5).

The highest thickness of subscapular, suprailiac, and abdominal skinfolds was noted in the early maturing girls, while those experiencing menarche late and on average time had lower values. Yet, the differences did not achieve statistical significance (Table 2, 4).

Girls and women with early and average-timed onset of menarche were also characterized by lower values of trunk-to-total skinfold ratio, compared to their counterparts categorized as having the first menstruation early. These differences mirror the relatively higher trunk adiposity in

Table 2 Mean (X) and standard deviations (SD) values of various skinfold thicknesses of Bengali girls (aged 7–21 years) in three menarche categories: early: < -1 SD, average:X ± 1 SD, late: > 1 SD.

Menarcheal status	Triceps skinfold [mm]		Biceps skinfold [mm]		Subscapularskin-fold [mm]		Suprailiac skinfold [mm]		Medialcalfskin-fold [mm]		Abdominal skinfold [mm]	
	X	SD	X	SD	X	SD	x	SD	x	SD	x	SD
Early	15.1	4.1	9.4	3.7	13.3	4.0	9.8	3.5	13.7	4.2	15.9	4.8
Average	15.1	4.0	9.4	3.7	12.9	4.1	9.6	3.5	13.2	3.9	15.7	4.7
Late	15.3	4.0	9.1	3.6	12.4	3.8	9.1	3.5	13.1	3.8	15.2	5.0

Table 3 Mean (X) and standard deviations (SD) values of various skinfold ratios and body fat of Bengali girls (aged 7–21 years) in three menarche categories: early: < -1 SD, average: X ± 1 SD, late: > 1 SD.

Menarcheal status	Trunk-to-total skinfold ratio		Trunk-to-limbs skinfold ratio		Abdominal-to-trunk skinfold ratio		Body fat [%]	
	X	SD	X	SD	X	SD	X	SD
Early	0.506	0.042	1.037	0.177	0.408	0.041	24.3	5.1
Average	0.503	0.041	1.025	0.169	0.413	0.047	24.0	5.1
Late	0.493	0.044	0.989	0.182	0.416	0.042	23.8	4.9

Table 4 Difference between the mean values of various skinfold thicknesses of Bengali girls (aged 7–21 years) in three menarche categories: early: < -1 SD, average: X ± 1 SD, late: > 1 SD.

Comparison	Triceps skinfold [mm]	Biceps skinfold [mm]	Subscapular skinfold [mm]	Suprailiac skinfold [mm]	Medial calf skinfold [mm]	Abdominal skinfold [mm]
Average vs early	0.034	0.031	-0.414	-0.281	-0.503	-0.240
Average vs late	-0.223	0.299	0.515	0.506	0.155	0.478
Early vs late	-0.257	0.268	0.929	0.788	0.658	0.718

Table 5 Difference between the mean values of various skinfold ratios and body fat of Bengali girls (aged 7–21 years) in three menarche categories: early: < -1 SD, average: X ± 1 SD, late: > 1 SD.

Comparison	Trunk-to-total skinfold ratio	Trunk-to-limbs skinfold ratio	Abdominal-to-trunk skinfold ratio	Body adiposity [%]
Average vs early	-0.003	-0.012	0.005	-0.293
Average vs late	0.009***	0.035*	-0.003	0.161
Early vs late	0.012*	0.048*	-0.008	0.454

*p<0.05; ***p<0.0001

early maturing girls. Noted discrepancies turned out to be statistically significant between average and early, as well as late and early maturing girls (Table 5).

This observation was confirmed by the highest value of trunk-to-limbs skinfold ratio in early maturing girls due to greater accumulation of fat tissue on the trunk relative to the limbs. The differences were statistically significant between average and early, as well as late and early maturing girls (Table 5).

Early maturing individuals were characterized by greater general body fat. Yet, the differences were not statistically significant (Table 3, 5).

Discussion

Age at menarche and overall adiposity

In the present study, early maturing girls were characterized by greater general body fat ratio, in comparison to their counterparts who experienced menarche late or on an average time. This is in line with a study conducted by Wilson et al. (Wilson et al. 2015), where younger menarcheal age was associated with increased adiposity in young adult women. The findings are analogous to other large-scale studies which have also shown an evident relationship between an early first menstruation and greater adiposity in adulthood (Freedman et al. 2003; Garn et al. 1986; Trikudanathan et al. 2013).The present findings are in line with a recent randomized study by Bell et al. (Bell et al. 2018) who noted that a relatively late first menstruation was associated with lower adiposity later on. Increased obesity associated with relatively early menarche appears to persist at least into middle adulthood (Dreyfus et al. 2015). Other studies noted that the tendency towards greater overall adiposity tends to be observed in adolescence (Biro et al. 2003; Freedman et al. 2002).

The mechanism guiding the relationship between menarche and body fat ratio is still not fully known. It was suggested, that both phenomena – adiposity and early maturation – are not necessarily interdependent, but rather related to the same factor, namely excess adiposity during childhood (Ong et al. 2007; Lenthe et al. 1996), especially as it has recently been shown that the relation between age at menarche and adiposity is largely accounted for by body fat at the age of 8 (Bell et al. 2018). This further suggests that adiposity in childhood tends to track forward to later life stages. Similar findings have been presented in previous studies (Johnson et al. 2015; Power et al. 1997). In this context, it should also be mentioned that the described association may be caused by the differing pace of the maturation process, that tends to be accelerated in individuals with relatively early puberty, in comparison to late maturation. Consequently, the impairment of not only biological but also behavioral processes that results from more rapid maturation alone can be associated with an increased body fat ratio (Must et al. 2005; Reynolds and Sontag 1950).

It has also been suggested that genetic factors associated with adiposity such as leptin or insulin-like growth factor I (IGF-I) may play a role in the regulation of the onset of puberty (Wilson et al. 2015).

It should be noted, that the differences in adiposity between early and late maturing girls may be associated with different lifestyle choices, particularly in terms of physical activity. For example, the authors of the CARDIA study reported higher levels of physical activity in later-maturing girls, which, on top of influencing the body fat ratio, may have delayed menarche (Chavarro et al. 2005).

It should be emphasized that elevated body adiposity related to early menarche can have significant health-related consequences. Girls experiencing menarche at a relatively young age are characterized by higher blood pressure in adulthood (Werneck et al. 2018). Additionally, it has also been suggested, that a later (but within the normal range) pubertal onset is potentially protective against obesity and cardiometabolic risk in later life (Dreyfus et al. 2015).

Age at menarche and body fat distribution

In the present study, early-maturing girls were characterized by a greater central (android) adiposity, in comparison to their average and late maturing counterparts. We consider surface anthropometric measurements to be able to accurately predict overall and regional adiposity as measured by DXA method. Trunk adiposity is strongly correlated with skinfold thickness, particularly suprailiac and abdominal skinfolds (around 90% and 60% of the explained variability, respectively, for boys and girls) (Flavel et al. 2012; Leppik et al. 2004).

This is in line with a study in Portuguese girls. Higher waist circumferences were noted in girls with earlier menarche. Differences in the body fat distribution occurred regardless of differences in the body fat ratio (Leitão et al. 2013). The present findings are analogous to the BioCycle study that showed that early menarche was associated with a tendency towards central obesity (i.e., elevated trunk adiposity) (Chen et al. 2011).

Central adiposity has been linked to decreased insulin sensitivity, suggesting that early menarche can be a predisposition to illnesses such as type II diabetes, hypertension, coronary heart disease, stroke or metabolic syndrome. This was confirmed by a study directly examining the relationship between the age of the first menstruation and insulin resistance. Wilson et al. (Wilson et al. 2015) found a 41% difference in insulin sensitivity between late and early maturing girls which is consistent with studies linking younger menarcheal age with higher fasting insulin concentration as well as increased insulin resistance, measured by homeostatic model assessment for insulin resistance (HOMA-IR) (Chen et al. 2011; Feng et al. 2008). Dreyfus et al. (Dreyfus et al. 2015) demonstrated that each 1-year of earlier maturation increased the risk of impaired fasting glycaemia (IFG) by 13% and of metabolic syndrome by 19%. The risks increased independently of the overall body fat ratio. This association has also been noted in Bangladeshi girls in whom the age at menarche was inversely associated with the occurrence of the metabolic syndrome. An analogous relationship was also shown in the presence of certain components (i.e., high triglyceride, low HDL cholesterol) of the metabolic syndrome when examined individually (Akter et al., 2012). The association of early menarche with an increased risk of metabolic abnormalities was noted in various populations (Akter et al. 2012; Rah et al. 2009; Stöckl et al. 2011). We concluded that these phenomena are present regardless of ethnicity and the overall socioeconomic or developmental status of a particular society.

Body composition during childhood, particularly at the age of 8 years, is critical to the association between age at menarche and adiposity. On the other hand, the age of 12 has been proposed as a point when obesity risks decline. This observation was made using indicators of general and central adiposity (i.e., the waist circumference). This appears to be consistent with other data that classify menarche under 12 years of age as early maturation (Dreyfus et al. 2015; Kvalheim et al. 2016; Leitão et al.

2013; Werneck et al. 2018). In the analyzed population, the average age at menarche was 11.67 years, with a standard deviation of 1.32. Hence, the cut-off point of early menarche was 10.36 years of age, which is lower than the previously mentioned threshold of the age of 12. This difference may be associated with the specific population, i.e., middle-class West Bengali girls. Most other research was conducted primarily in populations of Caucasian origin.

The association between insulin resistance, glucose deregulation, central obesity, and age at menarche is favoured by the metabolic and hormonal changes (i.e., modifications in oestrogen, progesterone and sex hormone-binding globulin levels) in girls who mature at earlier age, during a window of susceptibility (Prentice and Viner 2013). Interestingly, in a large scale genetic study, there were no significant associations of individual, central adiposity loci with the onset of menarche. However, the authors pointed out, that their results may suggest a more complex genetic relationship between the moment of the first menstruation and an android fat deposition (Fernández-Rhodes et al. 2013).

Strengths and limitations

Among the strengths of the current study is the large number of participants from the same population. In addition, the study was conducted in a city whose characteristics allow extrapolation of the results to the entire Bengali population. The present study also had some limitations. One of them is the use of the retrospective recall method to determine age at menarche. According to some authors, this method may not be accurate enough because of the time lag between menarche and the date of contact.

Conclusions, possible practical application and further research

Early, average and late maturing girls from the West Bengali population differed in terms of body composition. The differences were particularly evident when body fat distribution was taken into consideration, as individuals experiencing menarche relatively earlier were characterized by greater trunk/abdominal adiposity in comparison to their average and late maturing counterparts. We concluded that in this population, early menarche is associated with a tendency towards a central (android) fat tissue distribution and, therefore, an increased risk of abdominal obesity.

The present research, as well as a plethora of previous studies, showed that the tendency towards elevated overall adiposity and central deposition of fat tissue in early maturing girls persists into young adulthood. Furthermore, there is evidence that it may even be present into middle age (Freedman et al. 2003; Trikudanathan et al. 2013).

Given the association between body composition, fat distribution, and age at menarche, we concluded that early maturation may predispose to abnormalities such as type II diabetes, hypertension, coronary heart disease, stroke, or metabolic syndrome as these features have been shown to be elevated in individuals with increased android deposition of adipose tissue (Wilson et al. 2015).

Data on menarche may be critical in identifying women at risk for metabolic abnormalities later in life. Early detection of such problems will, in turn, help prevent the metabolic syndrome and, subsequently, also various cardiovascular diseases.

It should be noted that understanding the potential impact of menarche on a woman's future metabolic health can be an important prophylactic tool to identify

increased risk and prevent the occurrence of metabolic abnormalities. This can often be achieved through simple lifestyle and dietary habits, as these mediators are especially critical in younger women.
Future research should investigate the relationship between age at menarche and metabolic characteristics, preferably in ethnically diverse populations. It should also be emphasized that longitudinal studies, as well as well-designed research conducted in large cohorts, will be particularly valuable. In addition, it would be beneficial to adjust the results for various lifestyle factors such as diet or physical activity, as well as for ethnically determined characteristics related to body composition.

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Appendix

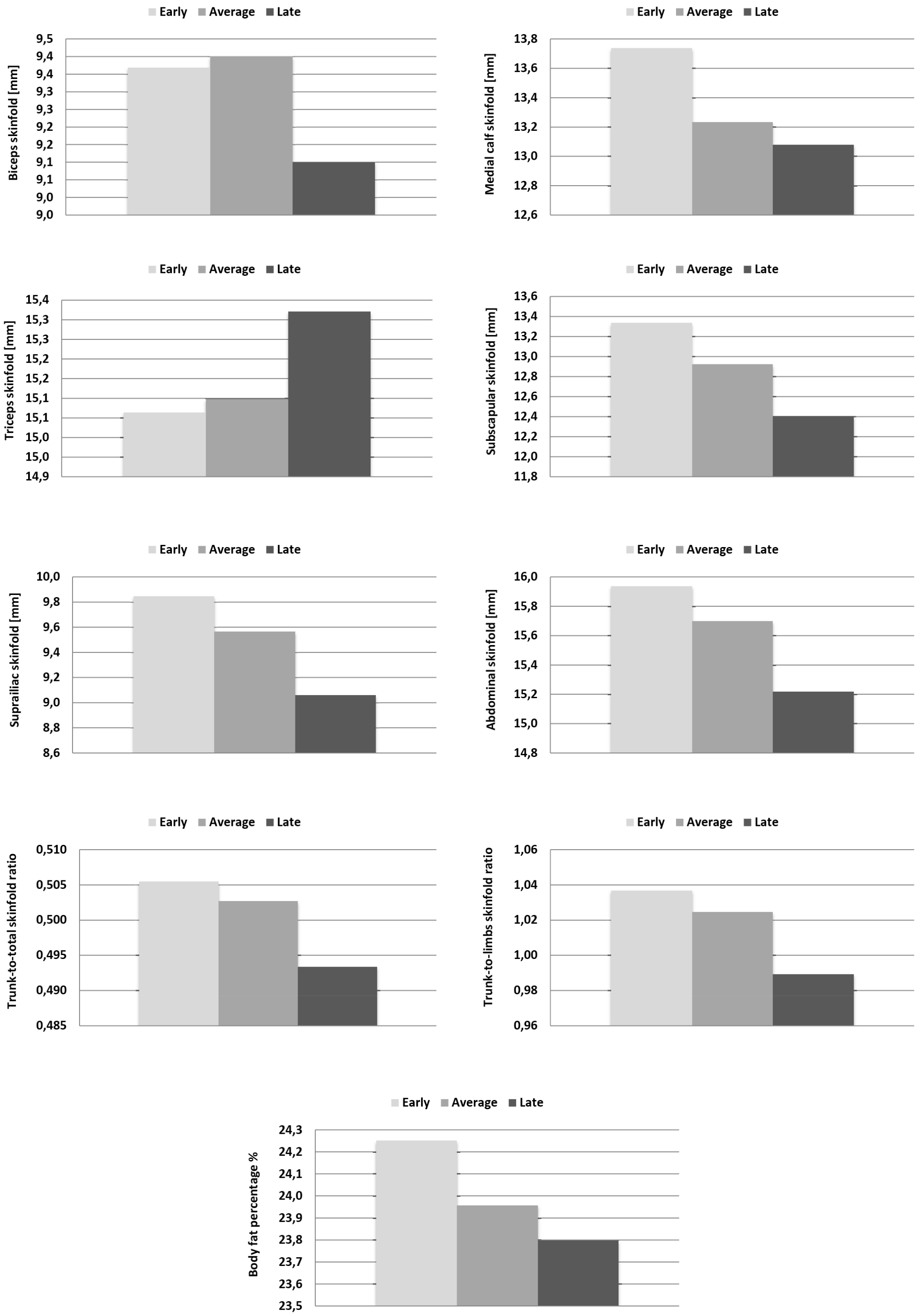

Figure 1 Differences in mean values of analyzed characteristics between the girls in three menarche categories.