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The Relation of Menarcheal Age to Anthropometric Profiles in Korean Girls

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The aim of this study was to represent the trend of early menarche and to assess the association of age at menarche with anthropometric profiles of Korean children and adolescents. A cross sectional survey was conducted with 13,371 girls aged 10 to 18 yr, recruited nationwide from April, 2005 to March, 2006. Height, weight and waist circumference of the subjects were measured; and the subjects self-reported their ages at menarche. We found that the menarcheal girls were taller (P<0.05 for the girls between 10 and 14 yr) and heavier (P<0.05 for the girls between 10 and 18 yr) than non-menarcheal ones. Menarcheal girls also showed higher body mass index (BMI), and greater waist circumference than non-menarcheal ones. Significant differences were represented according to the age at menarche in terms of BMI, waist circumference, % body fat mass, waist hip ratio and neck circumference as well as height and weight (P<0.05). In conclusion, girls who matured early were taller and heavier in early adolescence than those who matured later.

Key Words: Menarche; Korea; Body Composition; Anthropometry

INTRODUCTION

There is a strong evidence of a downward secular trend in age at menarche in Europe and the USA during the last century, and in Japan and China during the past few decades (1). In Korea, there was a downward secular trend in pubertal timing, and age at menarche has been advanced by 2 yr during the last 80 yr (2). Early age at menarche has been shown to be associated with increased adult body mass index (BMI) (3). Girls who experience a relatively early age at menarche tend to be more obese as adults (4-12). During childhood and puberty, obese girls grow faster and have earlier menarche (13). Several longitudinal studies have found a negative relation between age at menarche and adult weight-for-height (8-12, 14-16) by the analysis of BMI in all except one study (14). One research showed no association between age at menarche and adult BMI (5). Although the biological mechanisms underlying the inverse association between menarcheal age and adult obesity are uncertain, it has been suggested that various endocrine factors influence both the rate of sexual maturation and the accumulation of body fat (8). Garn et al. (1986) found that women (20 to 35 yr old) who reported menarche before age of 11 yr old were 2 to 3 kg/m^2 heavier than those who underwent menarche after 14 yr old. Other factors across the life course may also explain the relation between age of menarche and adult BMI (16). Socioeconomic status at birth and in adult life, parity, current smoking, and alcohol intake are all associated with BMI in adult life (17). Social class is also negatively associated with age at menarche (12). But no studies of the association of age at menarche and adult BMI have taken all of these factors into account simultaneously (17). Since the early 19th century, secular changes have been described for age at menarche as well as for adult height (18). Several studies show that women with earlier menarche reach a shorter adult height compared with women who have menarche at a later age (4, 7, 12, 19-22). It has been believed that late maturers grow taller and leaner than early maturers but there have been only a few studies to prove this relation in Korean population.

The aim of this study was to represent the trend of early menarche and to assess the association of age at menarche with anthropometric profiles of Korean children and adolescents.

MATERIALS AND METHODS

Participants and procedures

This study was performed as a part of the fifth nationwide cross-sectional anthropometric survey for Korean children and ado-

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lescents from April, 2005 to March, 2006 by Korea Centers for Disease Control and Prevention and the Korean Pediatric Society. All participants were informed about the procedures and aims of this study. Anyone who was reluctant to participate in this study was excluded. Children with growth hormone deficiency, growth related disorders, and other chronic debilitating conditions were also excluded from the study. Children with non-Korean parents were not included. Twins were also excluded from the study. The sample was stratified by age and province. Subjects were students at elementary, middle, and high schools across the nation. Data of the survey were collected from April, 2005 to March, 2006.

The questionnaire survey on the date of menarche was done either by self-reporting or by parents. A total of 13,371 girls aged 10 to 18 yr were recruited across the nationwide; of them, 9,840 girls aged 10 to 18 yr have experienced menarche at the time of study, but 3,531 girls aged 10 to 16 yr have not. All girls aged between 17 and 18 yr experienced menarche. Informed consents were received from all subjects. This study was approved by the ethics panel of the institutions (KHUMC-IRB-2005001). Ages of all children were confirmed in records of school registry of birth date. Girls were categorized at interval of one year. The trained technicians measured stature and weight of subjects in light clothing and no shoes. Standing height was measured to the nearest 0.1cm using the standard measuring instrument (Harpenden Portable Stadiometer, Holtain Limited, Wales, UK). Weight of girls was measured using calibrated mechanical step-scales (GL-6000-20, CasKorea, Seoul, Korea). Weight was recorded to the 0.1 kg sensitivity. A total of randomly selected 1,006 girls from the whole samples were also examined for body fat and waist hip ratio using the instrument for body composition assessment (Bioelectrical Impedance Fatness Analyzer, Biospace, Seoul, Korea). The body composition was measured in the fasting status.

Statistical analysis

SAS (SAS institute Inc., Cary, NC, USA) version 9.1 was used to analyze the data. The distributions and means of study populations were evaluated using descriptive statistics. The frequencies of menarche experience at current ages were calculated with chi-square test. We excluded girls who reported that their menarche, at age 7 yr old (n=3) and 8 yr old (n=11) from analyses. The differences of anthropometric profiles in menarcheal girls according to menarcheal ages were analyzed by Analysis of Variance (ANOVA). Tukey's multiple comparison test was applied to evaluate differences between groups by ANOVA. Student t-test was used to investigate the differences between groups. *P* value at 0.05 or less was regarded as significant.

RESULTS

The age at menarche and the rate of menarche experience

Older girls showed later onset of menarche and it was a statistically significant finding (Table 1). Fig. 1 also supports the trend of menarche occurring at an early age. All the girls older than 17 yr among the subjects recruited for this study had already experienced menarche. The largest number of girls experienced their menarche between the age 11 and 12 yr (Table 1).

Distribution of height, weight and body mass index in menarcheal girls according to age at menarche

One way ANOVA represented statistically significant differences in terms of height, weight and BMI ($P<0.001$) (Table 2). The girls that experienced menarche at an earlier age were taller and this difference depicted a statistical significance from the age of 10 to the age of 14 (Table 2). The difference of the mean weight was also analyzed and represented that menarcheal girls were heavier than non-menarcheal ones. From the age of 10 to 18, the menarcheal girls revealed significant differences with re-

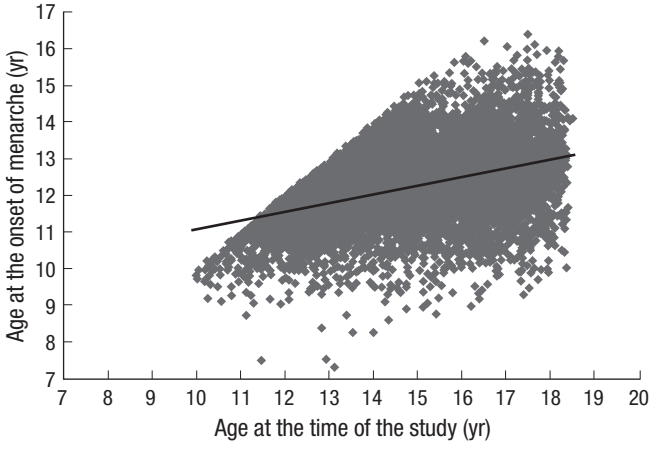

Fig. 1. Trend of menarche occurring at an early age.

Table 1. Comparison of age at menarche and the rate of menarche experience

Parameters	Age at the time of the study (yr)								
	10	11	12	13	14	15	16	17	18
No. of menarcheal girls	90	430	1,160	1,515	1,719	1,524	1,773	1,414	207
No. of non-menarcheal girls	1,550	1,158	603	191	41	9	3	0	0
Rate of menarche experience (%)	5.5	27.1	65.8	88.8	97.7	99.4	99.8	100.0	100.0
Age at menarche (yr)*	9.7±0.5	10.5±0.6	11.1±0.7	11.6±0.8	11.9±1.0	12.0±1.1	12.1±1.1	12.2±1.1	12.6±1.1

*tested by ANOVA, *P* value<0.001.

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Table 2. Distribution of height, weight and BMI in menarcheal girls according to age at menarche

Age at survey (yr)	Age at menarche (yr)	No. of cases	Height (cm)	*P* value	Weight (kg)	*P* value	BMI (kg/m^2)	*P* value
10	9	28	152.4±6.3*	<0.001†	49.9±9.6*	<0.001†	21.4±3.3*	<0.001†
	10	62	151.1±5.8		46.0±6.7		20.1±2.6	
	Non-menarcheal	1,546	142.1±6.4		37.3±7.6		18.3±2.9	
11	9	20	154.1±4.7	<0.001	51.0±6.3	<0.001	21.5±2.5	<0.001
	10	160	153.7±5.4		50.2±8.5		21.2±3.1	
	11	246	153.6±5.3		49.0±8.1		20.7±3.0	
	Non-menarcheal	1154	147.3±6.3		40.5±8.2		18.6±3.0	
12	9	23	157.7±5.3	<0.001	57.7±7.8	<0.001	23.2±2.8	<0.001
	10	187	157.4±5.1		54.6±9.3		21.9±3.2	
	11	604	156.3±5.0		50.8±8.4		20.8±3.0	
	12	348	155.8±5.1		48.1±7.7		19.8±2.8	
	Non-menarcheal	595	151.9±6.1		42.6±7.8		18.4±2.8	
13	9	17	158.6±5.4	<0.001	55.5±8.2	<0.001	22.1±3.0	<0.001
	10	125	158.4±5.3		55.3±8.4		22.0±3.1	
	11	494	158.6±5.2		54.4±8.6		21.6±3.0	
	12	697	157.6±5.2		50.3±8.4		20.2±2.9	
	13	175	157.3±5.2		48.5±7.4		19.6±2.7	
	Non-menarcheal	180	155.0±5.8		44.5±7.7		18.5±2.6	
14	9	17	157.2±4.0	<0.001	56.5±6.4	<0.001	22.9±2.4	<0.001
	10	123	158.5±5.0		57.1±9.0		22.7±3.4	
	11	461	159.3±5.0		56.1±8.8		22.1±3.1	
	12	678	159.4±5.1		53.4±8.3		21.0±3.1	
	13	376	159.1±5.3		50.1±7.5		19.8±2.6	
	14	68	158.2±5.9		47.8±6.7		19.1±2.4	
	Non-menarcheal	32	153.0±8.1		43.9±7.3		18.7±2.2	
15	9	18	159.2±4.4	0.328	55.2±12.3	<0.001	21.7±4.2	<0.001
	10	100	159.3±5.1		59.3±10.0		23.3±3.3	
	11	371	160.1±4.9		57.4±9.3		22.3±3.2	
	12	587	159.9±5.3		55.4±9.0		21.6±3.2	
	13	326	159.7±5.4		53.3±8.1		20.9±2.9	
	14	108	159.5±5.0		51.3±9.1		20.2±3.2	
	15	10	162.4±3.3		50.7±7.7		19.2±2.6	
	Non-menarcheal	8	156.8±10.7		48.4±12.1		19.4±3.5	
16	10	133	160.1±5.0	0.057	59.1±9.5	<0.001	23.1±3.3	<0.001
	11	415	160.0±5.1		57.0±8.3		22.2±2.9	
	12	648	160.4±5.1		55.9±8.3		21.7±2.9	
	13	424	160.6±5.0		53.3±7.8		20.7±2.7	
	14	137	161.0±5.1		53.8±8.7		20.7±3.0	
	15	22	158.2±4.6		49.9±7.2		20.0±2.9	
	16	1	158.5		43.2		17.2	
	Non-menarcheal	3	153.8±4.5		51.1±11.4		21.8±5.5	
17	10	65	159.8±5.2	0.132	61.1±10.8	<0.001	23.9±3.9	<0.001
	11	290	159.6±5.0		57.3±9.8		22.5±3.4	
	12	562	160.1±5.0		56.2±8.5		21.9±3.0	
	13	315	160.6±5.0		54.7±8.4		21.2±2.9	
	14	119	160.7±5.0		53.1±7.7		20.5±2.6	
	15	45	160.6±5.1		53.0±8.3		20.5±3.0	
	16	3	164.7±3.4		67.8±5.5		25.0±1.3	
18	11	26	159.1±4.2	0.588	58.4±8.1	0.001	23.1±3.0	<0.001
	12	79	160.7±4.6		58.1±7.9		22.5±2.9	
	13	41	160.8±6.0		53.1±7.1		20.5±2.4	
	14	30	161.2±5.9		52.7±7.2		20.2±2.0	
	15	14	161.9±4.7		54.3±6.4		20.7±1.8	

*Mean±SD; †tested by ANOVA.
BMI, body mass index.

spect to the average weight (Table 2). There were also statistically significant differences in the average BMI of menarcheal girls aged 10 to 18 (Table 2).

Percentage of body fat mass, waist hip ratio and neck circumference between menarcheal and non-menarcheal girls

Table 3 gives the comparison of the average % body fat mass,

Table 3. Comparison of proportion body fat mass, waist hip ratio and neck circumference between menarcheal and non-menarcheal girls

	Age at survey (yr)	Menarcheal girls	(Number)	Non-menarcheal girls	(Number)	*P* value
Body fat mass (%)	10	24.9±8.4*	(16)	23.1±8.3	(172)	0.405†
	11	25.7±7.3	(94)	22.1±7.4	(134)	<0.001
	12	24.6±7.0	(175)	22.6±6.5	(78)	0.039
	13	26.5±6.8	(199)	22.1±6.8	(33)	0.001
	14	20.1±2.9	(98)	19.2±3.1	(7)	0.182†
Waist hip ratio	10	0.87±0.03	(16)	0.86±0.04	(172)	0.243†
	11	0.87±0.04	(94)	0.84±0.04	(134)	<0.001
	12	0.84±0.04	(175)	0.82±0.03	(78)	<0.001
	13	0.84±0.05	(199)	0.81±0.03	(33)	<0.001
	14	0.81±0.03	(98)	0.81±0.02	(7)	0.954†
Neck circumference (cm)	10	29.2±3.5	(16)	27.8±2.7	(172)	0.059†
	11	30.3±2.7	(94)	28.0±2.4	(134)	<0.001
	12	30.6±2.0	(175)	29.3±1.8	(78)	<0.001
	13	31.0±2.1	(199)	30.2±1.7	(33)	0.034
	14	30.8±1.8	(98)	30.4±2.0	(7)	0.558†

*Mean±SD; †NS: Not significantly different at $P<0.05$.

Table 4. Mean height, weight and BMI of menarcheal girls whose onset of menarche was within 365 days at the time of study

Age (yr)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Number of subjects
10	151.0±5.8*	46.3±7.0*	20.3±2.7*	81
11	153.4±5.4	48.9±8.1	20.7±3.0	348
12	155.7±5.0	48.9±8.0	20.1±2.9	721
13	157.0±5.1	48.9±7.8	19.8±2.8	528
14	158.4±5.6	48.6±7.4	19.3±2.5	225
15	159.8±4.9	49.0±5.8	19.2±2.3	58
16	159.0±5.1	49.6±4.2	19.7±2.4	8

*Mean±SD.
BMI, body mass index.

waist hip ratio and neck circumference between menarcheal and non-menarcheal subjects. Non-menarcheal girls depicted slimmer figures than menarcheal ones with significant difference at the age of 11 to 13 ($P<0.001$). Table 4 depicts mean height, weight and BMI of menarcheal girls whose onset of menarche was within 365 days at the time of study.

DISCUSSION

Several studies have proven that girls with higher body weight, higher body mass index, more body fat, and greater height reach their menarche earlier (21, 23-26). It has been suggested that girls need to reach a critical weight or height for menarche to occur and that changes in dietary habits as observed in children may have caused this critical weight to be reached at an earlier age (18). Up to now it is unclear, however, whether energy intake or specific nutritional components play a role, or whether nutrition affects menarche through its effect on accumulation of adipose tissue (18).

Girls who are lean before, during, and after puberty tend to have a later menarche than those who are fatter (27). Waist circumference and abdominal sagittal diameter appear to be the best simple measures of visceral adipose tissue, and these indices are more consistently associated with several measures of cardiovascular risk, such as fasting and post glucose insulin levels (10).

Early maturers showed greater ponderosity and adiposity when compared with mid-onset or late maturers (10). The group of early maturers had a significantly greater waist circumference, visceral adiposity than mid-onset or late maturers but had no difference in the waist to hip ratio that is regional distribution of adipose tissue (10).

It has been addressed whether the associations of age at menarche with adult BMI and obesity are related to childhood BMI. According to Freedman et al. (28), underlying reason for the association of age at menarche with adult BMI is that childhood BMI drives or is at least permissive of the age at onset of sexual maturation and hence the age at menarche.

In the another literature published in 2005, Pierce and Leon noted that the association between age at menarche and mean adult BMI was only slightly confounded by early childhood BMI and that the relation between age at menarche and adult obesity was not confounded at all by childhood BMI (17). The gains in several growth parameters in early maturers that is peak height velocity and height gained after menarche were offset by a briefer period of prepubertal growth (10). Because early maturers started puberty 1.5 to 3.3 yr earlier than the mid-onset and late maturers, they lost several years of prepubertal growth which is 4-5 cm per year (10).

Girls who matured early were taller in early adolescence and shorter in early adulthood than those who matured later, despite having a greater peak height velocity and greater post menarcheal increment in height (10). There is a vast amount of literature reporting that women who reach their menarche at a later age will eventually grow taller compared with women who reach their menarche at an earlier age (18). This relation may be explained by the earlier closure of epiphyseal growth plates because of the increase in ovarian estrogens (7, 22). A delay in menarche allows more growth of the long bones before the epiphy-

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ses unite and results in a taller adult height (18). There is a Korean study with the aim of measuring the trend in age at menarche in Korea during the past few decades and the association of height with this trend (1). A total of 1061 Korean women born between 1920 and 1986 were randomly recruited from Ansan Cohort Study samples and separate school girl samples, and subjected to this analysis (1). In this research, mean menarcheal age decreased from 16.8 to 12.7 yr during the past 67 yr, corresponding to -0.64 yr per decade, while height increased from 149.23 to 161.75 cm during the same period, showing an inverse relationship in the change of trend between height and mean age at menarche (1). In the conclusion of this study, authors suggested that the downward secular trend in age at menarche may reflect the secular change in physical growth in Korean women during the past 67 yr (1).

In our research, the menarcheal girls were taller and heavier than non-menarcheal ones. Menarcheal girls also showed higher BMI and greater waist circumference than non-menarcheal ones. Non-menarcheal girls depicted slimmer figures than menarcheal ones with the analysis of percent body fat mass, waist hip ratio and neck circumference. Different groups of age at menarche at the certain ages represented significant (P<0.001) differences in terms of BMI, waist circumference, percent body fat mass, waist hip ratio and neck circumference as well as height and weight. These results suggest that certain weight or height might exist for the occurrence of menarche.

The velocity of height of obese girls is faster and they grow taller than their normal weight peers during the puberty. It could affect that obese girls reach their menarche earlier and also reach final height earlier and stay shorter as adults compared to girls who were not obese in childhood. Georgiadis et al. (1997) concluded that adult height is independently associated with menarcheal age (Odds ratio, 0.52; 95% CI, 0.04-1.00; P=0.03), whereas BMI, place of birth or residence and educational level do not seem to play a role of comparable significance (22).

Our study also compared % body fat mass between menarcheal and non-menarcheal girls and found that menarcheal girls had greater body fat mass. This result suggests that body composition index including body fat mass might be a stronger factor to the occurrence of menarche than simple growth in body size.

A few limitations should be noted. The present study was dependent on self-reported age at menarche, which implies that participants might not report accurately or younger girls may report menarcheal age more accurately, because the event was more recent. Older girls filled out the questionnaire related to the date of menarche. A questionnaire was sent to the parents of each student that was considered to be too young to recall the date of menarche through school nurses.

Nevertheless, some researches showed that recalled age at menarche was generally accurate both for teenagers and for women up to 30 yr of age and older (29, 30). In the French cohort, there are data on 549 women who answered the question on age at menarche twice with an 18-month interval. Of these women, 70.7 percent reported an identical age at first menstruation, and 98.5 percent reported an age at menarche within a year of that initially reported. These percentages did not differ for older compared with younger women (29). Must et al. (30) were able to compare the actual measured age at menarche and the reported age 33 yr later. They showed that the actual mean age at menarche did not differ from the recalled mean age at menarche which is 12.93 yr (95 percent confidence interval, 12.81-13.06) vs. 12.85 yr (95 percent confidence interval, 12.69-13.00). Moreover, any misclassification was not dependent on the age at menarche.

One more limitation concerns the study design. We conducted the cross-sectional study. This emphasizes the need for longitudinal studies in the causal relationship between age of menarche and anthropometric profiles.

In spite of the limitations mentioned above, this study has the several advantages over many earlier investigations. The strengths of this study include the fact that the study was relatively large and subjects were recruited across the nation, which implies that the obtained results from this study could be generalizable.

From the result of our research, the menarcheal girls showed taller and heavier figures than non-menarcheal ones. Menarcheal girls also showed higher BMI and greater waist circumference than non-menarcheal ones. Non-menarcheal girls depicted slimmer figures than menarcheal ones in terms of % body fat mass, waist hip ratio and neck circumference.

In conclusion, girls who matured early were taller and heavier in early adolescence than those who matured later. Our data provide useful reference points for investigators and clinicians who are interested in the relationship between growth and sexual maturation of girls.

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