Original Article

Earlier Menarche Can Be an Indicator of More Body Fat: Study of Sexual Development and Waist Circumference in Chinese Girls*

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Abstract

Objective This paper aims to study the relationship between body fat and sexual development in Chinese girls with different waist circumference.

Methods Six thousand one hundred and fifty six girls aged 6-19 were sampled. Their body weight, height, waist circumference, percentage of body fat and secondary sex characteristics were measured. All the subjects were divided into three groups: low class waist circumference, moderate class waist circumference and high class waist circumference. The menarche percentages were analyzed by using the status method. The menarche ages were analyzed by using the retrospective method. Estimates for mean age at entry into a pubertal stage and menarche were calculated by a probit analysis.

Results The incidences of moderate class and high class waist circumstance were 20.94% and 25.27%, respectively. The sexual development of the former was earlier than that of the latter. The percentages of the menarche were detected as high class>moderate class>low class. The menarche ages were expressed as high class<moderate class<low class.

Conclusion A close association is found between the waist circumference and sexual development, especially the menarche age. Girls with high class waist circumference are more vulnerable to earlier menarche and excess body fat. It is important to control the occurrence of central obesity through monitoring the change of waist circumference in puberty for girls' health.

Key words: Waist circumference; Sexual development; Menarche; Body fat; Girls

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INTRODUCTION

Puberty is a central process in the complex set of changes that constitutes the transition from childhood to adolescence. The development of secondary sexual characteristics and menarche are important milestones for determining sexual maturation in adolescent girls. Sexual maturation, the transition from the pre-reproductive phase to the reproductive one, is a dynamic biological process, characterized by visible changes in stature, body composition and body proportions. On the other hand, pubertal maturation in parallel with physical growth is the most reliable indicator of health status of adolescents. This is especially true of female pubertal maturation, in particular of the mean of menarche ages.

Since the 1970s, there has been a worldwide rapidly growing prevalence of overweight and obesity in children. Overall, China is at an early stage of the childhood obesity prevalence. Previous data

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of the National Survey on Chinese Students Constitution and Health have shown that children aged 7-12 years are the group of the highest prevalence rate of obesity[1]. The obese adolescent girls are generally characterized with central adiposity and low high-density lipoprotein cholesterol (HDL-C). Nearly 50% of overweight girls and 90% of obese ones have at least one index of metabolic syndrome (MC)[2]. It is of vital importance to study obesity of adolescent girls. The body fat still increases obviously after the middle adolescence. This trend will lead to overweight/obesity of the youth and adult. Therefore, a study is designed to involve girls aged 6-18 years that cover the overall adolescent process. The purpose is to seek the trend of sexual development and body fat distribution during the adolescence. It is essential to carry on colony survey. Body mass index (BMI), skinfold thickness and waist circumference are often used in a large sample survey. Furthermore there are body composition measurements, such as bioelectrical impedance method (BIA), dual-energy X-ray absorptiometry (DEXA), computer tomography (CT), magnetic resonance imaging (MRI), and others. Such "gold standard" measures, however, are not feasible in a large epidemiological study such as the National Survey on Chinese Students Constitution and Health. The increase of BMI shows the trend of growth and development. It is not equal to the increase of body fat mass. Some scholars have suggested that individuals whose BMI are 25-27 kg/m^2 should be examined further to determine whether there is an increase in fat mass[3]. Waist circumference can reflect the abdominal fat or visceral fat. It is an important indicator to evaluate central adiposity. Central adiposity is related to chronic disease risks in adolescents[4]. In large epidemiological studies of children and adolescents, only anthropometric measures of central adiposity are feasible. Waist circumference is appropriate. In China, there is already accepted BMI reference to screen overweight/obesity of adolescent. But there is not any uniform waist circumference reference yet. Scientists often combine waist circumference with risk factors of cardiovascular diseases when they study adult obesity. Our study has referred to the data of the 2008 Chinese Students Constitution and Health Surveillance and has selected P75 and P90 as the grouping standard. We attempt to test waist circumference reference without serum parameters.

Sexual development is closely related with body fat. The female puberty is earlier with the prevalence of overweight/obesity. The menarche ages of overweight/obese girls are generally earlier than those of normal girls[5]. During 1962-2000, the means of menarche ages of Beijing urban girls were reduced by 0.5-0.67 years every decade[6]. The percentages of body fat of the premature girls are higher than those of normal girls. This difference leads to the increase in prevalence of adult obesity. Beijing is one of the most developed cities in China. At the same time, it is one of the highest prevalent areas of obesity. We designed a cross-sectional study of body fat mass and sexual development of children and adolescent girls in order to probe the relationship between waist circumference, body composition and sexual development (especially the menarche age).

SUBJECTS AND METHODS

Participants

A cross-sectional study was conducted in 10 primary schools and 6 secondary schools in 2009 in Beijing. Six thousand one hundred and fifty six girls aged 6 to 19 years were sampled. The girls were grouped by 1-year age intervals. Each age group included all girls who were not >6 months older or younger than the median age of the group (e.g. the 10-year-old girl group included all girls aged 10.00-10.99 years), in which the 2 groups were exclusive. Every participant underwent complete medical history and physical examination and completed a brief questionnaire. Informed consents to participate were obtained from the parents and assent from the children, where appropriate. Girls with any acute or chronic medical problem and those who did not want to participate in the survey were excluded. This study was approved by the Ethics Committee of Peking University.

Anthropometric Values

Height and waist circumference were measured with standard techniques. Girls were asked to take off their shoes and stand erect on the scale with only underclothes to obtain their height. At the moment of measuring waist circumference, girls were urged to stand erect, stare straight ahead and breathe calmly. A flexible rule measuring tape horizontally circled the bodies 1.0 cm above the navel. The assistant stood behind the girls in order to make sure

that the tape was of correct position. The accuracy of the readings was within 0.1 cm. All pieces of equipment used were calibrated daily. The girls were divided into three groups, low class waist circumference, moderate class waist circumference and high class waist circumference according to P75 and P90 of the Reference Norms of Waist circumference for Chinese School-age Children and Adolescents[7].

Sexual Maturation

Breast development(B), pubic hair(PH) and axillary hair(AH) development for each girl were assessed by experienced pediatricians. The pubertal stages were graded according to the 5-stage scale described by Marshall and Tanner[8]. When the 2 breasts of an individual were not in the same stage of development, the stage of the more advanced side was recorded. The three scores were added together. Then Tanner scores were drawn. Furthermore, a 1-page questionnaire for each subject was collected to elicit information on the girls' age, presence or absence of menses and the menarche age. Data regarding menarche were collected by the status quo method. All girls were interviewed and asked if their menarche had already taken place at the time of interview. The means of menarche ages were determined by the retrospective method within the postmenarcheal group.

Body Composition Variables

Body composition was determined by using a Salus body composition analyzer (Biospace, Korea) according to the bioelectrical impedance method (BIA). Salus was a multifrequency eight-point tactile-electrode impedancemeter. Impedance measurements were taken after 2-3 min briefly when two pairs of electrodes were attached respectively on the two hands and feet with the subject in erect position, with legs slightly apart, and the arms not touching the torso. The computer software in the machine then used the measured resistance, the programmed probands' gender, age, stature height, and the measured weight to calculate the body density based on previously derived equations. This was then applied automatically to the standard densiometric formula according to Brozek to calculate the fat percentage. Calculation of body weight and body fat percent was performed as previously described elsewhere. Repeated measure was carried out at the definite time. All cases of overweight and obesity were defined following the Working Group on Obesity in China (WGOC) BMI-reference[9]. The underweight was defined following the WHO Child Growth Standards[10].

Statistical Analysis

The data were collected and analyzed by the status quo method. All data were checked for range and double-entered into Epi Data 3.0. After computing descriptive statistics (means, standard deviations, relative frequencies), the statistical significance of group differences was tested by means of *t*-tests and Chi-square analyses. The *P* values in Table 3, Table 4, and Table 5 were calculated for "trend test". Estimates for the mean age at entry into a pubertal stage and menarche were calculated by the probit analysis from the populations of girls with the characteristic at different ages. With the use of the probit analysis, cumulative frequency curves for different pubertal stages (stages 2 and 3) and menarche were constructed. The Statistical Package for the Social Sciences (SPSS) version 11.5 was used for all statistical calculation and analyses.

RESULTS

A total of 6 156 girls aged 6.09 through 19.66 years comprised the study sample. The numbers of every age group were balanced (Table 1). The total incidences of overweight and obesity were 11.43% and 9.05%, respectively. Beginning with the 12-year-old group, a trend appeared that the prevalence of overweight and obesity was rising with age. It reached the peak (24.36%) in the 14-year-old group. The highest prevalence of obesity was found in the 13-year old group (11.52%). The highest detection rate of overweight was 14.95% in the 14-year-old group. After 16 years overweight and obesity were decreased. The means of waist circumference of every age group were higher than Reference Norms of Waist Circumference for Chinese School-age Children and Adolescents[10]. The variation trend of waist circumference was similar to that of BMI.

Table 1. Sample Sizes of Four BMI Status in Different Menstrual Status of Each Age-group

Age(y)	Premenarcheal				Postmenarcheal				Total
	Underweight	Normal	Overweight	Obese	Underweight	Normal	Overweight	Obese	
6+	15	161	22	15	0	0	0	0	213
7+	35	335	49	42	0	0	0	0	461
8+	27	387	47	48	0	0	0	0	509
9+	26	424	58	53	0	1	0	0	562
10+	28	343	30	46	0	6	5	3	461
11+	32	307	34	23	0	104	16	27	543
12+	23	255	24	12	3	340	68	65	790
13+	4	40	3	1	3	325	55	55	486
14+	2	8	1	1	16	332	70	45	475
15+	0	5	0	0	8	419	83	44	559
16+	0	0	0	0	14	409	67	40	530
17+	0	0	0	0	16	383	67	32	498
18+	0	0	0	0	3	57	5	4	69
Total	192	2 265	268	241	63	2 376	436	315	6 156

Note. All cases of overweight and obesity were defined following the WGOC BMI-reference. The underweight was defined following the WHO Child Growth Standards.

Median Ages of Onset of Pubertal Development

The mean age of menarche was 12.19 years calculated by the probit analysis. As shown by relevant data , the menarche age of Beijing girls was 12.1±1.1 years in 2004[11]. At the age of 8, every sample was premenarcheal. At the age of 16, all probands had reached their postmenarcheal status. The median age for onset of breast development for the girls was 9.84 (95% confidence interval [CI]: 9.73-9.94) years. Less than 10% of the girls had stage 2 breast development before the age of 8(5th and 10th percentile ages were 7.85 and 8.25 years, respectively). The median age for onset of pubic hair development was 11.42 (95% CI: 11.35-11.49) years.

Waist Circumference and Sexual Development

According to P75 and P90 of waist circumference reference, the girls were divided into three groups (Table 2). About 50% of the girls were classified as low class waist circumference. It was noticeable that the rising trend of high class waist circumference was 2 years earlier than that of obesity. In 10 to 14-year-old groups, the menarche percentages were detected as high class waist circumference> moderate class waist circumference>low class waist circumference (Figure 1). In the 11-year-old group, 14.59% of low class girls had reached their postmenarcheal status. The percentage of moderate class was more than 1/3. Nearly 1/2 girls in high class had experienced their menarche. In the 12-year-old group, the percentages of low class, moderate class and high class were 44.21 %, 72.18%, and 80.56 %, respectively.

Table 2. Sample Sizes of Different Waist Circumference in Each Age-group(According to P75 and P90)

Age (y)	M (cm)	SD (cm)	Low Class		Moderate Class		High Class	
			n	%	*n*	%	*n*	%
6+	52.83	5.92	145	68.08	40	18.78	28	13.15
7+	54.88	6.84	319	69.20	73	15.84	69	14.97
8+	57.81	7.56	302	59.33	103	20.24	104	20.43
9+	60.23	8.49	314	55.87	124	22.06	124	22.06
10+	63.42	9.48	257	55.63	67	14.50	137	29.87
11+	65.86	9.50	281	51.75	126	23.20	136	25.05
12+	69.14	10.09	380	48.10	176	22.28	234	29.62
13+	71.19	9.69	239	49.18	102	20.99	145	29.84
14+	72.10	10.30	254	53.47	87	18.32	134	28.21
15+	72.22	8.89	268	47.94	145	25.94	146	26.12
16+	73.21	9.78	262	49.43	123	23.21	145	27.36
17+	72.98	8.80	250	50.20	111	22.29	137	27.51
18+	72.65	9.41	41	59.42	12	17.39	16	23.19
Total	66.41	11.17	3 312	53.79	1 289	20.94	1 555	25.27

Note. The groups of waist circumference were defined following P75 and P90 of the Reference Norms of Waist Circumference for Chinese School-age Children and Adolescents.

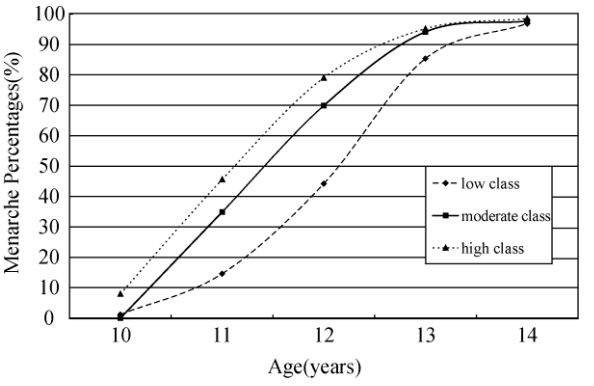

Figure 1. Comparison of the Menarche Percentages in Girls with Different WC (%) (According to P75 and P90).

The percentages of body fat of girls with different waist circumference were found as high class> moderate class>low class (Table3). The menarche ages were expressed as high class<moderate class< low class (Table 4). These differences were of statistical significance in most age groups. At the age of 10 and 11 years, the means of menarche ages of the high class and the moderate class were also younger than that of the low class; however, these differences had no statistical significance. The variation trend of Tanner Scores was low class< moderate class<high class in 7-17-year-old girls (Table 5). The differences in pubic hair and axillary hair had statistical significance in 10-16 year old girls (P<0.05).

Table 3. Comparison of Percentages of Body Fat in Girls Aged 6-18 years with Different Waist Circumference (%)

Age (y)	Low Class		Moderate Class		High Class		*P* Value
	M	SD	M	SD	M	SD	
6+	16.48	3.62	19.97	3.36	27.37	7.91	0.000
7+	16.89	3.77	21.61	4.03	29.06	5.56	0.000
8+	17.36	3.98	21.43	4.28	29.56	4.71	0.000
9+	17.93	3.75	22.68	4.15	30.49	5.47	0.000
10+	18.28	3.81	22.43	4.34	29.12	6.03	0.000
11+	18.44	3.74	23.06	4.14	30.25	5.31	0.000
12+	21.05	4.19	25.28	4.43	31.45	5.33	0.000
13+	23.64	3.76	26.86	3.51	33.73	4.79	0.000
14+	24.65	3.97	29.34	3.60	34.26	4.87	0.000
15+	26.34	4.18	29.36	4.04	34.09	4.77	0.000
16+	26.38	3.45	29.53	4.50	34.76	5.27	0.000
17+	27.44	3.71	30.54	3.34	34.92	4.10	0.000
18+	26.18	3.70	30.59	2.61	33.98	3.60	0.000
Total	21.24	5.48	25.75	5.29	32.10	5.62	0.000

Table 4. Comparison of Menarche Ages in Girls Aged 10-18 years with Different Waist ircumference (years)

Age (y)	Low Class		Moderate Class		High Class		*P* Value
	M	SD	M	SD	M	SD	
10+	10.41	0.53	-	-	10.01	0.61	0.317
11+	11.07	0.53	11.05	0.52	10.95	0.57	0.482
12+	11.74	0.63	11.47	0.72	11.38	0.66	0.000
13+	12.14	0.82	11.87	0.81	11.85	0.83	0.002
14+	12.20	1.04	11.96	0.83	11.82	0.99	0.002
15+	12.37	0.97	12.14	1.01	12.09	1.07	0.012
16+	12.47	1.10	12.29	1.08	12.02	1.15	0.000
17+	12.46	1.07	12.23	1.15	12.17	1.09	0.028
18+	12.76	1.19	12.46	0.91	12.47	0.70	0.529
Total	12.24	1.02	11.95	1.00	11.80	1.02	0.000

Table 5. Comparison of Tanner Scores in Girls with Different Waist Circumference

Age (y)	Low Class		Moderate Class		High Class		*P* Value
	M	SD	M	SD	M	SD	
7+	3.01	0.1	3.05	0.23	3.17	0.38	0.000
8+	3.09	0.31	3.18	0.59	3.56	0.86	0.000
9+	3.24	0.55	3.60	0.74	4.04	1.05	0.000
10+	3.86	1.29	4.42	1.54	5.59	1.93	0.000
11+	5.35	1.88	6.80	2.06	7.79	2.22	0.000
12+	6.58	1.91	8.06	1.84	8.86	1.93	0.000
13+	7.92	1.85	9.34	2.03	9.64	1.91	0.000
14+	9.24	1.84	9.84	1.95	10.98	1.99	0.000
15+	11.46	1.99	12.21	2.00	12.51	1.93	0.000
16+	12.6	1.74	13.07	1.52	13.4	1.49	0.000
17+	13.02	1.98	13.32	1.81	13.69	1.67	0.003
18+	12.71	1.99	13.17	1.99	13.63	1.67	0.262
Total	6.86	3.99	8.15	4.10	8.88	3.96	0.000

In addition, we compared the menarche percentages of underweight, normal, overweight and obese girls (Figure 2). In 10 to 14-year-old groups, the percentages of the menarche were detected as obese>overweight>normal>underweight girls.

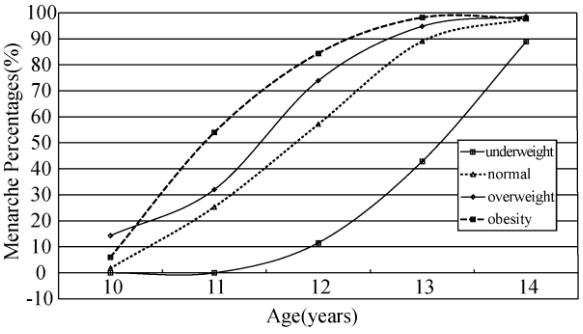

Figure 2. Comparison of the Menarche Percentages of Underweight, Normal, Overweight and Obese Girls (%).

Then according to P75 and P95 of waist circumference reference, the girls were also divided into three groups. In 10 to 14-year-old groups, the percentages of the menarche were detected as high class waist circumference>moderate class waist circumference>low class waist circumference (Figure 3). From the figure, more significant differences were found between the high class and the moderate one.

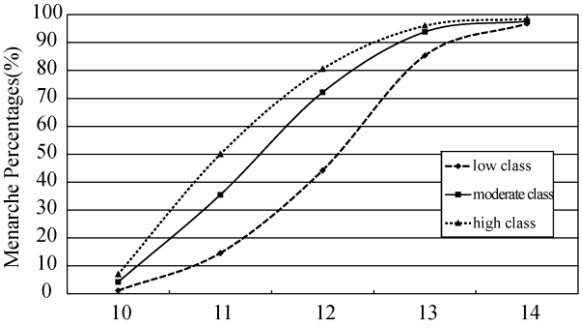

Figure 3. Comparison of the Menarche Percentages in Girls with Different WC (%) (According to P75 and P95).

DISCUSSION

Obesity in childhood and adolescence represents a worldwide epidemic in its nature . Data from adults suggest that central adiposity, independent of total adiposity, is more strongly related to chronic disease risks. Lu[4] found that obese girls were featured with hyperuricemia, hypercholesterolemia, hypertriglyceridemia and low HDL-C, indicating that the status of overweight and obesity was harmful to girls' health. In large epidemiological studies of children and adolescents, only anthropometric measures of central adiposity are feasible. Waist circumference is appropriate. If waist circumference is used as a screening tool for cardiovascular disease risks in children and adolescents, it could serve as either an alternative or as an adjunct to BMI. In China, the central obese colony with normal BMI accounts for 7.2% in males and 9.7% in females[12]. The morbidity of cardiovascular disease among them should be valued. The accumulated ratio of cardiovascular disease risks in males and females increase by 1.155 and 1.252 times respectively as waist circumference increases by 1 cm[13]. On the basis of the data presented, it is worth considering that waist circumference cut-offs should be race-specific. The use of waist circumference and BMI permits large sample sizes with sufficient statistical power to detect important differences. Also, the visceral adipose tissue depot, which is quite small during adolescence, might not be the most important aspect in the relationship between central adiposity and cardiovascular disease risks. Waist circumference is significantly associated with lipoprotein. Children's waist circumference increases with BMI. This trend will enlarge exponentially the risks of hyperlipidemia, hyperinsulinemia and MS[14].

Some scholars chose certain values of waist circumference as the standard to screen central obesity or to judge diseases. Most studies depended on the relationship between waist circumference and risks of diseases, especially MS and cardiovascular disease. The waist circumference standard of central obesity in Chinese adults is $\geqslant$85 cm for males and $\geqslant$80 cm for females[15]. Ma suggested that P75 and P90 of waist circumference are critical points of cardiovascular disease risks in Chinese children and adolescents[16]. Waist circumference in different regions of China differs dramatically from that in regions outside China. The median of waist circumference in our study is greater than that in other studies in this country[7]. We used P75 and P90 for girls and got the relevance ratio of different waist circumference series. The results fitted the changes and characters of every puberty stage. The trend of central obesity is earlier than that of BMI. So waist circumference is more sensitive to the rise of body fat than BMI. When it comes to P75 and P95, the difference of menarche percentages between the latter two groups are more significant. The P95 reference value of waist circumference of 18 years (80.31 cm) approaches to the standard of central obesity of Chinese adult. This may offer some new ideas for later researches.

An improvement of the socioeconomic environment during the last 150 years has led to a marked decline in the timing of sexual maturation.

So the mean ages of menarche in western industrialized countries are 12.5-13.5 years now and the majority of girls experience menarche between 12 and 14 years[17]. There has been a very significant downward secular trend for the menarche age of urban Chinese girls since 1979, especially in the past decade[1,18-20]. A secular increase was also observed in BMI of the girls in different age groups (7.5-18.5 years of age) among the similar population of the National Surveys on Students Constitution and Health undertaken in 1979, 1985, 1991, 1995, 2000, and 2005. The association between prevalence of obesity and decreasing of the mean of the menarche age resulted in the introduction of the so weight by Rose Frisch during the early 1970s. The original hypothesis – that the menarche onset was associated with the attainment of a "critical weight" – was plagued by faulty statistical analyses and extended critique in the literature. Today the Frisch hypothesis is obsolete and the ovarian function seems to be associated with the energy balance. However, up to now the strong association between body composition parameters and pubertal onset is reported in many studies. Puberty seems not simply to induce typical changes in body composition. A typical kind of body compositions seems to be essential for pubertal onset. Compared with Australian and other whites, Japanese have a higher percentage of body fat in the same waist circumference, BMI and skinfold thickness[21]. This is true to males and females. Chinese girls have nearly the same percentage of body fat as Euramerican girls even if their BMI are lower than the latter.

Numerous studies confirm that body fat is a decisive factor of sexual maturation. Obesity and overweight are related to sexual development advance. Most girls of higher BMI have earlier menarche than those coeval of lower BMI. Excess weight was associated with earlier thelarche, pubarche and menarche in girls during the preteen years. The menarche ages of overweight and obese girls are earlier than those of normal and underweight girls[22]. These associations of early pubertal landmarks with adiposity are independent of race or ethnicity. Earlier puberty is not associated with higher levels of gonadotropins[23]. The precocious girls with greater waist circumference are vulnerable to the adult chronic diseases even if their BMI is normal[24]. Kindblom[25] has presented that the advance puberty leads to the increase of the abdominal skinfold. Puberty onset can predict the female central fat distribution independently. The incidence of obesity of the precocious girls is elevated obviously. Their central fat mass is accumulated, and their risk of MS increases[26]. Girls with earlier menarche have more body fat mass. Serotinous girls are taller and thinner usually while the precocious ones are relatively shorter and heavier. Black girls whose menarche ages are the earliest have the highest prevalence of overweight and obesity[27]. Prematurity can increase the risk of obesity exponentially. Adult's BMI decreases as the menarche age increases[28]. In a study of 2 660 girls, Wronka[29] has confirmed that the menarche age has a significant negative correlation to BMI. A relevant cohort study has also shown that earlier menarche and obesity in late adolescence can significantly increase the risk of obesity in adulthood[30]. Lakshman's cohort study has revealed that earlier menstruation is closely related to diabetes and cardiovascular diseases[31-32]. The degree of the correlation is regulated by the obesity of the samples. An early age of menarche is associated with serious health problems, including the breast cancer and heart diseases. In our study, postmenarcheal girls are significantly taller and heavier than their premenarcheal counterparts. The comparison of the percentages of body fat also has yielded significant differences between premenarcheal and postmenarcheal girls. Postmenarcheal girls surpass their premenarcheal counterparts in the percentage of body fat.

The prematurity and central obesity of females are important factors which can lead to the rise of adult CVD. Therefore children should be guided energetically to diet reasonably, increase exercises and change their static living pattern. It is significant to pubertal girls that their waist circumference is to be monitored so as to reduce the prevalence of obesity and control the MS risk in girls with earlier menarche.

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