Timing and secular trend of pubertal development in Beijing girls

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Background: Historical research is limited in changes in pubertal development in Chinese girls. We aimed to identify the timing of pubertal characteristics and the secular trend of menarche age among Beijing girls from the 1980s through the 2000s.

Methods: Six data sets were analyzed, including the Beijing Child and Adolescent Metabolic Syndrome study in 2004, where 9778 Bejing girls aged 6-18 years were studied. The Fetal Origins of Adult Disease study provided retrospective menarche age from 1940 through 1960. Other four studies were conducted in Beijing to obtain supplementary information to assess secular trend in menarche age. Linear regression method was used to analyze the data.

Results: Among Beijing girls in 2004, the median age at menarche was 12.1 years, which was 0.6 years earlier in urban than in rural areas. The median age at Breast Tanner Stage 2 was 9.5±1.2 years, representing 9.4±1.1 years and 9.6±1.2 years for urban and rural girls, respectively. In contrast, the median age at Pubic Hair Tanner Stage 2 was 11.1±1.1 years, representing 10.8±1.1 and 11.4±1.1 years for urban and rural girls, respectively. The menarche age of urban girls decreased by 4.2 months per decade, and that of rural girls by 9.6 months per decade from 1980 to 2004.

Conclusions: Urban girls mature earlier than rural girls in Beijing. A secular trend towards earlier menarche was observed between the 1980s and the 2000s.

World J Pediatr 2014;10(1):74-79

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Introduction

Among girls, distinct individual differences exist in their pubertal age, such as their age to menarche, commencement of puberty, rate of development, maturational timing and the status of puberty. In each stage of puberty, age distribution remains normal.[1] However, the precise measurement of the degree of pubertal development remains challenging. The major methods used to measure these characteristics are semi-quantitative, where the period of puberty is sub-divided into several stages according to the standard criteria.

The Tanner staging method[2] is widely used to evaluate the development of secondary sexual characteristics. In addition, menarche is a maturational milestone for girls, which indicates that their ovaries and uterus have attained the biological ability to reproduce.[3] Moreover, in terms of human evolution, earlier sexual maturation has been observed. The median age at menarche is declining, and this is referred to as the "secular trend of development".[4] The menarche age of women in west Europe decreased by 4 years from the 1840s to the 1960s, with a mean of 3 to 4 months per decade.[5] Additionally, many population-based studies reported this secular trend.[6,7] However, a recent study has shown that this trend has leveled off or may even have been reversed in some industrialized countries.[8]

The secular trend of menarche is closely attributed to general improvements in environment, nutrition, stress and exposure to endocrine-disrupting chemicals.[8] Several studies[9-13] have shown that obesity, insulin resistance, hypertension and other metabolic abnormalities affect earlier pubertal development. Therefore, examining the secular trend in pubertal development in the general population is necessary, and appropriate recommendations can be

made, and tailored intervention can be proposed to improve child's health condition. This is especially relevant since there is a paucity of information on changes in pubertal development of Chinese girls.

The current study aimed to examine the pubertal development of Beijing girls, based on a large representative survey conducted in 2004. This study also assessed the secular trend of menarche in Beijing women.

Methods

Data sources

The Beijing Child and Adolescent Metabolic Syndrome (BCAMS) study

BCAMS is a large representative sample of children in Beijing. Subjects were recruited from a cross-sectional population-based survey or the BCAMS study.[14] In this study, a stratified, random cluster sampling design was used to enroll children aged from 0 to 18 years. Four of 8 urban districts and three of 10 suburban districts of Beijing were randomly selected in 2004. A total of 9778 girls aged from 6 to 18 years formed a sample of young Beijing women.

The BCAMS study included a questionnaire, a medical examination, anthropometric measurements, finger capillary blood tests, and other laboratory tests. The questionnaire asks about household characteristics, family disease histories, life styles, and whether the respondent has begun to menstruate.

Medical examination was conducted among school-aged children of 6-18 years of age. Anthropometrical measurements included height, weight, waist circumference, and percent of body fat mass. Pubertal development of the breast and pubic hair was assessed at the same time by two trained female pediatricians in a private room, and the assessment was completed according to the Tanner stage criteria.[15] Both visual inspection and palpation were used to reduce misclassification of breast development stage. Informed consent was obtained from children's parents and schools before the examination. The Institutional Review Board and Ethics Committee of the Capital Institute of Pediatrics, Beijing, approved the study protocol.

Historical data on median age of menarche (MAM) for 1940-1960: Fetal Origins of Adult Disease (FOAD) study

The FOAD study[16] was carried out by the Medical Research Council, UK, in 1995 to determine the impact of fetal development on chronic diseases among the Chinese people. The Peking Union Medical College (PUMC) Hospital is located at the center of Beijing, and kept exceptionally detailed information on the birth size of infants, and mothers' health records, which included data on menarche. We had access to 4094 obstetric records of women who delivered in the hospital from 1948 to 1954. Based on these records, 975 of their babies (of which 481 were females) were identified and followed up from 1995 to 2001. Original obstetric records and follow-up data provided retrospective information on the menarche age of the mothers and their daughters. This information indicated the menarche of Beijing urban girls in 1940 and 1960. Owing to the living conditions of the people in China in the 1950s, and the central location of the PUMC Hospital, data from this FOAD study may represent a higher socio-economic status of Beijing women at that time. Because nutritional status affects the timing of puberty, we present the menarche data of the FOAD study for comparison and reference. The study was approved by the PUMC Ethics Committee under the informal verbal agreement of all participants.

Other data on menarche in Beijing

We reviewed relevant studies conducted in China, and combined the data from Beijing women with those of the BCAMS study so that we could assess the secular trend in the age of menarche. The data on menarche from 1985 to 2000 were obtained from reports of the Chinese National Survey on Students Constitution and Health (CNSSCH),[17-19] which was conducted every five years to assess the health status of school-age children using nation-wide representative samples.[20] In addition, we included data from a cross-sectional population study in girls of 13 Chinese nationalities conducted in 1980.[21]

Data analysis

The data were analyzed using the SPSS software program, version 13.0 (SPSS, Inc., Chicago, Illinois, USA). In the BCAMS study, "probit" data transformation was applied. The median age, variance of menarche, and the Tanner stage of each breast/pubic hair appearance, were analyzed by the status quo method.[2] Tanner stage 2 of the breast (B2) and pubic hair (PH2) were recognized as signals of the onset of puberty.[22] The U test was applied to compare the maturational age between urban and rural girls. In the FOAD study, a retrospective self-reported age at menarche was used to estimate the mean age and variance of menarche. In other surveys, the menarche data were calculated by the status quo method. Linear regression model was used to test the secular trend of menarche, and the intercept and slope of the line of regression were estimated between different periods and areas. Spearman's rank-order correlation coefficient test was also used in the analysis of these data sets.

Results

Pubertal development among Beijing girls: the BCAMS study

The BCAMS study screened 9778 girls aged from 6 to 18 years, including 5040 (51.5%) girls from urban living areas. About 99% of the girls completed examinations of pubic hair and breast development and filled in questionnaires about menstrual cycle (Table 1). Probit transformation of menarche data sets showed that the median age of B2 and PH2 was 12.1±1.1 years. There were significant differences between urban and rural girls. The median age of B2 and PH2 was 9.5±1.2 years and 11.1±1.1 years in urban and rural girls, respectively. We also determined that 59% of urban girls and 47% of rural girls experienced menarche at the age of 12 years (x^2=11.36, P<0.001). In general, more than 85% of girls started their menstrual cycles at the age of 13 years.

Age of menarche of Beijing girls between 1940 and 1960: the FOAD study

Based on obstetric records obtained from the PUMC Hospital, over four thousands women were found to be delivered in that hospital from 1948 to 1954, and were enrolled in the FOAD study. Of those who had been enrolled in the study, 3608 also had records of menarche and were enrolled in our study. These mothers were born between 1916 and 1934 and their mean age was 26.2±4.4 years (range: 16-39 years) at the time when they gave birth. Their self-reported mean age at menarche was 14.9±1.7 years, which represented the menarche of FOAD girls in 1940.

In the period of 1995 through 2001, 975 girls who represented offsprings of the mothers were followed up in the FOAD study. In 481 (49%) girls of this group, 479 had self-reported data on menarche. The mean recalled menarche age of this group was 13.39±1.4 years, which represented the menarche of FOAD girls in 1960. Only 347 of the 479 girls were daughters of the 3608 mothers who represented the pubertal development cohort in the 1940s. The menarche age between daughters and mothers was correlated (r=0.308, P<0.001).

Table 1. Characteristics and sexual maturation of school-age girls in Beijing: the BCAMS study of 2004

Variables	Total (y)		Urban (y)		Rural (y)*	
	n	Median±SD	n	Median±SD	n	Median±SD
Breast development	9678		4952		4726	
B2	1202	9.5±1.2	577	9.4±1.1	625	9.6±1.2
B3	1002	12.0±1.1	615	10.8±1.1	387	11.4±1.1
B4	3462	12.5±1.1	1819	12.2±1.1	1643	12.7±1.1
B5	1624	17.6±1.3	798	17.3±1.2	826	17.7±1.3
Pubic hair	9671		4949		4722	
PH2	905	11.1±1.1	542	10.8±1.1	363	11.4±1.1
PH3	1442	12.0±1.1	739	11.8±1.1	703	12.4±1.1
PH4	2434	13.8±1.2	1259	13.5±1.2	1175	14.2±1.1
PH5	1378	17.9±1.2	714	17.8±1.2	664	18.0±1.2
MAM	9690	12.1±1.1	4959	11.9±1.1	4731	12.5±1.1

The Status quo method was used to estimate the status of pubertal development, and a probit transformation was applied to calculate the median age.*: a statistical comparison with girls in urban areas, all P<0.01. SD: standard deviation; B2: breast development of Tanner stage 2; B3: breast development of Tanner stage 3; B4: breast development of Tanner stage 4; B5: breast development Tanner stage 5; PH2: pubic hair development Tanner stage 2; PH3: pubic hair development Tanner stage 3; PH4: pubic hair development Tanner stage 4; PH5: pubic hair development Tanner stage 5; MAM: median age at menarche; BCAMS: Beijing Child and Adolescent Metabolic Syndrome study.

Table 2. Characteristics and study data of the median age of girls at menarche (MAM) in Beijing from 1940s to 2000s

Data sources	Sample representing menarche period	Age range of population (y)	Urban			Rural		
			Sample size	MAM (y)	SD	Sample size	MAM (y)	SD
FOAD study*								
Mothers†	1940s	16-39	3608	14.9	1.7	NA	NA	NA
Daughters	1960s	41-53	479	13.4	1.4	NA	NA	NA
13 Chinese nationalities' study	1980	10-25	820	12.8	0.14‡	985	14.9	0.71‡
CNSSCH, 1985	1985	9-20	2446	12.6	NA	NA	13.0	NA
CNSSCH, 1991	1991	9-18	1016	12.5	NA	1019	12.5	NA
CNSSCH, 2000	2000	9-18	1402	12.1	NA	1434	12.5	NA
BCAMS study	2004	6-18	4959	11.9	1.1	4731	12.5	1.1

*: the method used to estimate median age at menarche. All are status quo except this study which was completed according to a retrospective analysis; †: the mothers who gave birth from 1948 to 1954 in Peking Union Medical College Hospital. They were born from 1918 to 1932. Their menarche may represent menarcheal age of urban girls in Beijing during the period of the 1940s; ‡: standard error of the mean. FOAD study: Fetal Origin of Adult Disease cohort study; CNSSCH: Chinese National Survey on Students Constitution and Health; BCAMS: Beijing Child and Adolescent Metabolic Syndrome study; SD: standard deviation; NA: not available.
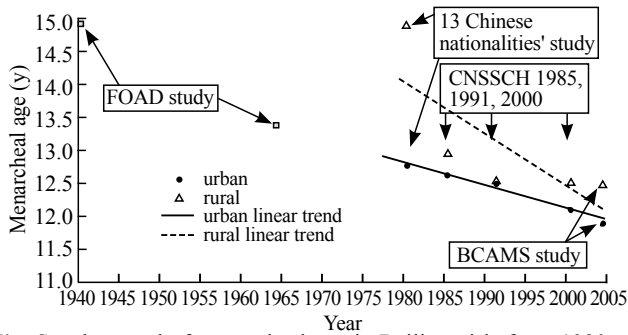
Fig. Secular trend of menarcheal age in Beijing girls from 1980 to 2004. Trend lines were made by linear regression analysis, which showed a trend toward earlier menarche age from 1980 to 2004. FOAD study: Fetal Origin of Adult Disease cohort study; CNSSCH: Chinese National Survey on Students Constitution and Health; BCAMS: Beijing Child and Adolescent Metabolic Syndrome study.

Analysis of the secular trend of menarche between the 1980s and the 2000s

Using the results of menarche studies in Beijing in the period of 1980-2000[17-19] and the data of the FOAD and BCAMS studies (Table 2), we generated a curve of change (Fig.) showing the menarche of Beijing girls in urban and rural areas. The trend of menarche was also analyzed from 1980 to 2004. Because of lack of population representation, the data of the FOAD study in the period of 1940 through 1960 were not used directly to study the secular trend. Instead, they were plotted into the figure for reference purposes only. The mean age of menarche declined continuously but the rate was different for girls from urban and rural areas. In addition, linear regression analysis showed that the menarche age of rural girls decreased more evidently than that of urban girls (9.6 months *vs.* 4.2 months per decade) in the period of 1980 to 2004.

Discussion

The data on pubertal development of Chinese children are rarely reported. Therefore, classification criteria based on the data collected from studies of western countries are still used in China. The present study was based on the data of the BCAMS study of 2004, which may be representative of the current status of pubertal development in school-age girls in Beijing, and may provide a useful reference range.

The BCAMS study showed that the 5th and 10th percentiles of the starting year for B2 were 7.5 and 8 years respectively in Beijing girls. If the cut-off age of precocious puberty is set at 8 years of age, which was defined based on the data obtained from a longitudinal study,[15] the prevalence of precocious puberty of Beijing girls would be approximately 10% in 2004. In our study, however, we also found that menarche, B2

and PH2 appeared earlier in Beijing girls than those reported in a study conducted in Hong Kong in 1993.[23] The onset of menarche also occurred earlier than that of their counterparts in the United States in 1993.[24]

Breast development is the first sign of secondary sexual characteristics of Beijing girls (median age of B2: 9.5 years of age), after which pubic hair develops (median age of PH2: 11.1 years of age old) and finallly menarche appears (menarche: 12.1 years of age). The results of the study may vary owing to different geographical regions and different inherent populations.[25]

Before the 1950s, no data on the age of menarche are available in China except the PUMC Hospital contains detailed obstetric records from the 1940s to the present. The FOAD study, conducted between 1995 and 2001, was based on the data from the women who delivered in the PUMC Hospital during the period of 1948-1954. Subsequent follow-up studies were conducted on their offsprings. The PUMC Hospital is located in the center of Beijing. As to the living conditions of the people, these women represented a high socio-economic status in the 1950s in China. Given that the nutritional status of developing girls affects the timing of puberty, those women enrolled in the FOAD study might have exhibited menarche at an earlier age than other contemporary women. Therefore, the menarche of the mothers and their daughters may have been earlier than that of the general population at that time.

Mothers were 16 to 39 years old when they reported their menarche age before delivery. In contrast, daughters were 41-53 years old when they were followed up in 1995 and 2001 to recall their menarche age. The mean age of menarche of both generations was 14.9 and 13.4 years respectively. This retrospective method, which was used to estimate the age of menarche, is unsatisfactory possibly because of the inaccurate recollection of study subjects and a confounding factor in the analysis of the data. A study found a correlation coefficient of 0.8 with regard to the actual date and the date recalled 19 years later.[26] In contrast, 63% of girls recalled the date to within ±3 months.[27] Ye et al[28] reported an average age of 14.5 years at menarche in 1965, which was quite different from that found in the FOAD Study. However, different subjects and research methods may have also contributed to this discrepancy.

By combining our data with previous studies, we found that the menarche age decreased at a faster rate in rural girls than urban girls from 1980 to 2004. This secular trend was similar to the early change of menarche reported in some European countries and the United States. In industrialized countries and regions, the secular trend was towards an earlier mean age at

menarche. In addition, the decline rate was about 3-4 months per decade from the 1840s to 1960s. After the 1960s, and especially after the 1980s, the change became more moderate, paused and even reversed.[8,29] In contrast, the results obtained from girls of 13 nationalities contributed more to the steep decline of menarche in rural girls.[20]

The rural district (Pinggu District) selected for this study is also one of the districts involved in the BCAMS study. Therefore, we considered that the results of the study of 13 nationalities were reliable and comparable. The menarche trend in part reflects an improvement in overall nutrition. Living standards of the people in rural areas of Beijing were far behind urban areas several years ago. However, the gap has narrowed in recent years. Rural girls have experienced greater improvements than their urban counterparts in terms of nutritional transition, thus the decline rate in the menarche of rural girls is faster than that in urban girls.

Whether girls are more likely to be exposed to endocrine disrupting agents prompts us to make further investigation. The earlier onset of puberty may also be associated with the increasing prevalence of childhood obesity in Beijing,[9,13] especially after 1980. Menarche age is closely associated with the presence of body fat,[3,10] thus high subcutaneous fat levels are associated with an increased likelihood of early menarche.[12] Whether this decline will continue may depend largely on improved nutrition and environmental factors as well as host genetic factors, and also the interaction of host genes and environmental pressures.[30]

In conclusion, the BCAMS study provides reliable information on pubertal development in Beijing, China and shows that urban girls mature much earlier than rural girls. An updated reference range for normal pubertal development in Chinese girls needs to be established to determine precocious puberty or pubertal delay. Similarly, a longitudinal study of a similar population is needed to confirm these results. Finally, there is a secular trend in declining menarche age, and menarche decreased markedly in rural than in urban girls from 1980 to 2004.

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