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The Association of Overweight and Obesity with Menarche Age in Girls Aged 11-15 Years in Iran; A Cross-sectional Study

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ABSTRACT

Introduction: Epidemiologic studies have shown a discrepancy between overweight and puberty processes. This cross-sectional study was aimed to clarify these associations in the Iranian girl population.

Methods: A total of 1300 girls aged 11-15 years were randomly selected from Mashhad, in the northeast of Iran, using a multi-stage cluster sampling method. The demographic data were collected and weight, height, and waist circumference (WC) were measured, then Body Mass Index (BMI) and Waist-to-Hip ratio were calculated. Overweight and obesity were defined based on WHO reference data. Central obesity was defined as ≥90th percentile of WC. Linear regression and unconditional binary logistic regression were performed to investigate the association between socio-demographic parameters and age at menarche in months, puberty categories, and menarche age groups (<12 vs. ≥12 years) respectively.

Results: The prevalence of overweight, obesity, and abdominal fat distribution were 11.5%, 10.3%, and 10.5% respectively. Menarche was experienced by 63% of subjects at the mean age of 12.24±0.98 years. Regression tests revealed that the odds of menarche occurrence at the age of 12 or more was significantly lower in girls with higher BMI (OR: 0.31, 95%CI: 0.22-0.43) than their leaner counterparts (P< 0.001).

Conclusion: The findings suggest that being overweight or obese is a possible predictor of experiencing menarche at a younger age.

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Introduction

Puberty, as an important part of human reproductive life, is the end point of complex series of developmental events by which children obtain secondary sexual characteristics (1, 2). Normally the onset of puberty (the age of which 95% of children attain Tanner Stage 2) among girls occurs during ages of 8-13 years with the average of 11. Menarche, as the end stage of puberty in girls, usually occurs about 2-3 years after thelarche (3). Timing of normal pubertal maturation has received more attention over the past several years, because of its association with health and psychosocial problems (4).

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Some studies have shown a significant decline in age of pubertal maturation from the late 19th century to the end of 20th (1, 5-7). Comparing data from National Health Examination Survey (NHES) cycles I and III indicated that the average age at menarche in US decreased from 12.75 to 12.54 years (8). Similar results were reported by Bogalusa heart study (9). Such reduction in the age of menarche also has been reported among Iranian women by 0.15 years per decade (10). Recent large studies suggested that this secular trend of the pubertal age is continuing (11, 12), and generally attributing to substantial improvement in socio-economic conditions, nutritional status, sanitation and general health (13-16).

Entering puberty at younger ages in girls appears to be a risk factor for psychological problems (anxiety, negative self-image) (4), breast cancer (4, 17, 18), diabetes (19, 20), and higher sexual activity as they mature physically at a time when they are immature mentally. Furthermore children with earlier puberty are often shorter because of accelerated bone maturation and early epiphyseal fusion (21).

The "Critical Weight" hypothesis suggested by Frisch and Revelle several decades ago proposed that the attaining of a certain minimum weight or body fat percentage is necessary for pubertal development and menstrual function (13, 22-25). Decreasing age of puberty onset over the time seems to be concurrent with the global increasing prevalence of overweight and obesity (26, 27).

Obesity is a major health problem that is growing to epidemic problem worldwide in both developed and developing countries (2, 28), such as Iran. Childhood obesity is associated with lots of medical complications and to subsequent increase obesity-related morbidity and mortality (29). Besides, excess adiposity may also influence pubertal development (2, 11). Girls with heavier weight are more likely to reach menarche at a younger age than normal weight girls (30-32). Previous studies have examined the relationship between obesity and menarcheal timing (33, 34). Therefore the aim of this study was to investigate the association of Body Mass Index (BMI), Waist Circumference (WC) and Waist to hip ratio (WHR) as markers of fatness, with the occurrence of menarche among a sample of Iranian adolescence girls.

Materials and Method

Sample population

Across sectional study was carried out on 1300 healthy girls, in Mashhad, a large city in North-east of Iran. Subjects were selected from all seven urban educational regions, 2-3 schools of each region based on student population (totally 17 schools). A multistage stratified clustered sampling method was used. The exclusion criteria were presence of any chronic disease which may affect growth or cause delayed puberty (7). Additionally if the subject had not remembered the time of her first menstruation she ruled out too. Informed consent was obtained from the study participants or their parents. This study was designed based on the ethical standards of the Helsinki Declaration and was approved by the ethical committee and research council of the Mashhad University of Medical Sciences.

Demographic data

Every participant underwent medical examination, if she was eligible she completed a brief demographic questionnaire containing personal information (birth date, age, school grade, parents education and occupation). The students were asked to specify whether they had experienced menarche at the time of interview, and if the answer was positive menarche age was recorded.

Anthropometric measurements

Height and weight were measured by trained staffs to the nearest 0.1 cm using a portable stadiometer (Seca 216, Germany) and the nearest 0.1 kg using a balanced portable digital weight scale (Beurer BF66, Germany) while children wearing light indoor clothing and without shoes. Waist circumference was obtained over the unclothed abdomen at the narrowest point between the rib cage and the superior border of the iliac crest (35), using a non-elastic flexible tape and measurements were recorded to the nearest 0.1 cm. All pieces of equipments were calibrated daily. In all subjects BMI was calculated using weight (kg)/height^2 (m). Overweight and obesity were then defined based on BMI percentiles of WHO (World Health Organization) references for age and sex (36), as more than or equal to 85th and 95th BMI percentiles, respectively. Abdominal obesity was also determined as WC≥90 percentile for age and sex (36-38).

Statistical analysis

Normality of data was assessed using the Kolmogorov-Smirnov test. The data were represented by frequency (percent) and mean (SD) for qualitative and quantitative variables respectively. Chi-square test and Independent-sample t-test were used to compare between qualitative and quantitative variables, respectively. To investigate the association between age at

menarche in months and socio-demographic parameters, as binary variables, uni-and multivariate linear regression were performed. Socio-demographic variables were included BMI, WC, WHR, mother's and father's education. Unconditional binary logistic regression was used to assess the relationship between puberty categories (Non-pubertal vs. pubertal groups) and socio-demographic variables. The same test analyzed the relationship between menarcheal age groups (<12 years vs. ≥12 years) and socio-demographic factors. The last two tests were also performed in uni- and multivariate analyses for estimating un-adjusted and adjusted Odds Ratios (ORs), respectively and the 95% confidence intervals (CI). Statistical analysis was performed using SPSS for windows version 16.0 (SPSS Inc., Chicago, Illinois, USA). A probability of P=0.05 was considered statistically significant.

Results

Sample population characteristics:

The mean age of the sample population was 13.23±1.02years, and the mean and SD of BMI, WC and WHR were 19.9±3.5, 67.2±7.7 cm and 0.77±0.06 cm respectively. In total 63% of participants had experienced menarche with the average age of 146.9±11.37 months (12.24±0.98 years). The total prevalence of overweight and obesity were 11.5% and 10.3% respectively based on BMI percentiles of WHO references for age and sex. As shown in Table 1 abdominal obesity, WHR, puberty occurrence and age at menarche showed significant differences in two obesity categories (P<0.001).

Relationship of socio-demographic variables with menarche age

Compared to non-pubertal group, mean BMI, WC and WHR were higher in pubertal counterparts (20.7±3.4vs. 18.5±3.2kg/m^2, P<0.001), (68.7±7.5 vs.64.9±7.6cm, P<0.001) and (0.77±0.06 vs.0.78±0.06) respectively (Figure-1).

Table-2 demonstrates associations between age at menarche in months and socio-demographic variables using linear regression before and after adjusting for possible confounders. Age at menarche decreased significantly by 5.49 months in overweight and obese girls compared to the reference group. Similarly, girls with abdominal obesity or WC of above 90th percentile had experienced menarche 2.86 months earlier. Regarding to the parental education level, there was a significant reverse association between mother's education level and menarche timing.

Using a model of stepwise multivariate regression analysis with all variables being entered the model, only BMI and WC remained in the final model.

We also categorized menarche age into two age groups, younger than 12 and 12 or more, using logistic regression analysis to assess the relationship between socio-demographic characteristics and age at menarche (Table-3).

The findings showed that all obesity indexes were significantly associated with age at menarche. According to BMI categories, overweight and obesity lowered probability of being in the group with higher age at menarche (OR: 0.32, 95%CI: 0.24-0.43, P<0.001). The odds of having higher menarche timing among girls with WC above the 90th percentile was 0.47 times

Table 1. Socio-demographic characteristics of girls aged 11-15 in Mashhad

Variable	Obesity categories		P-value
	Normal weight n (%)	Overweight & obese n (%)	
Abdominal obesity			<0.001*
Yes	23(2.3)	111(40.8)	
No	958(97.7)	161(59.2)	
WHR			<0.001*
<0.80	749(76.4)	145(53.3)	
≥0.80	232(23.6)	127(46.7)	
Puberty			<0.001*
Yes	593(60.3)	217(78.9)	
No	390(39.7)	58(21.1)	
Menarche age(months)	148.39±11.68	142.90±11.02	<0.001†
Father's education			
Non-university educated	756(76.9)	211(76.7)	0.950*
University educated	227(23.1)	64(23.3)	
Mother's education			0.270*
Non-university educated	825(83.9)	223(81.1)	
University educated	158(16.1)	52(18.9)	

† Independent-samples t-test
* Chi-Square Tests

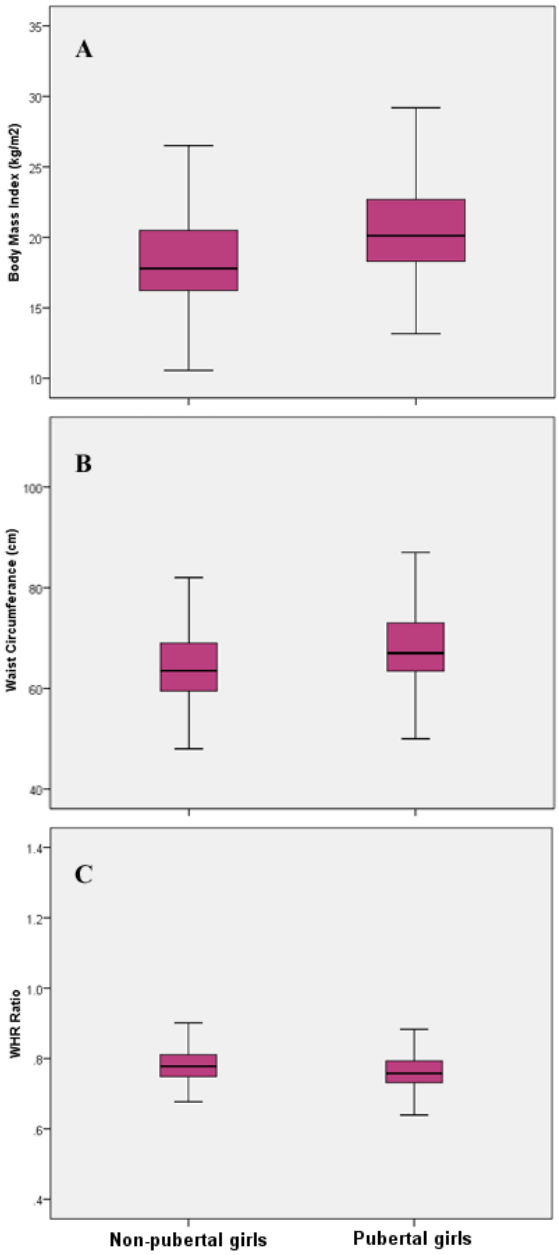

Figure 1. Mean Body Mass Index (A), Waist Circumference (B) and Waist-to-Hip Ratio (C) based on puberty status in girls aged 11-15 in Mashhad

(95%CI: 0.32-0.67, P<0.001) of the contemporary girls with WC less than 90th percentile. WHR had reverse association with menarche timing (OR: 1.42, 95%CI: 1.07-1.89, P<0.001) and higher WHR increased the possibility of being in the group with menarche occurrence at 12 or more years old. In adjusted model only BMI (OR: 0.31, 95%CI: 0.22-0.43, P<0.001) and WHR (OR: 2.08, 95%CI: 1.48-2.92, P<0.001) were significantly associated with age at menarche.

Relationship of socio-demographic variables with pubertal status

In different classification, participants were divided in to pubertal and non-pubertal groups based on menarche occurrence. In the Logistic regression model, all obesity indicators and father's education level showed significant correlation with menarche. BMI (OR:2.46 ,95%CI: 1.79-3.38 , P<0.001) and WC (OR:1.78 ,95%CI: 1.18-2.67 , P=0.006) had positive relation , while WHR (OR:0.55 ,95%CI: 0.43-0.71, P<0.001)and father's education (OR:0.68 ,95%CI: 0.53-0.89, P=0.004)were negatively correlated with puberty. Puberty was significantly associated with obesity status (OR: 2.63, 95%CI: 1.81-3.82, P<0.001) and WHR (OR: 0.41, 95%CI: 0.31-0.54, P<0.001), but not anymore with abdominal obesity after adjusting in multivariate model (Table-4).

Discussion

We conducted the current study to estimate the average age at menarche in a sample of Iranian girls and to assess the association of obesity indexes with it. Menarche was occurred at the age of 13.23±1.02 yrs in our study sample which was more than menarcheal age of Tehranian girls but less than age at menarche in all other provinces (39). Iran has different ethnicities (Persian, Azeri, kurd, Arab, and Gilaki) living in various geographic regions with different climates. All these, besides the socioeconomic differences and industrialized lifestyle in metropolitan cities such as Tehran (the capital of Iran) could cause the differences in maturation time (40). The mean age at menarche in the United States is 12.7 yrs (8), Germany 12.8 yrs (41), Turkey 12.4 yrs (7), Kuwait 12.41 yrs (42), United Kingdom 12.9 yrs (43), Nigeria 13.2 yrs, India 13.8 yrs (44), and in Ethiopia 15.8 yrs (45). It seems that lower socio-economic conditions and growth retardation might lead to slower puberty process and delay in maturation. Our results suggest that there is a significant inverse relationship between BMI and both menarche occurrence and mean age at menarche in adjusted and unadjusted analysis, which is in line with previous studies that indicate the same association between weight and puberty (7, 46, 47). A similar cross-sectional study in Iran showed that overweight and obese girls reached pubertal age earlier than normal weight ones (6). In one study that conducted on 811 French Canadian girls, there was an association between overweight and both early and late maturation in girls (48). Another study on comparison of normal weight versus overweight and obese girls indicated that body fat associate with early puberty (34). In a cross-sectional study in Kuwait, Al-Awadhi, et al. (49), concluded that there is an inverse association between high BMI and age at menarche. A retrospective study on Korean

Table 2. Association between age at menarche and socio-demographic variables, using uni- and multivariate linear regression

Variables	Unadjusted			Adjusted*		
	B(95% CI)	Beta	Pvalue	B(95% CI)	Beta	Pvalue
Step 1 **Overweight & Obesity**						
BMI †per < 85th (Reference)						
BMI per ≥ 85th	-5.49(-7.28,-3.70)	-0.21	<0.001	-6.17(-8.28,-4.06)	-0.23	<0.001
Abdominal Obesity						
WC†per < 90th (Reference)						
WC per ≥90th	-2.86(-5.03,-0.41)	-0.08	0.022	1.43(-1.40,4.26)	0.04	0.320
Step 2 **Waist-to-Hip Ratio**						
< 0.80 (Reference)						
≥ 0.80	1.70(-0.19,3.58)	0.06	0.078			
Mother's Schooling						
Non-university Educated (Reference)						
University Educated	-2.50(-4.65,-0.35)	-0.08	0.023			
Father's Schooling						
Non-university Educated (Reference)						
University Educated	-0.94(-2.90,1.01)	-0.03	0.345			

Dependent variable: Age at menarche in month , All significant and non-significant variables from univariate tests were entered in the multivariate analyses (2 steps hierarchical modeling) to control their confounding effect by adjusting.
*Adjusted R^2
† BMI: Body Mass Index, WC: Waist Circumference

middle school students, revealed that the girls with early menarche have more body weight and BMI comparing to those with late menarche (50). In contrast, a research suggested that there is no correlation at population level between BMI and age at menarche (51).

Use of BMI alone has some limitations in children, because the relation between the fat and fat free mass varies at different ages, so WC is suggested to be superior to the BMI for predicting obesity-related health diseases (52). Also we assessed the relationship of WC with menarcheal age.

Similar positive relations were found between abdominal obesity and both puberty occurrence and menarche age in univariate but not multivariate model. It seems that WC association with menarche is indirectly, via girls' weight.

Table 3. Association between different groups of age at menarche and socio-demographic variables, using uni- and multivariate logistic regression

Variables	Unadjusted		Adjusted	
	OR(95% CI)	P-value	OR(95% CI)	P-value
Step 1 **Overweight & Obesity**				
BMI per < 85th (Reference)				
BMI per ≥ 85th	0.32(0.24,0.43)	< 0.001	0.31(0.22,0.43)	< 0.001
Abdominal Obesity				
WC per < 90th (Reference)				
WC per ≥90th	0.47(0.32,0.67)	< 0.001	0.69(0.42,1.12)	0.128
Step 2 **Waist-to-Hip Ratio**				
< 0.80 (Reference)				
≥ 0.80	1.42(1.07,1.89)	0.015	2.08(1.48,2.92)	< 0.001
Mother's Schooling				
Non-university Educated (Reference)				
University Educated	0.74(0.54,1.01)	0.058	0.69(0.49,0,95)	0.250
Father's Schooling				
Non-university Educated (Reference)				
University Educated	1.01(0.76,1.34)	0.966		

Dependent variable: Age at menarche in two categories (<12 years as reference vs. ≥12 years), All significant and non-significant variables from univariate tests were entered in the multivariate analyses (2 steps hierarchical modeling) to control their confounding effect by adjusting
† BMI : Body Mass Index, WC: Waist Circumference

Table 4. Association between puberty status and socio-demographic variables, using uni- and multivariate logistic regression

Variables	Unadjusted		Adjusted	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Step 1				
Overweight & Obesity				
BMI per < 85th (Reference)				
BMI per ≥ 85th	2.46(1.79,3.38)	<0.001	2.63(1.81,3.82)	<0.001
Abdominal Obesity				
WC per < 90th (Reference)				
WC per ≥90th	1.78 (1.18,2.67)	0.006	1.53(0.92,2.55)	0.102
Step 2				
Waist-to-Hip Ratio				
< 0.80 (Reference)				
≥ 0.80	0.55(0.43,0.71)	<0.001	0.41(0.31,0.54)	<0.001
Mother's Schooling				
Non-university Educated (Reference)				
University Educated	0.83(0.62,1.11)	0.202		
Father's Schooling				
Non-university Educated (Reference)				
University Educated	0.98(0.73,1.08)	0.070		

Dependent variable: Puberty status based on menarche occurrence (non-pubertal girls as reference vs. pubertal girls), All significant and non-significant variables from univariate tests were entered in the multivariate analyses (2 steps hierarchical modeling) to control their confounding effect by adjusting.
† BMI : Body Mass Index, WC: Waist Circumference

There was a tendency for those in the younger age at menarche to have a higher WC percentile. Some studies reported that WC is positively correlates with puberty timing (53). In a study probability of getting early puberty in Girls aged 7-9 with greater WC, was higher than those with less WC (35). Surprisingly, WHR had reverse association with both probability of having menarche and age at menarche, in comparison to BMI and WC. Samples with lower WHR were more likely to have menarche in younger ages.

In our study only mothers' educational level in univariate analysis was reversely related to menarcheal age, but it did not show any association with obesity status as well as puberty occurrence. Socio-economic factors could play an important role on weight status and menarcheal age. A study in the United States attained different results with a negative relationship between children's BMI and their parents' education (54). Some researches parallel to our results, have shown that menarcheal age decreases as socio-economic status improves (15, 55, 56), in contrast, some studies did not find any significant differences in menarcheal age between social classes (7, 57). It seems that higher educational level of parents, especially mothers, affects family nutritional behaviors, but children are also affected by their friends, environment and multimedia.

The role of body weight as an accelerator factor on the developmental process which was suggested by Frisch and Revelle (58, 59), several decades ago as "Critical Weight" hypothesis, now is well-accepted by the discovery of the leptin (adipocyte-derived hormone), (2, 59, 60). Leptin is secreted from fat tissue so its blood concentration is in direct proportion to the amount of total body fat mass. Other major effect of Leptin is controlling the energy stores in the adipose tissue by appetite reduction and increased thermogenesis (2). Therefore Leptin's role as an essential mediator of the impact of body fat mass on the onset of puberty can explain our results that higher BMI and more WC tended to be associated with an earlier puberty.

Our study had several limitations. First, it was based on a cross-sectional data, so the subjects' body weight at the menarche time was not available, therefore we could not determine the causal relationship between obesity and puberty. Also we had to rely on the subject's memory on menarche time. Similar to many other studies, our study did not include boys, because it was not a cohort study and there is no such an easy indicator (age at menarche in girls) event of puberty in boys. Although some studies emphasize that BMI can affect puberty duration, besides puberty onset, as our study was not a cohort study we only considered the age of menarche, because it is easy to measure and self-reported data are more reliable (61-63). Although we were not able to report the mean age of thelarche, pubarche and duration of

puberty process in comparison to other studies, as some studies showed that the duration of the pubertal transition has increased because of the decline at the age of breast development, not age of menarche (64). We did not measure body fat mass (FM) and fat free mass (FFM), previous studies suggested that menarcheal age was more related to FM/m^2 than to BMI (65). Further studies may need to distinct how other factors such as genetic, dietary patterns, environment and geographic locations linked to the puberty onset in girls.

Conclusion

Experiencing earlier menarche parallel to the increasing of body weight emphasizes the need for early prevention and treatment programs for childhood obesity. Longitudinal investigations can determine causal effect between obesity and puberty.

Conflict of interest

All Authors including Author A, Author B, Author C, Author D and Author E declare that they have no conflict of interest.

Abbreviations

BMI: Body Mass Index, NHES: National Health Examination Survey, WC: Waist Circumference, WHO: World Health Organization, WHR: Waist to hip ratio

Compliance with Ethical Standards

Funding

This study was funded by Deputy for research at Mashhad University of Medical Sciences.

Ethical approval

All procedures performed in the current study were in accordance with the ethical standards of the Ethics Committee of Mashhad University of Medical Sciences (Mashhad, Iran) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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