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Body composition and somatic indices: determinants of timing of menarche

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Abstract

Menarche is the signal of initiation of reproductive age of girls. Age at menarche is associated with health outcome at adulthood. Body fat mass and BMI influence menarcheal age. The aim of this study was to investigate the possible association of body composition and body fat distribution with age at menarche.

This was a cross sectional questionnaire based study conducted among school girls having age limit 10-14 years who experienced menarche not more than previous three months. Only unmarried adolescent females were included in the study however, females with gynecological, psychological or other medical problems were excluded from the study. Quantitative data were presented as percentage and/or mean ± standard deviation. T-test was done to determine significance of difference between physical characteristics of females early age at menarche and reference age at menarche. T-test, chi square test and logistic regression analysis were done. We also evaluated correlation between age at menarche and physical parameters. The significance levels of the tests were considered at a significance level of 0.05.

About one-four of study population acquired menarche at age below 12 years and remaining three-fourth acquired menarche at 12-14 years. Significant negative correlation was noted between age at menarche and body weight, BMI, body fat percentage, Waste circumference, Hip circumference, waist – hip ratio and waist- height ratio. Significant positive correlation was obtained between age at menarche and neck circumference. Significant association was observed between menarcheal age and study parameters. Logistic regression analysis suggests that body fat percentage, BMI, body weight, body fat distribution may be considered as risk factors for early menarche.

Age at menarche is negatively correlate with BMI, body fat percentage, Waste circumference, Hip circumference, waist – hip ratio and waist- height ratio. Thus BMI, Body fat% and central obesity markers are considered as determinant of age at menarche.

Keywords: Menarcheal Age; Body Fat %; BMI; Waste Circumference; Heap Circumference; Central Obesity

1. Introduction

Menarche, the first menses is a signal that indicates that a girl is entering into a reproductive age. Literature survey indicate that the average age of menarche has decreased significantly in last 100 years. Time dependent decrease trend of menarcheal age is known as secular trend. In the most develop countries like Europe and USA menarcheal age is decreased at a rate of 2-3 month per decade (1). Recently such a decline tendency has also been reported in developing countries (2). Menarcheal age is clinically valuable as it is associated with health outcome at adulthood. Girls with early menarche (below 12 years) tend to have higher blood pressure, glucose intolerance, cardiovascular disease and mortality from cancer (3).Younger age at menarche is a well known risk for unplanned pregnancy, unsafe abortion, endometrioses sexually transmitted diseases including AIDS (4-6). Statistically significant association was reported

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between breast cancer and early age of menarche in a meta-analysis using data from 117 epidemiological studies (7).Late menarche (> 14 years) is associated with increased risk of osteoporosis (8).

From the early 1800s to the mid of 1950s occurrence of menarche was found at increasingly younger ages (1). The declining trend is still continuing in many parts of the world (9, 10). The advancement of socioeconomic and health condition in the 20th century led to shift to earlier menarcheal age. This shift was noted worldwide and called secular trend (11, 12).

Various factors like socioeconomic status, genetic, heredity, ethnicity, psychological stress and chronic illness have been postulated to affect the age at menarche (13, 14).Diet having high content s of calories and rich in protein causes early menarche (15). A family based cross sectional study suggested that early menarche was associated with increase in body fat (16).Large scale studies suggested that a higher gain in body mass during childhood is related an early onset of puberty (17, 18).This study was aimed to investigate possible correlation between body composition body fat distributions with age of initiation of reproductive life of girls. This study is further attempted to investigate physical determinants of early menarche.

2. Material and methods

2.1. Subject

A cross-sectional study was done in Hooghly district and adjoining areas. The population was unmarried Bengali female adolescent students who were randomly selected from Secondary schools in the age group between 10 to 14 years who experienced menarche not more than previous three months to avoid significant change in BMI. It has been reported that there is no change in body weight greater than 5% in the previous three month (19). Willingness of the subject was considered. A total of 931 female students were involved in the study. Students having age less than 10 years or more than 14 years, married, who have not started menstruating, Who has previous experienced of menarche more than three month, those who were taking regular drugs or hormonal therapy and suffering from chronic disorders including diabetes mellitus, clinically established hypertension, liver cirrhosis and kidney disease, suffering with secondary dysmenorrhea were excluded from the study.

2.2. Questionnaire

A self-administered questionnaire having questions related to their age, age when menarche appear and socioeconomic characteristics were given to the subjects. Menarcheal age was obtained through recall, by calculating the time period between the day subjects menstruated first time and the date of birth. The questionnaires were translated to the local language (Bengali) as well.

2.3. Anthropometric measurement

Body weight was measured in light clothing and bare feet using bathroom scale accurate to 0.5kg. The scale was kept on a flat surface and adjusted with '0' mark. Now the subject was requested to step on it in bare feet. Weight was recorded to the nearest 0.5kg. Height was measured using anthropometric rod without footwear on to the nearest 0.1 cm (20). BMI was calculated from the height and weight using following equation: BMI (kg/m^2) = weight (kg) / $height^2$ (m).

NC was measured just below the laryngeal prominence (Adam's apple) using calibrated plastic tape (21) WC was measured mid-way between iliac crest and lowermost margin of the ribs in quiet breathing using plastic tape (21). Hip circumference (HC) was measured using plastic tape at horizontal level of greater trochanters with the leg close together. Waist- height- ratio (W: Ht) was calculated by dividing waist circumference with height.

2.4. Estimation of body composition

Percent body fat (BF%), fat mass (FM), fat free mass (FFM) and fat mass index (FMI) was estimated as a measures of body composition. BF% was estimated from BMI considering age and gender (22).

$$BF\% = (1.51 \times BMI) - (0.7 \times Age) - (3.6 \times Sex) + 1.4;\ \text{where sex 0 for female and 1 for male}$$

FM, FFM and FMI were computed following standard formulae (23).

$$FM\ (kg) = [(BF\%/100) \times weight\ (kg)$$

$$FFM\ (kg) = weight\ (kg) - FM\ (kg)$$

$$FMI\ (kg/m^2) = FM\ (kg) / height^2\ (m)$$

2.5. Somatic indices

Body fat distribution were assessed from somatic indices like BMI, waist to hip ratio (WC: HC) and waist to height ratio (WC: Ht).

$$BMI\ (kg/m^2) = weight\ (kg) / height^2\ (m).$$

$$WC: HC = WC\ (cm)/ HC\ (cm)$$

$$WC: Ht = waist\ (cm)/ height\ (cm)$$

2.6. Statistical analysis

Quantitative data were presented as percentage and/or mean ± standard deviation. T-test was done to determine significant of difference between physical characteristics of females early age at menarche and reference age at menarche. Chi square test was done for assessment of association between age at menarche and physical parameters. Bivariate and multivariate logistic regression analysis was done to evaluate risk factors of early menarche. We also evaluated correlation between age at menarche and physical parameters. The significance levels of the tests were considered at a significance level of 0.05.

3. Results

Age at menarche varies from 110 month to 168 month. Mean age at menarche was 150.11 ± 9.36 month. Distribution of study population on the basis of age at menarche was given in fig-1.

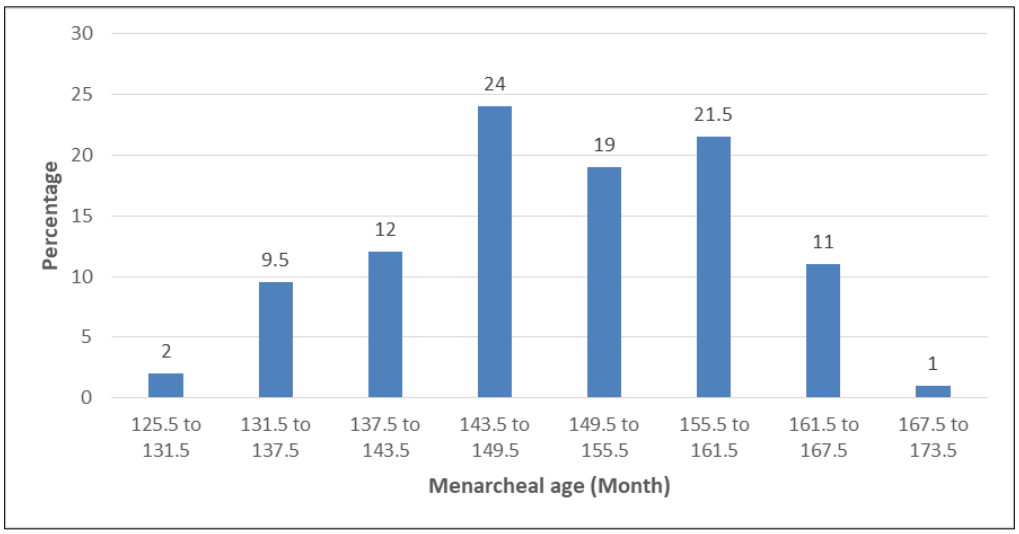

Figure 1 Distribution of study population on the basis of age at menarche

Study population was divided into two groups; control and experimental. Control group consists of school girls those attained menarche at 12 to 14 years of age (144 month to 168 month). Whereas experimental group is composed of girls those attained menarche at age below 12 years (<144 month).Anthropometric parameters of control and experimental group of girls was given in table-1. There was significant difference of weight, BMI, WC, HC and NC.

Body fat distribution were assessed using BMI; WC:HC, WC: Ht and NC: Ht. There was significant difference of BMI, WC: HC and WC: Ht between control and experimental group. However, there was insignificant difference of NC: Ht between control and experimental group.

Table 1 Comparison of physical characteristics of control and experimental group

Parameters	Control group	Experimental Group	P value
Height (cm)	150.20 ± 5.95	148.85 ± 3.90	>0.05
Weight (kg)	51.72 ± 10.25	60.10 ± 9.18	<0.001
Waist circumference (cm)	59.72 ± 7.03	64.39 ± 7.52	<0.001
Hip circumference (cm)	64.99 ± 7.55	68.12 ± 7.47	<0.01
Neck circumference	29.61 ± 2.46	28.45 ± 2.13	< 0.01
Menarcheal age (month)	153.45 ± 6.74	137.26 ± 3.74	<0.001

Table 2 Comparison of somatic indices of control and experimental group

Parameters	Control group	Experimental Group	P value
BMI (kg/m^2)	22.92 ± 4.39	27.14 ± 4.13	<0.001
Waist- hip ratio (WC: HC)	0.919 ± 0.038	0.945 ± 0.031	<0.001
Waist height ratio (WC:Ht)	0.398 ± 0.047	0.433 ± 0.049	<0.001
Neck height ratio (NC: Ht)	0.199 ± 0.030	0.191 ± 0.015	>0.05

Body composition characteristics of control and experimental group are presented in table-3. Experimental group (age at menarche below reference group) had significantly ($p< 0.001$) higher mean value for BF%, FM and FMI in respect to control group. Similar pattern was noted for FFM but level of significance was less ($p<0.01$)

Table 3 Comparison of body composition of and experimental group

Parameters	Control group	Experimental Group	P value
Body fat% (BF%)	25.29 ± 6.578	32.20 ± 6.689	<0.001
Fat mass (kg)	13.70 ± 6.103	19.91 ± 6.628	< 0.001
Fat free mass (kg)	38.02 ± 4.598	40.19 ± 3.146	< 0.01
Fat mass index (kg/m^2)	6.08 ± 2.712	9.00 ± 3.042	< 0.001

Correlation tests revealed statistically significant relationship all tested parameters with age at menarche except height and neck: height ratio. We found moderate negative correlation of tested somatic indices like BMI, waist: hip ratio and waist: height ratio. Similar pattern of correlation was also observed between body weight and age at menarche. We measured four body composition parameters like BF%, FM, FFM and FMI. All of these parameters significantly negatively correlated with age at menarche. We measured NC to assess upper body fat. Significant ($p<0.02$) positive correlation was noted between NC and age at menarche.

Chi square tests were done to determine association between anthropometric parameters with menarcheal age. Somatic indices (BMI, Waist: hip ratio, waist: height ratio) significantly ($p<0.001$) associated with age at menarche. There was no association ($p> 0.05$) between neck: height ratio and age at menarche. All body composition indices (BF%, FM, FMI and FFM) significantly associated with age at menarche see table-5).

Table 4 Correlation of various parameters with age of menarche

Parameters		**Correlation coefficient (r)**	**P value**
Type	Subtype		
Anthropometric	Height (cm)	0.125	>0.05
	Weight (kg)	(-) 0.377	<0.001
	Neck Circumference (cm)	0.169	< 0.02
	Waist circumference (cm)	(-) 0.208	<0.001
	Hip circumference	(-) 0.125	<0.01
Somatic Indices	BMI (kg/m^2)	(-) 0.432	<0.001
	Waist: hip ratio	(-) 0.300	<0.001
	Waist height ratio	(-) 0.245	<0.001
	Neck: height ratio	0.109	>0.05
Body composition	BF%	(-) 0.431	<0.001
	FM (kg)	(-) 0.425	<0.001
	FFM (kg)	(-) 0.254	<0.001
	FMI (kg/m^2)	(-) 0. 442	<0.001

Table 5 Chi square test for association of study parameters with age at menarche

Parameters		**Age of menarche (Year)**		**Chi square (df)**	**P value**
Name	**Subgroup**	**12-14**	**<12**		
BMI (kg/m^2)	≤ 18.0	52	2	47.176 (2)	< 0.001
	18.1 – 24.9	156	24		
	≥25.0	100	66		
WC:HC	≤ 0.90	82	4	26.467 (2)	< 0.001
	0.91-0.95	172	56		
	> 0.95	54	32		
WC: Ht	≤ 0.40	170	22	33.518 (2)	< 0.001
	0.41-0.45	92	36		
	> 0.45	46	34		
NC: Ht	< 0.180	26	12	2.878 (2)	> 0.05
	0.181 – 0.200	63	20		
	> 0.2001	65	14		
BF %	≤ 22.00	58	3	30.395 (2)	< 0.001
	22.10 -29.99	57	12		
	≥30.0	39	31		
FM	≤ 9.99	51	3	26.477 (2)	< 0.001

	10.00-19.99	78	20		
	> 20.00	25	23		
FMI	≤4.99	62	6	20.196 (2)	<0.001
	5.00-9.99	77	25		
	≥ 10.00	15	15		
FFM	≤ 34.99	40	03	9.406 (2)	< 0.01
	35.00- 39.99	54	16		
	≥ 40.0	60	27		

We calculated odd ratio and relative risk for tested parameters for assessment of risk factors for early menarche. In case of somatic indices except NC: Ht, odd ratio and relative risk increased with increase value of tested parameters. Risk of early menarche was more among overweight (BMI ≥ 25.00 kg/m^2) girl in compare with reference group of girls (BMI 18.5 – 24.99 kg/m^2). Like BMI, central/abdominal obesity markers (WC: HC and WC: Ht) should be considered as risk factor for early menarche as odd ratio and relative risk increases with increasing value of central obesity markers from their reference level. In case of body composition odd ratio and relative risk increased with increase value of tested parameters. Risk of early menarche was more among fatty (BF% ≥ 22.00) girl in compare with reference group of girls (BF% < 22.00). Like BF% similar pattern was noted for FM, FMI and FFM (see table-6).

Table 6 Logistic regression analysis to evaluate risk factors of early menarche

Parameter		**Age at menarche**		**OR**	**RR**	**95% CI**
Name	**Subgroup**	**12-14**	**<12**			
BMI (kg/m^2)	≤ 18.0	52	2	0.250	0.900	0.057—1.094
	18.1 – 24.9	156	24	1	1	Ref
	≥25.0	100	66	4.290	1.439	2.524---7.291
WC:HC	≤ 0.90	82	4	1	1	Ref
	0.91-0.95	172	56	6.674	1.246	2.340----19.033
	> 0.95	54	32	12.148	1.518	4.065---36.303
WC: Ht	≤ 0.40	170	22	1	1	Ref
	0.41-0.45	92	36	3.023	1.232	1.679----5.443
	> 0.45	46	34	5.711	1.539	3.049---10.697
NC: Ht	< 0.180	52	24	1	1	Ref
	0.181 – 0.200	126	40	0.684	0.901	0.377---1.254
	> 0.201	130	28	0.467	0.831	0.248—0.879
Body Fat %	≤ 22.00	116	6	1	1	Ref
	22.10 -29.99	114	24	4.070	1.151	1.603—10.328
	≥30.0	78	62	15.367	1.706	6.337---37.264
FM	≤ 9.99	102	6	1	1	Ref
	10.00-19.99	156	40	4.359	1.187	1,783---10.653
	> 20.00	50	46	15.640	1.813	6.260---39.071
FMI	≤4.99	124	12	1	1	Ref
	5.00-9.99	154	50	3.354	1.208	1.711---6.576

	≥ 10.00	30	30	10.333	1.823	4.740---22.525
FFM	≤ 34.99	80	6	1	1	Ref
	35.00- 39.99	108	32	3.951	1.206	1.576—4.899
	≥ 40.0	120	54	6.000	1.349	2.465---14.605

4. Discussion

According to Frisch and Revelle hypothesis menarche in the adolescent girl can occur when her body weight reaches a minimum of 48 kg or 17% of body fat percentage (24). In our study median weight was 53.33 kg (range 33 to 78 kg) and median BF% was 27% (range 12.9% to 42.4%). Our finding suggested that beside body weight and body fat percentage other factors also act as determining factors of age at menarche.

In this study girls with early menarcheal age (< 12 years) had significantly greater mean weight, WC and HC compared with girls with reference menarcheal age (12-14 years). Somatic indices like BMI, WC: HC and WC: Ht significantly higher in girls with early menarcheal age than girls with reference menarcheal age. Body compositions like BF%, FM, FMI and FFM were significantly higher in experimental group of girls than control counterpart. All tested parameter except height and neck circumference negatively and significantly correlated with age at menarche. Significant inverse relationship between menarcheal age and obesity and positive relationship between menarcheal age and height was reported by various studies (25). Height was insignificantly positively correlated with age whereas neck circumference significantly and positively correlated with menarcheal age.

BMI is the most commonly used overall obesity index (26, 27). Previous studies reported that overweight girls reach menarche at an earlier age (28, 29). Our study support previous observation as BMI of experimental group of girls was significantly higher than control group. The girls who had started menstruating had significantly higher body weight and BMI. It may be concluded that overweight is more prevalent in girls who attained menarche before 12 year of age than girls who attained menarche from 12 to 14 years of age.

Since overall obesity significantly associated with menarcheal age, we undertook chi square test and correlation test for assessment of association and correlation between body composition and age at menarche. All body fat indices are associated and significantly negatively correlated with age at menarche. Thus adolescent girls who attained menarche before 12 year of age had significantly higher BF%, FM, and FMI. Thus adolescent girls with higher body fat content begin menstruating at an age earlier than girls with low body fat level. Body fat can affect menarcheal age through leptin. Leptin is a peptide hormone secreted from adipocytes in response to increase amount of body fat. Leptin stimulates the hypothalamus to increase secretion of gonadotropin releasing hormone (GnRH). On the other hand GnRH stimulates pituitary- ovarian axis and accelerate puberty (19).

In order to assess impact of body fat distribution on menarcheal age we studied correlation between various obesity markers and age at menarche. There are several anthropometric indicators for body fat including BMI, WC, W:Ht, HC, W:H, NC and NC: Ht. (30). Central or abdominal obesity indicated by WC, W: Ht, W: HC (31).NC and NC: Ht are good indicators of upper body fat (32, 33).

Abdominal obesity markers significantly negatively correlated with age at menarche. however there was insignificant correlation between upper adiposity marker and menarcheal age. Thus excess fat deposition in abdomen induce early onset of menarche among adolescent girls.

Finally we calculated odd ratio for assessment of risk factor among study parameters. Our finding suggested that body weight as well as BMI, abdominal obesity (WC, WC: HC, WC: Ht) and body fat (BF%, FM and FMI) should be consider as determinant of age at menarche. Overweight or obesity, high abdominal obesity and high fat content in the body induce early onset of reproductive life in adolescent girls. It was reported that Insulin resistance and hyperinsulinemia are common in obese children which effects on several organs including adrenal gland, liver, adipocytes and ovary leading to increased bioavailability of sex hormones and induces early puberty (34).

5. Conclusion

Body weight, BMI, body fat level and body fat distribution particularly abdominal obesity are negatively correlated with menarcheal age. Overweight or obesity, high abdominal obesity and high fat content in the body induce early onset of

reproductive life in adolescent girls. In conclusion, monitoring of weight gain and obesity from the beginning of live is essential to avoid early menarche.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Written consent for participation was obtained from the parents and Scholl authorities.

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