Original Article

Relationship between body mass index and timing of maturation

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Abstract

Background: Menarche is the first menstrual period. The increasing incidence of overweight/obesity and decline in the median age at menarche had led investigators to hypothesize potential associations of age at menarche with body mass index (BMI). We assess these associations between reproductive and nonreproductive age females. **Aim:** The present study assessed the relationship between BMI and the timing of menarche among contemporary Nigerian girls. **Methods:** The present cross-sectional anthropometric study was performed in 2014 using 600 menstruating and 200 nonmenstruating girls aged 11–18 years in Nigeria. We classified the menarcheal age of our participants into early, ideal, and late. Participants were also categorized based on their nutritional status into underweight, normal, and overweight. **Results:** Mean age at menarche was 13.54 years. Age at onset of menarche was inversely associated with BMI. Precocious menarche (<12 years) when compared to ideal (12–13 years) or late (≥14 years) menarche was found to be associated with a higher BMI ($F = 10.64$, $P < 0.05$). Overweight girls also reach maturation earlier than their contemporaries with moderate to lean body status ($F = 15.32$, $P < 0.05$). **Conclusion:** Girls with high BMI or overweight reach menarche earlier in life than their lean or low BMI counterparts.

Key words: Anthropometric, body mass index, menarche, overweight

INTRODUCTION

Menarche is the onset of first menses. It is a late event in puberty preceded by a growth spurt, breast development, and pubic hair growth. Weight, height, and body mass index (BMI) are body size variables that have over time shown strong significant correlation with age at menarche. There have been many other potential factors that were believed to have shown significant influence on physical maturation of girls such as genetic make-up, ethnicity, social status, physical activity, and environmental factors (Heidi 1986; Hulanicka and Waliszko 1991; Henneberg and Louw 1995; Karapanou and Papadimitriou 2010). Secular trend worldwide towards earlier age at menarche has been reported in several countries such as Nigeria (Chukwujekwu *et al*. 2014), Egypt (Gehan *et al*. 2007), Somalia (Marshall and Tanner 1969; Eveleth and Tanner 1990), the Netherlands (Talma *et al*. 2013), Iran (Pejhan *et al*. 2011), Bangladeshi (Akter *et al*. 2012), and the USA (Herman-Giddens *et al*. 2007;

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Fida *et al.* 2012). It has been estimated that in most part of the 20th century age at menarche has progressively dropped by 1 month/decade on the average (Fredriks *et al*. 2000). Black girls adopted from developing countries exhibit sexual precocity in developed countries (Freedman *et al*. 2002; Parent *et al.* 2003). The racial difference between black and white girls may be responsible for their menarcheal timing due to genetic difference (Karapanou and Papadimitriou 2010).

Age at menarche in industrialized countries has remained relatively stable (Vercauteren and Susanne 1985; Lindgren *et al*. 1991; Dan and Roberts 1993). Earlier studies by (Lind Lindgren and Hauspie 1989; Eiben 1994; Prebeg 1995) reported a possible increase in menarcheal age among girls from Scandinavian countries. It appears, therefore that from these studies, age at menarche is still decreasing in many countries but has level off or rising in others.

BMI has shown significant influence on age at menarche with a number of studies noting that increased BMI is associated with earlier onset of menarche (Kaplowitz *et al.* 2001; de Muinch Keizer and Mul 2001; Wang 2002; Anderson *et al*. 2003). These studies reported secular shift towards younger age at menarche with increasing BMI (Wattigney *et al*. 1999). High adiposity at a prepubertal age (5–9 years) is correlated with increased likelihood of early (<12 years) onset of menarche (Freedman *et al*. 2002). Frisch and Revelle (1970, 1971) proposed a body weight of 47.8 kg for the onset of menarche. Many studies around the world have previously reported secular changes in BMI (Fredriks *et al*. 2000; Bundred *et al*. 2001; Armstrong *et al*. 2003; Lissau *et al*. 2004). Flegal and Troiano (2000) found that there is an increase in mean BMI levels with distributions skewed to the right, suggesting the extent overweight has been on the increase than that reported by (Jolliffe 2004). Regarding factors predisposing increase in BMI include total caloric intake, decrease in physical activities (Berkey *et al*. 2000). Several studies have previously reported that taller girls (St George *et al*. 1994; Koprowski *et al*. 1999; Petridou *et al*. 1996; Bharati and Bharati, 1998) and girls with more body fat (Merzenich *et al*. 1993; St George *et al*. 1994; Koprowski *et al*. 1994; Petridou *et al*. 1996; Bharati and Bharati, 1998) reach menarche earlier. Higher levels of physical activity in girls have also been found to be associated with delayed menarche (Merzenich *et al.* 1993). Hughes and Jones (1985) reported that menarcheal age was higher in countries where dietary fiber intake was higher (Eiben 1989). Blood leptin (a polypeptide) levels were also much more strongly correlated with gluteofemoral than upper body fat, suggesting that leptin may transmit stimulus about fat distribution to the hypothalamus at puberty (Lassek and Gaulin, 2007).

The present study sought to compare body dimensions (particularly BMI and weight) and nutritional status based on menarcheal categories in a sample of adolescent girls in Nigeria. We next examined these body dimensions between premenarcheal and postmenarcheal girls.

MATERIALS AND METHODS

Data were collected from secondary school girls aged 11–18 years from low socioeconomic status. Random sample technique was used to select three public schools each from Nsukka and Zaria Local Government Areas. An overall participation rate of about 94% resulted in 800 usable questionnaires (600 postmenarcheal and 200 premenarcheal girls). The study protocol was reviewed and approved by Health Research Ethic Committee of Ahmadu Bello University, Zaria and relevant authorities of participating schools.

After a pilot study, data were collected through questionnaires distributed to the participants of the study. After a brief explanation of the work and nature of questions raised in the questionnaire, respondents who agreed to participate in the study were advised to feel free to ask any of the research assistant's questions they found difficult to understand. Permission to conduct the study was obtained from authorities of participating schools or relevant authorities. To assess age at menarche, each participant was asked if she had had her first menstrual period. Anthropometric measurements of weight, height, chest, hip, thigh and waist circumferences (WCs) were measured. Height was measured with a stadiometer (190 cm long). Subjects stood bare-foot with arms straight and relaxed and the head held in the Frankfort plane. Weight was taken using a beam scale (capacity 120 kg). Subjects wore only light clothing, and the scale was checked each day for accuracy and precision. Chest circumference (CC) was measured with an inelastic tape (140 cm long) while subjects stood with shoulders and arms relaxed. The research assistant faced the subject while passing the tape around the upper chest. CC was measured midway between quiet expiration and inspiration. Hip circumference was measured with the tape wrapped around the largest part of the buttock. Thigh circumference (TC) was measured at the level of the mid-point on the lateral surface of the thigh, mid-way between trochanterion and the tibia. While WC was measured with the tape between the mid-point of the lowest rib and top of iliac crest at expiration according to Jelliffe *et al*. (1989) protocol. All circumferences were measured with subject standing. BMI was calculated as weight (kg) divided by the square of height (m) and classified as underweight (<5th), normal weight (5-84.99th), or overweight (≥85th BMI percentile for age) (WHO, 1995). Further, girls who had begun menstruating (n = 600) were then split into three groups:

Those with precocious menarche (i.e., onset at age <12), those with an average timing of menarche (i.e., onset at age 12–13 years), and those with delayed onset of menarche (i.e., age >13 years).

Statistical Analyses

The study population was characterized using the number and mean (standard deviations [SDs]) for continuous variables. Similarly, one-way analysis of variance (one-way ANOVA) were used to examine statistically significant differences in the distribution of continuous variables defined by age at menarche. Pearson correlations between the anthropometric variables and age at menarche were performed. We then compute a multiple regression analysis, with stepwise technique, using the anthropometric variables and menarcheal age as dependent variable to search for the strongest predictors of menarcheal age.

P values <0.05 (two-sided) were considered statistically significant, and the statistical analyses were conducted using IBM SPSS version 22 (IBM SPSS Inc., Chicago, IL, USA).

RESULTS

General characteristics of study participants, according to anthropometric parameters, nutritional status, and age at menarche, are presented in Table 1. The average age at menarche was 13.54 years (SD = 0.90). Regarding nutritional status, overweight participants reach menarche earlier 13.11 years (SD = 0.95) when compared with other categories. The results also showed that only 30 (5%) underweight girls are menstruating while 85 (14%) were overweight and menstruating, and this is statistically significant ($P < 0.05$). Those under thin category reach menarche at older age 14 years (SD = 0.87). Anthropometric dimensions of overweight participants are significantly higher when compared to participants in other categories ($P < 0.05$). Similarly, the anthropometric dimensions; BMI, weight, and CC were significantly higher among participants who have early menarche as compared to participants in the other categories ($P < 0.05$). Still on the same table, we found significant inverse interactions between age at menarche with BMI and weight ($P < 0.05$).

Table 2 presents the results of the study participants based on when they reach maturity. One way ANOVA indicated that participants under early categories have significantly higher BMI ($F = 11.90$, $P < 0.01$). Their weight and CC are significantly higher than that of girls in other menarcheal categories ($F = 27.08$, $P < 0.01$ and $F = 71.71$, $P < 0.01$), respectively. However, hip, waist, and TCs are not statistically significant ($P > 0.05$).

Table 3 shows the comparison between mean anthropometric dimensions of premenarcheal and postmenarcheal girls. The mean anthropometric measurements were significantly higher among

Table 1: Menarcheal age and anthropometric parameters of postmenarcheal subjects according to body dimension categories

Characteristics	Mean (SD)	Mean (SD)			*F*	*P*
		Underweight	Normal	Overweight		
n	600	30	485	85		
Age (years)	16.46 (1.38)	16.83 (1.37)[a]	16.49 (1.36)[ab]	16.14 (1.47)[b]	3.54	0.03
Menarcheal age (years)	13.54 (0.90)	14.00 (0.87)[a]	13.59 (0.87)[b]	13.11 (0.95)[c]	15.32	0.01
Height (cm)	154.92 (0.05)	161.17 (3.03)[a]	155.42 (5.12)[b]	149.88 (3.97)[c]	7.20	0.01
Weight (kg)	49.02 (3.85)	44.43 (1.85)[a]	48.55 (2.92)[b]	53.34 (5.26)[c]	10.59	0.01
BMI (kg/m^2)	20.50 (2.13)	17.11 (0.55)[a]	20.14 (1.54)[b]	23.72 (1.78)[c]	27.05	0.01
Chest circumference (cm)	72.33 (6.54)	72.50 (6.40)	72.01 (6.32)	74.08 (7.55)[a]	3.64	0.03
Hip circumference (cm)	78.85 (7.61)	74.06 (9.51)[a]	78.69 (7.57)[ab]	83.35 (7.06)[b]	2.67	0.04
Waist circumference (cm)	64.30 (5.67)	64.83 (6.60)[a]	66.26 (5.51)[ab]	69.83 (6.60)[b]	3.44	0.03
Thigh circumference (cm)	42.77 (4.70)	40.77 (4.70)	42.75 (4.59)	49.87 (4.65)[a]	2.59	0.04

Data are expressed as mean (SD), [a,b,c]Variables with different superscript are significantly different at *P*<0.05. BMI - Body mass index, SD - Standard deviation

Table 2: Menarcheal age and anthropometric parameters of postmenarcheal subjects according to menarcheal categories (*n*=600)

Parameters	Mean (SD)			*F*	*P*
	Early (*n*=8)	Ideal (*n*=292)	Late (*n*=300)		
Age (years)	16.13 (1.64)	16.07 (1.47)	16.86 (1.16)	26.58	0.01
Menarcheal age (years)	11.00 (1.00)[a]	12.83 (0.38)[b]	14.31 (0.47)[c]	10.64	0.01
Height (cm)	156.13 (6.31)	154.97 (5.37)	154.84 (5.51)	0.24	0.79
Weight (kg)	55.38 (9.21)[a]	49.78 (3.67)	48.11 (3.49)	27.08	0.01
BMI (kg/m^2)	22.73 (3.37)[a]	20.80 (2.07)	20.14 (2.07)	11.90	0.01
Chest circumference (cm)	74.04 (4.91)	73.08 (6.86)	71.71 (6.16)[a]	5.04	0.01
Hip circumference (cm)	79.26 (4.96)	79.30 (7.16)	78.41 (8.07)	1.03	0.36
Waist circumference (cm)	63.01 (5.20)	64.44 (5.74)	64.2 (5.67)	1.44	0.24
Thigh circumference (cm)	43.86 (3.18)	43.56 (4.92)	42.77 (4.70)	2.43	0.09

SD - Standard deviation, BMI - Body mass index. [a,b,c]Variables with different superscript are signifi cantly different at *P*<0.05

postmenarcheal girls as compared to premenarcheal girls ($P < 0.05$) [Tables 4 and 5].

DISCUSSION

In this cohort study, early menarche (≤12 years) was associated with a higher BMI and anthropometric dimensions as compared with participants with late menarche (≥14 years). We observed associations between various weight categories with age at menarche. In addition, we observed associations between anthropometric dimensions and menstrual status (premenarcheal or postmenarcheal).

Hence, our study mainly attempts to answer three questions, which were; (1) what is the relationship between BMI and age at menarche? (2) What is the relationship between certain anthropometric dimension and age at menarche? (3) What is the association of body size parameters between premenarcheal and postmenarcheal girls? We analyzed data from a group of Nigerian secondary school girls from Nsukka and Zaria Local Government Areas of Enugu and Kaduna States respectively. Three schools each were visited per Local Government Area. The ethnicity of subjects from Nsukka was Igbos while only Hausa girls constitute participants from Zaria. We hope that answers to the above questions provided by this study would further add strength to the current pool of evidence regarding the relationship between BMI, anthropometric dimensions, and body size parameters with age at menarche.

Table 3: Mean values for anthropometric variables of menstruating and nonmenstruating females

Anthropometric parameters	Mean (SD)		*t*	*P*
	Postmenarcheal	Premenarcheal		
n	600	200		
Age (years)	16.46 (1.38)	11.63 (0.66)	47.63	0.001
Height (cm)	154.92 (0.05)	147.56 (3.54)	17.91	0.001
Weight (kg)	49.02 (3.85)	38.38 (2.60)	36.41	0.001
BMI (kg/m^2)	20.50 (2.13)	17.64 (1.40)	17.52	0.001
Chest circumference (cm)	72.33 (6.54)	65.41 (6.15)	13.16	0.001
Hip circumference (cm)	78.85 (7.61)	67.20 (4.35)	20.56	0.001
Waist circumference (cm)	64.30 (5.67)	56.38 (4.42)	18.02	0.001
Thigh circumference (cm)	42.77 (4.70)	37.73 (2.79)	14.35	0.001

SD - Standard deviation, BMI - Body mass index

Table 4: Correlation between menarcheal age and anthropometric variables

Parameters	MA	HT	WT	BMI	CC	HC	WC	TC
MA	-	−0.05	−0.33[a]	−0.22[a]	−0.09[b]	−0.10[b]	0.01	−0.06
HT		-	0.03	−0.66[a]	0.10[b]	0.25[a]	0.09[b]	0.10[b]
WT			-	0.73[a]	0.15[a]	0.17[a]	0.04	0.11[a]
BMI				-	0.05	−0.04	−0.03	0.02
CC					-	0.35[a]	0.57[a]	0.15[a]
HC						-	0.31[a]	0.42[a]
WC							-	0.11[a]
TC								-

[a]$P<0.01$, [b]$P<0.05$. MA - Menarcheal age (years), HT - Height (cm), WT - Weight (kg), CC - Chest circumference (cm), HC - Hip circumference (cm), WC - Waist circumference (cm), TC - Thigh circumference (cm), BMI - Body mass index

Table 5: Linear and multiple regression models (selected at a stepwise algorithm) for predicting menarcheal age

Parameters	Predictive equations	*R*	Model R^2	SE	*P*
BMI	MA=15.414 + (−0.091) × BMI	0.215	0.046	0.881	0.0001
WT	MA=17.326 + (−0.077) × WT	0.329	0.109	0.852	0.0001
CC	MA=14.408 + (−0.012) × CC	0.087	0.007	0.899	0.0001
HC	MA=14.447 + (−0.011) × HC	0.097	0.009	0.898	0.0001
WT and BMI	MA=17.311 + (−0.087) × WT + 0.024 × BMI	0.332	0.110	0.852	0.0001

BMI - Body mass index, WT - Weight, CC - Chest circumference, HC - Hip circumference, SE - Standard error

Previous studies have examined the relationship between BMI and early onset of menarche (Must *et al*. 2005; Pierce and Leon, 2005; Bau *et al*. 2009). Some of the findings of these earlier studies are similar to ours (Must *et al*. 2005; Pierce and Leon, 2005; Bau *et al*. 2009). Girls in early menarcheal age category reach menarche earlier than girls in other categories, and these girls have higher values of both BMI and anthropometric dimensions. A study by (Talma *et al*. 2013) on Dutch, Turkish, and Moroccan girls living in the Netherlands showed significant relationship between BMI and age at menarche, whereas (Wang 2002) who studied BMI in relation to age at menarche among girls in the USA reported the same (Wattigney *et al*. 1999) who studied the incidence of increase in obesity in black and white girls in the Bogalusa Heart Study also confirmed the significant secular change toward early menarche with increase in BMI.

Analysis of cross-sectional data collected from National Health and Nutrition Examination Survey, indicates that the odds ratio for overweight boys was 0.65 (at 95% confidence intervals 0.44–0.98) when comparing early and late maturing boys (Wang 2002). Earlier study in Spain by (Vizmanos and Marti-Henneberg 2000) noted that BMI and age at puberty were correlated in boys, while body fat was not correlated with puberty, though boys who mature earlier have low body fat. This is also in agreement with the results of the longitudinal study of (Biro *et al*. 1995) in which they reported that boys who matured earlier have lower BMI ($P < 0.001$) with lower body fat mass ($P < 0.01$).

The decline in menarcheal age is believed to be related to the incidence of obesity, though obesity cannot be said to be the sole factor because the secular change was also found in normal weight girls (Aksglaede *et al*. 2009).

Kaplowitz, 2008 hypothesized that obesity may be ensuring that pregnancy occurs only when there is

adequate fat stored to sustain both the mother and conceptus.

Our study confirmed the differences in BMI in premenarcheal and postmenarcheal girls which were demonstrated in the studies of O'Dea and Abraham, (1995) and Anderson *et al.* (2003). However, several other studies show that girls who have relatively higher BMI are more likely to have earlier menses, as well as a relationship between BMI and other measures of pubertal onset (Anderson and Must, 2005; Kaplowitz, 2008). Few studies have found a relationship between body fat and earlier puberty in boys. Mice and humans that are leptin-deficient fail to enter puberty unless leptin is administered. Evidence from current rodent studies indicate that very low levels of leptin stimulate gonadotropin secretion at the level of hypothalamus and pituitary. Recent evidence indicates that leptin seems to play a permissive role and not the critical metabolic signal triggering puberty.

This study also tried to examine the relationship between certain anthropometric dimensions with age at menarche. Some former studies have shown an inverse relationship between age at menarche with hip and TCs and positive relationship with WC (Lassek and Gaulin 2007). Many studies have reported that taller girls (Moisan *et al*. 1990; Koprowski *et al*. 1999), with more adiposity (Matkovic *et al*. 1997; Bharati and Bharati, 1998) have earlier menarche than their counterparts that are short and lean. Ellison (1981) and Chang *et al*. (2000) related age at menarche to height proposing that skeletal maturation is more significant than adiposity for menarche.

Finally, this study tried to test the hypothesis that postmenarche girls' BMI and anthropometric dimensions are relatively higher than that of their premenarche counterparts. We observed that the BMI and the measured anthropometric parameters of postmenarcheal girls are higher than that of premenarcheal girls which in congruent to the results of previous studies (Khakbazan *et al*. 2005; Kim *et al*. 2010; Rigon *et al*. 2010). A study by Garn *et al*., (1986) described the relationship between BMI and onset of menarche among 10–35 years. They observed that early maturing (<11 years) females had their BMI value 2–3 kg/m^2 higher than their late maturing (>14 years) counterparts. In conclusion, results from previous and present study suggest that weight and BMI are key factors in determining age at menarche. Other factors have also been found to influence age at menarche such as environmental and genetic factors. Despite the geographical genetic difference between subjects in the present study, BMI, weight, and other body size variables still exert significant influence in determining age at menarche.

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Conflicts of Interest

There are no conflicts of interest.

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