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Original Research Article

Systematic Review on Secular Trends and Determinants of Age at Menarche

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Abstract

Adolescent girls when face bleeding from vagina for the first time; is known as menarche that influence lateral life. This review summarizes the findings of important associated environmental factors and reasons in determining the secular trends as well as for exact age of menarche in different ethnicities. The databases of Pubmed and Google Scholar were searched out for 1260 articles using the key words; "adolescent girls; age at menarche; association; environmental factors". All retrieved articles were screened and finally 77 articles were taken into account to study the secular trend and influence of environment factors on the age at menarche. The detailed review of such studies confirmed that menarcheal age in girls had trend to decline; even age of menarche <12 years. The relationship of environment factors with age at menarche has been found controversial during the literature search. The occurrence of changes in birth weight, weight at childhood, adolescent height and socioeconomic status have affect the mean age at menarche but to know the valid marker responsible for such secular change is still a question in solving the problem.

Keywords: Adolescent girls, Age at menarche, Association, Environmental factors

INTRODUCTION

Menarche is first menstrual bleeding in girls that is taken a milestone in female reproductive life and is considered as one of the important indicators of puberty in girls (Banik, 2011). Mean age at menarche varies in different ethnicities (Biro et al., 2001; Mao et al., 2011; Facchini et al., 2008; Liena et al., 2006) and it was assessed that mean menarcheal age has declined over last several decades (Anderson et al., 2003; Graham et al., 1999; Herman-Giddens, 2007; Hwang et al., 2003). There is a secular trend in the mean age at menarche with its steady decline over last several decades (Herman-Giddens, 2007; Hwang et al., 2003). Age at menarche had been reported to be decreasing over the years (Chang and Chen, 2008) that may be due to improvement of general health and nutrition of a population (Marshall and Tanner, 1986).

Age at menarche is considered as an important predictor of health status during adolescence, adulthood, and post-menopause. Early menarche is associated with chronic diseases specially, it is considered a higher risk factor for breast cancer in the women (Chie et al., 1997; Peeters et al., 1995; Tovar-Guzman et al., 2000). Various cardiovascular diseases have been reported to be associated with early menarche girls (Cooper et al., 1999; Lakshman et al., 2009). Girls who have less age at menarche may face more ischemic heart disease (Cooper et al., 1999; Wu et al., 2006) and mortality from stroke (Cui et al., 2006). On the other hand, elevated blood pressure and glucose intolerance in the body have been associated more with the women having early menarche as compare to late menarcheal women (Remsberg et al., 2005). Similarly, high bone mineral

density has a positive relation with age at menarche (Ito et al., 1995). Recent studies revealed association of age at menarche with body composition, insulin sensitivity, blood lipid levels (Feng et al., 2008) and earlier menarche (before 12 yrs) results in higher mortality (Lakshman et al., 2009).

Age at menarche is a complex trait of human female and is influenced by genetic as well as and environmental factors. Some studied exhibited role of such factors in pubertal timing that 57-82% of the variance in pubertal timing is due to heritable factors so the rest of 18-53% influence can be determined by environmental factors (Morris et al., 2011; Anderson et al., 2007). Although, genetics play a major role in determining the variation in age at menarche but a number of environmental factors have been well documented that may contribute to age at menarche like birth size (Terry et al., 2009), weight gain in childhood (Amigo et al., 2010; Mesa et al., 2010), height (Hesketh et al., 2002), physical activity (Chavarro et al., 2004), alcohol use (Costello et al., 2007), family relationship (Ellis et al., 1999), Childhood stress (Hoier, 2003; Comings et al., 2002), parental marital relationship (Ellis and Garber, 2000) and socioeconomic status (James-Todd et al., 2010; Rigon et al., 2010).

In epidemiological studies, investigation of environmental as well as genetic factors contributing to puberty and age at menarche both are important to understand the physiological mechanism and associated health problems. In this paper, I will review association of environmental factors and secular change in age of menarche in human females. After providing an overview on the results of the environmental factors under this literature search, I aim to give recommendations for future studies to identify environmental factors as well as genetic factors involved in determining the variation in the menarcheal age.

METHODS

The databases of Pubmed and Google Scholar were searched electronically till July 2016 using keywords “adolescent girls; age at menarche; association; environmental factors” and 1260 articles were collected. All retrieved 1260 articles were screened keeping their relevancy to the topic of this manuscript. Emphasis was give to study the secular trend and influence of environment factors on the age at menarche in different ethnicities. Finally, 77 articles comprising of association studies of environmental factors with age at menarche were taken in to account for detailed review and discussion.

RESULTS

Age at menarche is influenced by various environmental factors and a number of studies have been conducted to determine these factors, as well as to diagnose the possible early menarcheal consequences (Kaplowitz, 2008; Karapanou and Papadimitriou, 2010). The factors reported in 19th century that had influence on the physical maturation of girls were climate, ethnicity, social status, urban or rural residence, physical activity, education, sexual stimulation, housing, inheritance, and health status (Heidi, 1986). In the 20th century, same study was carried out and association of other factors like season and month at birth, physique, position at the sibship, family income, occupation of parents, education of parents and family size were reported with the age at menarche (Heidi, 1986).

Recent studies also confirm the possible association of such factors with age at menarche like birth size (Terry et al., 2009; Sloboda et al., 2007; Charmaine et al., 2006), weight gain in childhood (Dunger et al., 2006; Sloboda et al., 2007; Amigo et al., 2010; Mesa et al., 2010), height (Mesa et al., 2010; Hesketh et al., 2002), physical activity (Chavarro et al., 2004), alcohol use (Costello et al., 2007; Biehl et al., 2007), family relationship (Ellis et al., 1999), Childhood stress and absence of a father were found to be associated during this study (Hoier, 2003; Comings et al., 2002), parental marital relationship (Ellis and Garber, 2000) and socioeconomic status (James-Todd et al., 2010; Rigon et al., 2010). However, this review comprised of discussion on four important environmental factor i.e. birth weight, height at childhood, weight at childhood and presence of high socioeconomic status at childhood.

Trend in the different ethnic populations

Age at menarche varies among different populations of the world (Table 1). The mean age at menarche in 1980 observed in Swiss females was 13.4 years (Largo and Prader, 1983) and it was 12.4 years for Japanese girls (Hoshi and Kouchi, 1981). Study conducted in 1987 on US girls revealed 12.7 years of age at menarche for white girls while black girls had 12 years age of menarche (Biro et al., 2001) and on other hand two similar surveys carried out in US from 1988 to 1994; first documented 12.6 years age of menarche for white girls and 12.1 years age of menarche for black girls (Anderson et al., 2003) whereas second survey comprised of three ethnic groups showed 12.55 years age of menarche for Non-Hispanic White, 1206 years age of menarche for Non-Hispanic Black and 12.25 years age of menarche for Mexican-American girls (Chumlea et al., 2003). One study conducted in US from 1992-93 explored the ages of menarche as 12.88 years for Caucasian females and 12.16 years for African-American females (Herman-Giddens et al., 1997). A cross-sectional growth study in 1990 on Catalan population reported 12.31 years of age at menarche in girls (de la Puente et al., 1997). Two

Table 1. Studies showing average age at menarche in different populations

Year of survey	Population	N[a]	AAM[b]	Study type	Reference
1954-80	Swiss	143	13.4±1.0	Longitudinal	(Largo and Prader, 1983)
1979-80	Japan	284	12.40±3.04	Correlation	(Hoshi and Kouchi, 1981)
1987	White	1166	12.7±1.2	Longitudinal	(Biro *et al.*, 2001)
	Black	1213	12.0±1.2		
1990	Catalan	5472	12.31	Cross-sectional	(de la Puente *et al.*, 1997)
1988-94	White	1454	12.6±0.11	Cross sectional	(Anderson *et al.*, 2003)
	Black	296	12.14±0.25		
1988-94	Non-Hispanic White	427	12.55±1.23	Cross sectional	(Chumlea *et al.*, 2003)
	Non-Hispanic Black	576	12.06±1.54		
	Mexican-American	515	12.25±1.44		
1992-93	Caucasian	17077	12.88±1.20	Cross-sectional	(Herman-Giddens *et al.*, 1997)
1992-93	African- American		12.16±1.21		(Herman-Giddens *et al.*, 1997)
1993	Chinese	12727	13.7	Cohort	(Graham *et al.*, 1999)
1993	Chinese	6467	12.38±0.40	Cross-sectional	(Huen *et al.*, 1997)
1992-94	Caucasian	1082	11.5±1.3	Cohort	(Wattigney *et al.*, 1999)
1992-94	African- American	1082	11.4±1.3	Cohort	(Wattigney *et al.*, 1999)
1996	Greek	1134	12.27±1.13	Retrospective	(Papadimitriou *et al.*, 1999)
1997	Thai	15998	12.51±1.17	Retrospective	(Chompootaweep *et al.*, 1997)
1999	India	366	13±1.0	Anthropometric	(Bagga and Kulkarni, 2000)
1999	Chinese (Urban)	1171	12.8±0.9	Cross-sectional	(Hesketh *et al.*, 2002)
1999	Chinese (Rural)	815	13.2±1.0	Cross-sectional	(Hesketh *et al.*, 2002)
1999-00	Indian (Urban)	94	12.99±1.11	Correlation	(Deo and Gattarji, 2004)
1999-00	Indian (Rural)	74	13.38±1.07	Correlation	(Deo and Gattarji, 2004)
1998-01	South Korea	1061	12.67±1.17	Cohort	(Hwang *et al.*, 2003)
1999-01	Norway/Western Countries	2759	12.75±0.05	Cross sectional	(Liena *et al.*, 2006)
	Eastern Europe	90	12.45±0.25		
	Sub-Saharan Africa	97	12.75±0.45		
	North Africa/ Middle East	221	12.55±0.15		
	South Asia	367	12.6±0.1		
	East Asia/ Pacific	96	12.3±0.2		
1995-2001	Portuguese	3329	12.44±1.26	Anthropometric	(Padez, 2003)
2001	Jordanian	1823	13.79±1.23	Cross-sectional	(Ammari *et al.*, 2004)
2003	Chinese	1573	11.67±0.93	Correlation	(Tang *et al.*, 2003)
2002-04	Kazakhs (Urban)	267	13.12±1.39	Retrospective	(Facchini *et al.*, 2008)
2002-04	Kazakhs (Rural)	252	13.27±1.32	Retrospective	(Facchini *et al.*, 2008)
2002-04	Russian (Urban)	262	12.79±1.25	Retrospective	(Facchini *et al.*, 2008)
2002-04	Russian (Rural)	256	13.4±1.43	Retrospective	(Facchini *et al.*, 2008)
2006	Greek	750	12.29±1.19	Retrospective	(Papadimitriou *et al.*, 2008)
2008	Chinese	6476	12.62±0.99	Cross-sectional	(Mao *et al.*, 2011)

[a]number of studied subjects
[b]mean age at menarche

different studies during same year (1993) in Chinese population had difference of more than one year in menarcheal ages as one study mentioned 13.7 years of age at menarche (Graham et al., 1999) while other mentioned 12.38 years of age at menarche in girls (Huen et al., 1997). Similar to a previous study on Caucasian and African-American females (Herman-Giddens et al., 1997), another study conducted during 1992-94 presented 11.5 years age of menarche for Caucasians and 11.4 years age of menarche for African-Americans (Wattigney et al., 1999).

In 1996, data collected for Greek girls showed 12.27 years of age at menarche (Papadimitriou et al., 1999) following the next years study (1997) on Thai girls that reported 12.51 years of menarcheal age (Chompootaweep et al., 1997). Menarcheal age noted for Indian girls in 1999 was 13 years (Bagga and Kulkarni, 2000) and during the same year it was 12.8 years for those Chinese girls who were living in urban areas while Chinese girls living in rural areas had 13.2 years of menarcheal age (Hesketh et al., 2002). Study in 1999-2000 on Indian girls showed 12.99 years age of menarche for urban area girls and 13.38 years for rural area girls (Deo and Gattarji, 2004) and a cohort study during 1998-2001 on South Korean girls revealed 12.68 years of menarche age (Hwang et al., 2003). Multi-population study comprised of data on various girls of different parts of the world during 1999-2001 documented variation in menarcheal ages; it was 12.75 years for girls of Norway/Western Countries, 12.45 years for girls of Eastern Europe, 12.75 for girls of Sub-Saharan Africa, 12.55 years for girls of North Africa/ Middle East, 12.6 years for girls of South Asia and 12.3 years for East Asia/ Pacific (Liena et al., 2006).

During 1995-2001, investigated age of menarche for Portuguese girls was 12.44 years (Padez, 2003) and another study in 2001 reported higher menarcheal age of 13.79 years in Jordanian girls (Ammari et al., 2004). Chinese study in 2003 exhibited 11.67 years of menarcheal age in girls (Tang et al., 2003). Menarcheal data of Kazakh and Russian girls during 2002-2004 explored that Kazakh girls of urban area had 13.12 years of menarcheal age while rural area girls had 13.27 years of menarcheal age and Russian girls of urban areas showed 12.79 years of menarcheal age while rural area girls had13.4 years of menarcheal age (Facchini et al., 2008). In addition to previous study (Papadimitriou et al., 1999), another recent Greek study in 2006 reported 12.29 years of menarcheal age in girls (Papadimitriou et al., 2008) and a recent Chinese study in 2008 revealed that the menarcheal age of girls was 12.62 years (Mao et al., 2011). Menarcheal data not only represented variation of age in different ethnicities but it is also important to take into account that a secular decline in average age at menarche has been reported in various studies. The secular changes in the mean age at menarche have been associated with different populations of US girls; survey conducted in 1992-1993 on Caucasians (Herman-Giddens et al., 1997) reported highest age at menarche (12.88 years) but lateral surveys presented comparatively less age at menarche (Wattigney et al., 1999; Anderson et al., 2003). On other hand, data collected during 1988-1994 showed 12.6 years of menarcheal age for white girls in one study (Anderson et al., 2003) and it was 12.55 years for Non-Hispanic white girls in other study (Chumlea et al., 2003) conducted during the same period. However, lowest menarcheal age (11.5 years) in lateral study in 1992-1994; gave evidence of secular change in age of menarche in Caucasian girls (Wattigney et al., 1999). Similar secular change can be observed in African-American girls where early study (Herman-Giddens et al., 1997) present higher age at menarche (12.16 years) while lateral study (Wattigney et al., 1999) exhibited lower age at menarche (11.4 years). However, only Black girls in US showed opposite trend in menarcheal age as it was 12 years in early study (Biro et al., 2001) and 12.14 years in lateral study (Anderson et al., 2003). Like Black girls of US, studies about Greek girls also revealed opposite trend as older study (Papadimitriou et al., 1999) showed less age at menarche (12.27 years) while recent study (Papadimitriou et al., 2008) documented high menarcheal age (12.29 years).

Indian studies committed that menarche age is decreasing; a study reported that age at menarche has been lowered by two years as compared to the age at menarche (13 years) investigated in the current study (Bagga and Kulkarni, 2000) and the theory was supported by a lateral study that further showed a decline in the age of menarche (Deo and Gattarji, 2004). Secular decline of 2.8 years, from 16.5 years to 13.7 years of menarcheal age has been claimed over an 40-years time interval in Chinese girls (Graham et al., 1999). The claim (Graham et al., 1999) seems to be true as maximum results of lateral studies provided in Table 1 for Chinese girls also exhibited a decrease in menarcheal age by describing <13 years of age at menarche (Huen et al., 1997; Mao et al., 2011; Hesketh et al., 2002) rather than >13 years of menarcheal age (Graham et al., 1999) with exception of only one study that concluded <12 years of menarcheal age in Chinese girls (Tang et al., 2003).

Moreover, secular trend of decline in the age of menarche in the girls got conformity by detailed overview of individual results of searched articles about other ethnicities like Japanese study revealed that menarcheal age noticed in 1979-1980 is less as compared to 13.27 years observed in 1958 (Hoshi and Kouchi, 1981); study on Portuguese population reported a decrease in mean age at menarche from 15 years for girls born in 1880 to 12.44years for those born in the 1980s (Padez, 2003) and authors of South Korean women study documented a decline in the age at menarche from 16.8 to 12.7 years during the past 67 years (Hwang et al., 2003). Variation in the menarcheal ages between the urban and rural girls

Table 2. Studies showing association of low birth weight with age at menarche

Year of survey	Population	N[a]	AAM[b]	Year[c]	P-value	Reference
1989-90	Australia	156	12.6±2.2	0	0.272	(Charmaine *et al.*, 2006)
1995-97	Norwegian	3155	13.25±0.0	+1	0.03	(Romundstad *et al.*, 2003)
1996-97	Poland	810	12.7±1.74	+1	<0.05	(Koziel and Jankowska, 2002)
1998-99	Philippine	997	13.1±0.8	0	>0.05	(Adair, 2001)
2001-06	White	262	12±1.72	0	0.79	(Terry *et al.*, 2009)
	African-American					
	Puerto Rican					

[a] Number of studied subjects
[b] Mean age at menarche with standard deviation
[c] Possible difference in the age at menarche due to low birth weight among subjects of a study

of the same ethnicity has also been noticed that the mean age at menarche is lower for those girls who live in urban areas as compared to the girls living in rural areas on the basis of results of the three studies conducted on different ethnicities where Chinese study reported menarcheal ages of 12.8 years for urban girls and 13.2 years for rural girls (Hesketh et al., 2002); Indian study revealed menarcheal ages of 12.99 years for urban girls and 13.38 years for rural girls (Deo and Gattarji, 2004) and study among Kazakhs and Russian females revealed menarcheal ages of 13.12 years for urban Kazakhs, 13.27 years for rural Kazakhs, 12.79 years for urban Russians and 13.4 years for rural Russians (Facchini et al., 2008).

Determinants of age at menarche

Birth weight

Some studies describe an influence of prenatal and postnatal growth for adrenarche (Ong et al., 2004), central fat distribution (Garnett et al., 2001), and insulin sensitivity at age of 8 years (Bavdekar et al., 1999) while in other studies, low birth weight in girls has been reported to be associated with reduced ovarian size (Ibanez et al., 2003), reduced ovulation rate (Ibanez et al., 2002), ovarian hyperandrogenism after precocious pubarche (Ibanez et al., 1998) and earlier menarche (Romundstad et al., 2003). Nowadays it is increasing evidence that reproductive health like menarche, menstrual disorder, polycystic ovarian syndrome may be determined by early events (Gluckman and Hanson, 2006). Studies in Table 2 illustrated an association of lower birth weight with age at menarche. Three studies comprised of Australian girls during 1989-90 (Charmaine et al., 2006); Filipino girls during 1998-1999 (Adair, 2001) and girls of White, African-American and Puerto Rican ethnicities during 2001-2006 (Terry et al., 2009) gave an idea of association of age at menarche with low birth weight but the results were found non-significant. However, two other studies conducted on Norwegian girls during 1995-1997 (Romundstad et al., 2003) and Poland girls during 1996-1997 (Koziel and Jankowska, 2002) demonstrated that the girls who had lower weight at birth gained an earlier age at menarche than other girls; their results indicated a significant positive association of low birth weight with age at menarche and there is need of further assessment studies.

Weight at childhood

Age at menarche in girls had association with attainment of a body weight of 47.8 kg known as critical weight that caused the change in metabolic rate and result in an impact on the hypothalamic sex steroid receptor reducingits feedback sensitivity and a sufficient rise in estrogen secretion to support menstruation (Frisch and Revelle, 1970). Lateral study conducted by same researchers reported that mean body weight at menarche about 48 kg had no significant effect on variation of menarcheal ages and previous hypothesis of a direct relation between a critical weight and menarche is proposed (Frisch and Revelle, 1971). The hypothesis of Frisch and Revelle 1971, described that start of menstruation at a "critical" weight" associated with the achievement of a characteristic of body composition and lateral attempt was made to confirm it in another study conducted on body fat of girls under 8 years of age; the girls with simple obesity showed greater percentage of body fat

Table 3. Studies showing association of higher weight at childhood with age at menarche

Year of survey	Population	N[a]	AAM[b]	Noticeable Age[c]	Year[d]	P-value	Reference
1929-50	US	181	12.9±0.09	11.4	-3	<0.05	(Frisch and Revelle, 1970)
1929-50	US	181	12.9±0.09	11.9	-2.1	>0.05	(Frisch and Revelle, 1971)
1974	US	215	12.47±0.20	8	-4.67	>0.05	(Crawford and Osler, 1975)
1989-90	Australia	156	12.6±2.2	8	-5.9	<0.001	(Charmaine *et al.*, 2006)
1991	India	366	13±1	9	-6	<0.05	(Bagga and Kulkarni, 2000)
1970-94	US	3272	12.54±0.10	>10	-2.64	0.05	(Anderson *et al.*, 2003)
1996-97	Poland	1060	12.44±2	14	-5.2	<0.05	(Koziel and Jankowska, 2002)
1998-99	Philippine	997	13.1±0.8	8	-1.5	>0.05	(Adair, 2001)
2001-06	US	262	12.5±1.72	7	-3.44	0.01	(Terry *et al.*, 2009)
2010	Italy	3784	12.4±1.3	<12	-0.14	<0.05	(Rigon *et al.*, 2010)

[a]Number of studied subjects
[b]Mean age at menarche with standard deviation
[c]Noticeable age among at which higher weight was found to be associated with age at menarche
[d]Possible difference in the age at menarche due to higher weight gained at specific age among subjects of a study

than normal menarcheal girls but had no signs of puberty and results of this study were documented as the achievement of a critical body weight is not necessary to be associated with menarche (Crawford and Osler, 1975).

Table 3 presents an association of weight gained at adolescent age and menarchear age also have been taken into account in various studies like a study reported that girls who gained more weight at the age of 9 years had early menarche (Bagga and Kulkarni, 2000). Similarly, three other studies described association of higher body mass index of girls at 8 years of age with earlier menarche but one study showed highly significant result (Charmaine et al., 2006) while other two studies reported non-significant results for importance of such association of weight gained at age of 8 years with menarcheal age (Adair, 2001; Crawford and Osler, 1975). However another most recent study opposite to the results of all previous studies suggested a significant association of weight gained at age 7 years and age at menarche; women with an earlier age at menarche were more likely to be heavier at age 7 years compared with those who attained later age at menarche (Terry et al., 2009) while other studies highlight the importance of weight gained at the age of >10 years with age of menarche (Rigon et al., 2010; Anderson et al., 2003). All studies listed in Table 3 showed negative association of higher adolescent weight (obesity) with age at menarchebut with different level of significance. Study on US girls revealed that the percentage of girls increased from 16% to 27% over the 25 years between the 2 surveys who were 10 to 15 years old and showed >85th percentile for body mass index that result in strongly association of higher relative weight with earlier menarche (Anderson et al., 2003). In an Indian study, weight has been predicted an indicator of fat accumulation that had significant correlation with age at menarche (Bagga and Kulkarni, 2000) and same results were found in Poland girls (Koziel and Jankowska, 2002) and in a most recent study on Italian population (Rigon et al., 2010) whereas it is also noticeable that few studies have listed non-significant association of weight gained at childhood with age at menarche (Frisch and Revelle, 1971; Crawford and Osler, 1975; Terry et al., 2009) that need further attention in future research.

Height at childhood

The year of maximum increment in standing height has been reported to be associated with age at menarche Table 4. Some studies revealed that the girl who are taller at adolescent age; they had more age at menarche indicating a positive association like it has been reported that average US-girls attains maximum height increment during the year preceding the year of menarche (Simmons and Greulich, 1943) and other study on height and age at menarche described clearly that late maturing US-girls are taller as compared

Table 4. Studies showing association of more height at childhood with age at menarche

Year of survey	Studied Population	N[a]	AAM[b]	Noticeable Age[c]	Year[d]	P-value	Reference
1935	US	187	12.63±0.25	>7	-1	<0.05	(Simmons and Greulich, 1943)
1929-50	US	181	12.9±0.09	11.9	+2.1	<0.02	(Frisch and Revelle, 1971)
1970	US	181	12.9±0.09	11.4	+3.1	<0.05	(Frisch and Revelle, 1970)
1974	US	215	12.47±0.20	8.7	-0.4	<0.001	(Crawford and Osler, 1975)
1979-80	Japan	284	12.4±3.04	9	-5.81	<0.01	(Hoshi and Kouchi, 1981)
1982	South Brazil	2083	12.44±0.13	<12	-2	<0.05	(Mesa *et al.*, 2010)
1987	Papua New Guinea	310	15.8±1.5	14.3	0	>0.05	(Groos and Smith, 1992)
1989-90	Australia	156	12.6±2.2	>8	±5.9	>0.05	(Charmaine *et al.*, 2006)
1990	Catalan	5472	12.31	-----	----	<0.05	(de la Puente *et al.*, 1997)
1991	Oman	683	13.3±0.09	-----	----	<0.05	(Musaiger, 1991)
1991	India	366	13±1.0	9	+6	<0.05	(Bagga and Kulkarni, 2000)
1993	New Zealand	415	12.9±2.1	7	--	<0.05	(St George *et al.*, 1994)
1997	Netherland	3562	13.15±1.85	>11	-3	<0.05	(Mul *et al.*, 2001)
1997	India	533	13.75	--	--	<0.05	(Rao *et al.*, 1998)
1999	China (Urban)	214	12.8±0.9	12	-5	<0.05	(Hesketh *et al.*, 2002)
	China (Rural)		13.2±1.0				

[a]Number of studied subjects
[b]Mean age at menarche with standard deviation
[c]Noticeable age among at which maximum height may be found to be associated with age at menarche
[d]Possible difference in the age at menarche due to maximum height gained at specific age among subjects of a study

to early maturing girls (Frisch and Revelle, 1970). Similar estimated relationship between height and age at menarche in lateral study showed that menarcheal age increases as mean height increases significantly (Frisch and Revelle, 1971) and an Indian study also reported that height is known as an indicator of skeletal maturity that had a significant positive correlation with age at menarche (Bagga and Kulkarni, 2000). On other hand, some studies exhibited opposite results that the girls who are taller at their adolescent age; they have trend to gain early menarche indicating negative correlation like a results of a previous study on US-girls has been demonstrated that taller girls had younger at age at menarche than normal girls (Crawford and Osler, 1975) and same significant negative association was found later in Japanese girls (Hoshi and Kouchi, 1981); the girls participating in survey of Netherland (Mul et al., 2001); Chinese girls (Hesketh et al., 2002) and South Brazilian girls (Mesa et al., 2010).

Adolescent age at which a girl gains maximum height is also important to be taken into account in studying the association of height and menarcheal age an older study showed that height gained at >7 years of age is important to be associated with early age at menarche (Simmons and Greulich, 1943) and this study was supported by another later study where height gained at 7 years of age in girls has been illustrated to be associated with age at menarche (St George et al., 1994) while some other studies reported height gain at ≤ 9 years of age (Bagga and Kulkarni, 2000; Hoshi and Kouchi, 1981; Crawford and Osler, 1975) and height gain at > 9 years of ages (Frisch and Revelle, 1971; Frisch and Revelle, 1970; Mesa et al., 2010; Mul et al., 2001; Hesketh et al., 2002) in girls are significantly associated with age at menarche. Unlike significant association, non-significant results between correlation of height and menarcheal age have been reported. It has been documented in a study that height is not a valid predictor for age at menarche so height trait was rejected to be associated with age at menarche (Groos and Smith, 1992) and same conclusion was drawn by different authors of another study (Charmaine et al., 2006) that invite

Table 5. Association of high socioeconomic status at childhood with age at menarche

Year of survey	Population	N[a]	AAM[b]	Noticeable Age[c]	Year[d]	P-value	Reference
1996-97	Poland	1060	12.7±1.74	8.8	0	>0.05	(Koziel and Jankowska, 2002)
1997	India	533	13.75	9	-2.3	<0.05	(Rao *et al.*, 1998)
1998-99	Philippine	997	13.1±0.8	8	-1.5	<0.05	(Adair, 2001)
2001-06	US	237	12±1.6	7	+11	<0.05	(James-Todd *et al.*, 2010)
2001-06	White	262	12.5±1.72	7	+3.44	0.01	(Terry *et al.*, 2009)
	African-American						
	Puerto Rican						
2008	US (White)	2379	12.4±4.5	8	+9	<0.05	(Braithwaite *et al.*, 2009)
	US (Black)				-9		
2009	Italy	3783	12.4±1.3	---	0	>0.05	(Rigon *et al.*, 2010)

[a]Number of studied subjects
[b]Mean age at menarche with standard deviation
[c]Noticeable age among at which socioeconomic status was found to be associated with age at menarche
[d]Possible difference in the age at menarche due to socioeconomic status gained at specific age among subjects of a study

future researchers to make the idea clearer about this adolescent trait.

Socioeconomic status at childhood

Higher socioeconomic status were defined, presence of households, higher maternal education, better housing quality, valuable assets such as a TV or refrigerator (Adair, 2001), family income, paternal occupation, education (James-Todd et al., 2010), highest education level of parents or guardians, house hold income (Braithwaite et al., 2009) and parity, family size, parents education and their occupation (Rao et al., 1998). Studies revealed that the girls belong to low socio-economic class had different age at menarche as compare to high socio-economic class girls (Table 5). Indian study revealed significant association for those girls who belong to high class with early menarche indicating a negative correlation (Rao et al., 1998). The results of Rao et al. 1998 were supported by another findings of such negative association among higher class of Filipinos with their age of menarche (Adair, 2001). Recently, a cohort study on US-Black girls aged 9 to 10 also exhibited negative correlation by demonstrating that high class girls had earlier age at menarche (Braithwaite et al., 2009). However, results US-White girls showed opposite results in the same study that girls with high socioeconomic status at their adolescent age were late maturing indicating a positive association of high socioeconomic status and age at menarche (Braithwaite et al., 2009) similar positive correlation between higher socioeconomic status at adolescent age of girls and age at menarche have been found in other studies (Terry et al., 2009; James-Todd et al., 2010).

Availability of higher socioeconomic status at the age of 7 years may result in the positive association of this trait with age at menarche in the girls (Terry et al., 2009; James-Todd et al., 2010). One previous study revealed a negative association of higher socioeconomic status that girls have at 8 years of age (Adair, 2001) while other lateral study disagreed by indicating positive association higher socioeconomic status at 8 years of age (Braithwaite et al., 2009) and another study explored importance of presence of higher socioeconomic statusat 9 years of age for negative association of this trait with menarchear age (Rao et al., 1998). A most recent study on Italian population documented that there were no confirmation of current socioeconomic factors to play as significant on age at menarche (Rigon et al., 2010) same like a previous study on Poland girls that also described no indicators for significant association of socioeconomic status and age at menarche (Koziel and Jankowska, 2002).

DISCUSSION

Trends in the age at menarche

The studies mentioned in the Table 1 show variations of menarcheal ages in the girls of different ethnicities. It is noticeable that not only there is a variation of age at menarche among various ethnicities (Papadimitriou et al., 1999; Biro et al., 2001; Mao et al., 2011; Deo and Gattarji, 2004; Facchini et al., 2008; Liena et al., 2006) but variation of menarcheal ages was also found within the same ethnicities like Caucasians (Herman-Giddens et al., 1997; Wattigney et al., 1999; Biro et al., 2001; Anderson et al., 2003); Black (Biro et al., 2001; Anderson et al., 2003); African-Americans (Wattigney et al., 1999; Herman-Giddens et al., 1997); Greek (Papadimitriou et al., 2008; Papadimitriou et al., 1999); Indians (Bagga and Kulkarni, 2000; Deo and Gattarji, 2004) and Chinese girls (Graham et al., 1999; Huen et al., 1997; Mao et al., 2011; Tang et al., 2003; Hesketh et al., 2002) as worked out by different authors during various time intervals. The detailed review of such studies confirmed that menarcheal age in girls had trend to decline; even age of menarche <12 years has been well documented in the studies conducted after 1990s (Tang et al., 2003; Wattigney et al., 1999). However, few studies revealed contradictions about such secular trend in Black girls (Biro et al., 2001; Anderson et al., 2003) and Greek girls (Papadimitriou et al., 2008; Papadimitriou et al., 1999) indicating an increase of menarcheal from early to lateral findings opposite to the results of secular change in various ethnicities.

Studies comprising of urban and rural data (Table 1) exhibited lower age of menarche for the girls living in urban areas than those who live in rural areas (Facchini et al., 2008; Deo and Gattarji, 2004; Hesketh et al., 2002); also scientists have been emphasized that better health and living standard affect the mean age at menarche (Graham et al., 1999; Padez, 2003) so the reason behind this variation of menarcheal ages in the same ethnicity may be a result of such differences between these two areas. Moreover, black girls had lower age than white girls in the same environment (Anderson et al., 2003) and the results on secular change of age at menarche in some studies (Ammari et al., 2004; Chumlea et al., 2003) have not been found significantly different so there is still need to give more attention and conduction of further studies to know the influence of environmental factors as well as genetic factors to make the concept clear.

Complexity in proposing a single factor affecting age at menarche

The relationship of environment factors with age at menarche has been found controversial during the literature search. Some studies (Table 2) about association of birth weight with age at menarche gave significant results (Romundstad et al., 2003; Koziel and Jankowska, 2002) but other studies provide no significant association between these two traits (Charmaine et al., 2006; Terry et al., 2009; Adair, 2001). All studies listed in Table 3 showed negative association of higher weight at childhood (obesity) with age at menarche that show more importance of this trait and should be considered in future studies with more attention however some studied about such negative association reported with P-value <0.05 (Anderson et al., 2003; Bagga and Kulkarni, 2000; Koziel and Jankowska, 2002; Rigon et al., 2010) and few other studies reported P-value > 0.05 (Frisch and Revelle, 1971; Crawford and Osler, 1975; Terry et al., 2009).

Few studies (Table 4) revealed that late maturing girls are taller (Simmons and Greulich, 1943; Bagga and Kulkarni, 2000; Frisch and Revelle, 1970; Frisch and Revelle, 1971) while on other hand, some studies support that early maturing girls are taller (Crawford and Osler, 1975; Hoshi and Kouchi, 1981; Hesketh et al., 2002; Mesa et al., 2010; Mul et al., 2001) while other documented that height has also been reported as invalid predictor for age at menarche (Groos and Smith, 1992; Charmaine et al., 2006). Authors demonstrated different adolescent ages in their studies at which girls gain higher weight (Bagga and Kulkarni, 2000; Charmaine et al., 2006; Adair, 2001; Crawford and Osler, 1975; Terry et al., 2009; Anderson et al., 2003) or maximum height (St George et al., 1994; Bagga and Kulkarni, 2000; Simmons and Greulich, 1943; Crawford and Osler, 1975; Hesketh et al., 2002; Mesa et al., 2010; Mul et al., 2001) to be associated with age at menarche that again gave unclear idea about association of these traits and menarcheal age. Comparison of the studies (Table 5) for importance of specific adolescent age and presence of socioeconomic status also exhibited contradictions to be associated positively or negatively with the age at menarche in the girls (Adair, 2001; Braithwaite et al., 2009; James-Todd et al., 2010; Rao et al., 1998) and same opposite results can be seen on the significant association (Adair, 2001; Braithwaite et al., 2009; James-Todd et al., 2010; Rao et al., 1998; Terry et al., 2009) and non-significant association (Koziel and Jankowska, 2002; Rigon et al., 2010) of socioeconomic status with age at menarche that again confuse the concept of association of this trait with menarcheal age and there is need of further studies.

CONCLUSION

The occurrence of changes in birth weight, weight at childhood, adolescent height and socioeconomic status have affect the mean age at menarche and it has been observed that menarcheal age is decreasing in various ethnicities of the world but to know the valid marker

responsible for such secular change in the menarche age is still a question as so for our reviewed data on environmental factors that had contradictions in the finding of different authors about the specific traits to be associated with age at menarche and non factor alone can be called as valid indicator of age at menarche. So there is still need for much work on a range of environmental factors as well genetic studies to investigate the facts.

Competing Interests

Author declares that he has no competing interests.

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