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Association of early menarche with elevated BMI, lower body height and relative leg length among 14- to 16-year-old post-menarcheal girls from a Maya community in Yucatan, Mexico

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Abstract: Human body segments have different timing and tempo of growth. Early menarche (EM) as an indicator of early reproductive maturity results in a shortened height and leg length. Relatively larger trunk may increase risk for more body fat deposit and higher body mass index (BMI) due to the allometry of total body fat with body proportions. The objective of the study was to assess the association of EM with BMI, absolute body size [height, sitting height (SH), subischial leg length (SLL)] and relative body dimensions [sitting height to subischial leg length ratio (SHSLLR), relative subischial leg length (RSLL)] among 14- to 16-year-old post-menarcheal girls from a rural Maya community in Quintana Roo, Yucatan, Mexico. In a cross-sectional study, post-menarcheal girls (n=51) aged 14 to 16 years had EM (n=22) (<12 years of age) and not early menarche (NEM, n=29). Anthropometric measurements of height, weight, and SH were recorded. Derived variables were BMI, height and BMI-for-age z-scores, SLL, SHSLLR, and RSLL. Mean value of age at menarche (AM) was 13 years (EM 11 years, NEM 14 years). Mean values of height (EM 159 cm, NEM 164 cm), BMI (EM 20 kg/m^2, NEM 19 kg/m^2), sitting height (EM 81 cm, NEM 78 cm), SLL (EM 79 cm, NEM 85 cm), SHSLLR (EM 102.93%, NEM 92.03%), and RSLL (EM 49%, NEM 52%) were different ($p<0.05$) in the two groups. BMI showed significant negative correlation with AM (Pearson's r=-0.29, $p<0.04$). Linear regression models adjusted for age showed that EM had different interrelationships ($p<0.05$) with body dimensions: positive with BMI, SH, SHSLLR, and negative with height, SLL, and RSLL. Earlier AM was associated with higher BMI, SH, SHSLLR and lower SLL, RSLL, explaining lower body height and leg length among the participant EM girls. In the light of life history theory, EM results in a growth trade-off, short stature and larger trunk relative to leg length that might enhance risk for body fat gain.

Key words: Early menarche, BMI, sitting height, leg length, body proportion

Original article

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Introduction

Early menarche (EM), defined by at least one menstruation before the twelfth birthday of a girl (Arcoverde et al. 2020; Must et al. 2005) is reported to be associated with lower body height in comparison with peers of not early menarche (NEM) when socioeconomic and other environmental factors remain constant in both groups (Conway et al. 2012; Kang et al. 2019). A previous study also reported the association of EM with early age at peak height velocity and low leg length-to-sitting height ratio (Conway et al. 2012). EM acts as a risk factor for developing overweight and obesity in adolescence and adulthood (Martínez et al. 2010; Rosenfield et al. 2009). Several studies have examined issues regarding menarche and adiposity: Brazil (Arcoverde et al. 2020), Iran (Pejhan et al. 2013), Korea (Oh et al. 2012), Kuwait (Al-Awadhi et al. 2013), Mexico (Datta Banik et al. 2015), Spain (Labayen et al. 2009), and the USA (Adair and Gordon-Larsen 2001). However, it is not clear from the literature review whether obesity and higher body fat are the responsible factors for EM or earlier age at menarche (AM) plays an important role in the development of body fat and other health risks like cardiovascular diseases and even cancer in adulthood (Datta Banik and Dickinson 2014, 2016; Méndez-Domínguez 2011).

Data on menarche and physical growth in girls are reported from the northeastern states of Mexico (Méndez-Estrada et al. 2006) and other regions like Oaxaca (Malina et al. 2004) and Yucatan (Méndez-Domínguez 2011). However, reports on the association of EM with differential growth patterns of height and relative body dimensions (leg length and trunk length relative to height) are not available. AM has been reported to be associated with household socioeconomic factors, mother's and grandmother's childhood living conditions in Yucatan, Mexico (Azcorra et al. 2018; Datta Banik and Dickinson 2016). Poor household socioeconomic status and living conditions of the Maya community in Yucatan are important factors that are responsible for poor nutrition and physical growth of children (Azcorra et al. 2016, 2018).

Life history theory integrated with a biocultural approach indicated that early reproductive maturity results in a growth trade-off and short stature in a sample of adult women in the U.S. (Rivara and Madrigal 2019). Leg length and other body dimensions relative to height among individuals are used as proxy of early life environmental conditions that influence physical growth in children (Bogin 2012; Bogin and Varela-Silva 2010). Shorter relative subischial leg length (RSLL) is a marker that indicates negative impacts of adverse environmental conditions on physical growth in early childhood; infection, disease burden, poor nutrition, and chronic energy deficiency may result in growth trade-off with respect to absolute size and relative body dimensions (Bogin and Varela-Silva 2010). Lower leg length (knee height) showed earlier age at maximum increment compared to standing height and, thereby, indicated earlier maturity among boys and girls from Merida, Mexico (Datta Banik et al. 2017) that was explained by the facts of differential growth and maturity patterns of different body dimensions (Bogin 2021). In such a condition, risk for body fat gain is caused by larger trunk relative to leg length due to earlier onset of puberty. In addition, early puberty is reported to be associated with psychosocial stress developed due to poor household socioeconomic status, absence of father, etc. (Braithwaite et al. 2009; Deardorff et al. 2011, 2014; Henrichs et al. 2014; Steppan et al. 2019; Sun et al. 2017; Webster et al. 2014). Studies also reported that growth failure and delayed maturation may occur due to persistent nutritional stress, particularly in small-scale societies (McIntyre and Kacerosky 2011); however, growth rate increases and menarche occurs earlier if energy supply elevates that might lead to growth trade-off, shortened height, and higher body fatness (McIntyre and Kacerosky 2011; Wells 2018). Studies from Yucatan showed an association between better living conditions and higher body fat with earlier AM (Azcorra et al. 2018; Méndez-Domínguez 2011).

Association between higher BMI and body fat with lower relative leg length has been reported from the USA (Bogin and Varela-Silva 2008) and India (Datta Banik 2022). In the present study, I was interested to test the hypothesis in a new sample from another non-European and low-to-middle-income country (Mexico), which was higher BMI associated with lower RSLL, especially among girls with EM. The objective of the present study was to find an association of EM with BMI, absolute body size [height, sitting height (SH), subischial leg length (SLL)] and relative body dimensions [sitting height to subischial leg length ratio (SHSLLR), relative subischial leg length (RSLL)] among 14- to 16-year-old post-menarcheal girls from a rural Maya community in Quintana Roo, Yucatan, Mexico.

Participants and methods

A cross-sectional study was carried out in 2019 at Quintana Roo, a rural Maya community in Yucatan, Mexico. The present report is descriptive in nature. Participants were 14- to 16-year-old girls. The study was approved by the bioethics committee of the Centre for Research and Advanced Studies (Cinvestav-IPN); the parents / caregivers and two witnesses from the community signed the consent form as per guideline of the committee and the participants gave their verbal consent before the commencement of the study.

According to the official records, the population size of the community in Quintana Roo (942 individuals in 2010) was the smallest among the 106 municipalities covering rural and urban areas of Yucatan (INEGI 2011). The population may be declining, as a recent household survey carried out in 2018–19 (López-Moreno 2021) recorded 780 individuals (385 males, 395 females) living in the community. However, individuals of the community who lived in the nearest cities and abroad for work were not counted in that survey.

Selection criteria for the participants in the present study were: 14 to 16 years old girls with post-menarcheal status, without any reported physical and mental health burden, residents of Quintana Roo municipality since birth, and both parents had at least one surname of Maya origin. Previous studies in Yucatan reported very few girls above 14 years of age had premenarcheal status (Datta Banik and Dickinson 2014).

A household sociodemographic survey recorded menarcheal status and 65 girls in this age group (14 to 16 years) reported age at menarche that was confirmed by their mothers and grandmothers. Early menarche (EM) was defined as menarche before the 12^{th} birthday (Must et al. 2005); 25 girls of the present study had EM. Other participant girls (n=40) had menarche after 12 years of age (not early menarche or

NEM). Only two girls were non-menstruating in the age group, and they were not included in the study. Sampling was probabilistic; sample size (EM=21, NEM=29) was estimated separately from the two sub-populations (EM=25, NEM=40) with 10% margin of error at 95% confidence level, and participants were selected at random from the list of individuals in each group. One EM girl in the community wished to participate in the survey and the final sample (n=51) of the present study included 22 EM and 29 NEM girls.

In Mexico, people use both paternal and maternal surnames. Maya surname was used as a proxy of genetic background of the population and to represent Maya ancestry (Vázquez-Vázquez et al. 2013); surnames were identified by an expert (see Acknowledgements). The parents of the girls had at least one surname of Maya origin and therefore, Maya ancestry of the participants was considered. Data of household characteristics (housing pattern, education, and occupation) were collected.

Anthropometric measurements were recorded following standard protocol (Lohman et al. 1988). Height (cm) and sitting height (SH in cm) were measured to the nearest 0.1 centimeter using a standard stadiometer with platform (Seca, Germany). Stadiometer and a standard anthropometric box [40 cm (tall) × 50 cm (wide) × 30 cm deep] were used to measure SH. Body weight was measured to the nearest 0.1 kg using a digital scale (Tanita Corp., Japan). Subischial leg length (SLL) was obtained from the difference between stature and sitting height. Other derived variables were body mass index (BMI, kg/m^2), relative sitting height to subischial leg length ratio (SHSLLR) (SH/SLL x 100), and relative subischial leg length ratio (RSLL) (SLL/height×100). Height-for-age and BMI-for-age Z-scores were calculated (de Onis et al. 2007; WHO 2007). All measurements were recorded on household visits by a single researcher (the author) and intra-observer technical error of measurement was within acceptable limits (Ulijaszek and Kerr 1999). An adult woman from the community or caregiver/mother was present when anthropometric measurements were being recorded from the participants. No girls were menstruating at the time of recording anthropometric measurements.

SPSS statistical software (version 15.00) was used for data analysis and descriptive characteristics of the sample for age and anthropometric variables (mean values and standard deviation) were calculated; significant differences of mean values of parameters between EM and NEM girls were estimated using Student's *t*-test. Linear regression models predicting height, BMI, SH, SLL, SHSLLR, and RSLL were developed to explain the interrelationships between EM and the dependent variables, after adjusting for age. The level of statistical significance was set at $p<0.05$ in all analyses.

Results

Household socioeconomic characteristics of the participant girls were similar; land ownership (100%), housing pattern (construction, number of rooms, toilet, kitchen), water connection and electricity (100%), parents' education (majority had school education) and occupation (daily wage laborer and small-scale cultivators in different government programs), civil status (84% of mothers were married and others were either unmarried or divorced), and average monthly per capita income ($90 US). Mean age (± SD) of the girls was 15.06 years that did not vary significantly ($p>0.05$) between EM (14.84 years) and NEM girls (15.22 years); t and p-values referred to the differences between EM and NEM groups (Table 1). Mean value of age at menarche (AM) of the participant girls was 12.91 years; significant difference ($p<0.05$) of AM was found in EM (11.03 years) and NEM (14.33 years) girls.

Table 1. Descriptive statistics of age, age at menarche, and anthropometric characteristics of post-menarcheal girls (n=51)

Variables	All (n=51) Mean (SD)	EM (n=22) Mean (SD)	NEM (n=29) Mean (SD)	t	*p*-value
Age (years)	15.06 (1.52)	14.84 (1.64)	15.22 (1.42)	-0.90	0.37
AM (years)	12.91 (2.01)	11.03 (0.76)	14.33 (1.39)	-10.02	<0.0001
Height (cm)	161.87 (7.38)	159.32 (7.29)	163.80 (6.95)	-2.24	0.03
Weight (kg)	50.62 (7.26)	50.95 (8.54)	50.36 (6.25)	0.28	0.78
BMI (kg/m^2)	19.28 (2.19)	20.00 (2.61)	18.73 (1.66)	2.10	0.04
Sitting height (cm)	79.42 (3.42)	80.67 (3.45)	78.47 (3.13)	2.38	0.02
SLL (cm)	82.45 (5.78)	78.65 (5.40)	85.33 (4.23)	-4.96	<0.0001
SHSLLR (%)	96.74 (7.31)	102.93 (6.90)	92.03 (2.56)	7.84	<0.0001
RSLL (%)	50.90 (1.84)	49.33 (1.68)	52.08 (0.73)	-7.93	<0.0001

EM: Early menarche; NEM: Not early menarche; SD: Standard deviation; AM: Age at menarche; BMI: Body mass index; SLL: Subischial leg length; SHSLLR: Sitting height to subischial leg length ratio; RSLL: Relative subischial leg length; t and p-values refer to the differences between EM and NEM groups.

Anthropometric parameters had shown significant differences ($p<0.05$) of mean values between EM and NEM girls, except body weight. The NEM girls were taller, had longer subischial leg length (SLL) and relative to height (RSLL), lower BMI, sitting height, and sitting height to subischial leg length ratio (SHSLLR), in comparison with the corresponding characteristics among EM peers (Table 1). Only one EM girl had height-for-age Z-score below -2.0 SD; other girls (n=50) were not stunted (low height-for-age). No girl had low or high BMI that could have been attributed as suffering from either undernutrition or having excess weight (overweight and obesity), respectively. Significant correlation ($p<0.001$) was observed between AM and anthropometric characteristics (BMI r = -0.30, SH r = -0.67, SHR r = -0.62, SLL r = 0.42, RSLL r = 0.62, and SHSLLR r = -0.61).

These results (not presented in tables) raised my interest to further explore the interrelationships between EM and anthropometric characteristics (absolute body size and relative to height). Linear regression models were used to find the interrelationships between EM (yes=1, no=0) and anthropometric characteristics (SH, SHR, SLL, SHSLLR, and RSLL), after adjustment for age among girls (Table 2). Parameter estimates of the response variable within 95% confidence interval for the coefficient showed significant interrelationships between variables that was estimated by ANOVA ($p<0.05$). The regression models accounted for >60% of total variability explained by adjusted R^2. EM was found

Table 2. Regression models to establish interrelationships between early menarche (EM) and body dimensions among post-menarcheal girls (n=51)

Dependent variable	Predictors	B	SEE	t	*p*-value	95% Confidence Interval for B	
						Lower	Upper
Model 1: Height (cm)	Constant	148.36	10.09	14.70	<0.001	128.07	168.66
	Age (years)	1.01	0.66	1.54	0.13	-0.31	2.34
	EM	-4.09	2.00	-2.05	<0.05	-8.11	-0.08
Model 2: BMI (kg/m^2)	Constant	14.46	3.03	4.77	0.00	8.37	20.55
	Age (years)	0.28	0.20	1.42	0.16	-0.12	0.68
	EM	1.37	0.60	2.29	0.03	0.17	2.58
Model 3: SH (cm)	Constant	73.85	4.72	15.64	<0.001	64.36	83.35
	Age (years)	0.30	0.31	0.99	0.33	-0.32	0.92
	EM	2.32	0.93	2.48	0.02	0.44	4.19
Model 4: SLL (cm)	Constant	74.51	6.76	11.02	<0.001	60.92	88.10
	Age (years)	0.71	0.44	1.61	0.11	-0.17	1.60
	EM	-6.41	1.34	-4.80	<0.0001	-9.10	-3.72
Model 6: SHSLLR (%)	Constant	99.47	7.08	14.05	0.00	85.24	113.71
	Age (years)	-0.49	0.46	-1.06	0.29	-1.42	0.44
	EM	10.71	1.40	7.65	<0.0001	7.90	13.52
Model 5: RSLL (%)	Constant	50.16	1.77	28.42	0.00	46.61	53.71
	Age (years)	0.13	0.11	1.10	0.28	-0.11	0.36
	EM	-2.70	0.35	-7.75	<0.0001	-3.40	-2.00

SH: Sitting height; EM: Early menarche (EM=1, Not early menarche=0); B: Regression coefficient; SEE: Standard error of estimate; SLL: Subischial leg length; SHSLLR: Sitting height to subischial leg length ratio (%); RSLL: Relative subischial leg length (%).

to be significantly related to the dependent variables (height, BMI, SH, SLL, SHSLLR, and RSLL) separately, after adjusting for age among girls ($p<0.05$). Interrelationships between EM and anthropometric parameters were different; regression coefficients were negative with height, SLL, RSLL, and positive with BMI, SH, SHSLLR. It was observed that EM girls had a risk for having 4.09 cm lower height, 1.37 kg/m^2 higher BMI, 2.32 cm higher trunk size (SH), 6.41 cm lower SLL, 10.71% higher SHSLLR, and 2.7% lower RSLL than NEM peers, holding age as another predictor in the model constant. In the normality tests (Shapiro-Wilk tests), distribution of the residuals was normal ($p>0.05$) and that showed no patterns. Relatively high tolerance (>0.97) and low variance inflation factor (<1.02) indicated no multicollinearity among predictors.

Discussion

The results of the present study among 14- to 16-year-old post-menarcheal girls from a Maya community in rural Yucatan, Mexico, showed significant interrelationships between EM and growth of body dimensions in terms of their absolute size and relative to height. It was observed that a relatively larger trunk (sitting height), and its relative size (SHSLLR) resulted in shorter leg length (SLL), its relative estimate (RSLL), and higher BMI among EM girls in comparison with NEM peers. The results from a rural community of a non-European and low-to-middle-income country (Mexico) further support the hypothesis that higher BMI is associated with lower RSLL (Bogin and Varela-Silva 2008, 2010).

Age at menarche (AM) as an indicator of sexual maturity was reported to be associated with physical growth, body fatness and health among girls during adolescence and physical and mental health in adulthood (Méndez-Domínguez 2011). A trend of decline in AM in the previous decades has been observed in different countries (Demerath et al. 2004; McDowell et al. 2007; Gomula and Koziel 2018). In Yucatan, Mexico, mean values of AM among girls (12.09 years in Merida City and 12.24 years in the municipality of Progreso) were lower than their mothers' AM (12.66 years and 12.41 years, respectively) (Wolanski et al. 1994). Other studies in Merida, Yucatan reported lower mean AM (11.83 years, Datta Banik et al. 2015, 11.21 years, Datta Banik and Dickinson 2016, 11.57 years, Datta Banik et al. 2020). Decline of AM over decades in some other Latin American countries was also reported from Colombia (Chavarro et al. 2004; Ireton et al. 2011) and Chile (Codner et al. 2004; Hernández et al. 2007). However, the participant girls (n=51) in the present study had a mean age at menarche of 12.91 years that was higher than that reported earlier from the Merida City, Yucatan. The result needs verification in future studies with a larger sample size.

Secular trend of height and improvement of leg length in terms of relative increase of knee height (lower leg length) among daughters of women representing the Maya community in Yucatan explained intergenerational influences, rural to urban migration, and substantial improvement in their living conditions (Azcorra et al. 2015). Maternal short stature has been reported to be associated with higher body fat in Maya children in Merida, Yucatan (Azcorra et al. 2016). Higher body fat has been found to be positively correlated with EM in girls from Merida, Yucatan (Datta Banik et al. 2015).

AM as a maturity indicator among girls depends on the environmental factors as well as genetic predisposition (Mukherjee and Datta Banik 2009; Morris et al. 2010, 2011). A study in Yucatan showed better living conditions experienced by mothers and adult daughters during their childhood lowered AM (Azcorra et al. 2018). Therefore, consistent with life history theory and intergenerational influences, maternal biological capital (short stature, body fat) may transmit characteristics to the offspring that influence child growth and development like early maturity in girls, as well as higher levels of body fat and short stature (Wells 2018; Wells et al. 2019). In the present study, EM as a maturity indicator, probably caused by several environmental factors including maternal life history trade-off, was found to be associated with growth trade-off of leg length. However, data on maternal anthropometric characteristics were not available, which was a limitation of the study. On the other hand, NEM girls with relatively slower maturation had more time for growth of leg length, its absolute size and relative to stature and trunk that might have lowered the risk of body fat gain as indicated by lower BMI in the present study.

Differential growth patterns of body dimensions (absolute size and relative to height) in children and adolescents are responsive to environmental conditions including nutrition and diet, disease, and household psychosocial and economic factors. Leg length and its relative size to trunk (sitting height) and stature (standing height) are the markers of quality of early life living conditions and probable epigenetic effects that determine physical growth and increased risk of body fatness. Developmental plasticity (Bateson et al. 2004) shaped by natural selection is one of the adaptive strategies in response to unfavorable environmental conditions, chronic diseases, and higher energy expenditure for recovery, leads to a consequential growth trade-off and results in smaller absolute size and relative body dimensions. Fetal origins of developmental plasticity, mother to offspring energy pathways and metabolic adjustment explain how early life environmental conditions and maternal capital (biological, social, material) can influence child growth, nutrition, and development (Kuzawa 2005; Wells 2010). The adaptive model of developmental plasticity is explained as developmental adjustment in response to maternal nutritional deficits in its prenatal life. The Developmental Origins of Health and Disease (DOHaD) hypothesis also supports the phenomenon of influences of early life nutrition and growth that shape adult phenotype (Barker 2004, 2007). The adaptive model of developmental plasticity explained the adjustment of phenotype *in utero*, in anticipation of postnatal life environmental constraints; however, reports stated that adaptive models did not emphasize maternal phenotype as the initial sources and information received by the offspring (Wells 2010, 2012, 2017, 2018). In light of the thrifty phenotype hypothesis, it can be explained that influences of adverse early life experience include shortened final body size and relative leg length (relative subsichial leg length or RSLL) – a relatively larger trunk may result in central obesity and more body fat deposit and their association with enhanced risk for non-communicable diseases in adulthood and "maternal capital" plays an important role (Hales and Barker 1992; Wells 2011).

Neonates smaller at birth undergo catch-up growth with faster increment in size and enhanced risk for body fat gain in late pre-school age (Ong et al. 2000) that may have negative consequences including early puberty, maturity, and shorter stature, compared to their peers who were larger neonates. A child born with suboptimum energy resources will face risk of growth failure, particularly in low- and middle-income countries (Mertens et al. 2020; Roth et al. 2017). However, higher input of energy, later in childhood and adolescence due to unhealthy food habits of consumption of processed and ultra-processed foods and sugary drinks and low physical activity may cause excess weight and body fat gain (metabolic loads) (Torres-Arroyo 2018) that might be associated with earlier onset of maturity and consequent shortened final body size, and relative leg length and elevated risk for the development of NCDs in adulthood (Méndez-Domínguez 2011). Coexistence of short stature and excess weight (overweight and obesity) in terms of nutritional dual burden is common in Yucatan population (Varela-Silva et al. 2012). Along with, consumption of non-essential energy-dense, industrially processed and ultra-processed foods and drinks are very high in Mexican populations (Bogin et al. 2014; Illescas-Zárate et al. 2021; López-Moreno 2021; Mendoza et al. 2017)

Life history strategies determine physical growth, development, sexual maturity, reproductive fitness, and survival (Rivara and Madrigal 2019). A mismatch between available energy and limited capacity to access may result in trade-offs that can be interpreted by a biocultural approach of evolutionary life history theory (McDade 2003). Sexual maturity in adolescence determines reproductive health and success in the life of women; proximate and ultimate causes and consequences of EM (Gillette and Folinsbee 2012) may have negative impacts on fecundity, quality, and quantity of offspring that can be analyzed in an evolutionary framework (Rivara and Madrigal 2019). EM as an indicator of early sexual maturity and its association with short stature and lower relative subischial leg length (RSLL) can also be explained in terms of evolutionary mechanisms of life history trade-off and intergenerational transmission of maternal capital, both *in utero* and postnatal. In this regard, Social-Economic-Political-Emotional (SEPE) inequalities and insecurities are important factors for growth failure in children (Bogin and Varea 2020; Scheffler et al. 2019). A life course, intergenerational model of SEPE factors (stressors) are viewed in human ecological perspectives of biology and behaviour, child growth, development, and health. In a literature review, Wells (2018) hypothesized that in an intergenerational perspective on developmental plasticity, life history trade-offs in the maternal generation favor the emergence of similar trade-offs in the offspring generation. Allocation of relatively higher energy to growth during pregnancy and lactation promotes the development of capacity in offspring for greater fat-free mass and metabolic turnover in life, adult size, and reduced risk for NCDs (Wells et al. 2016).

Intergenerational transmission of maternal life history trade-offs was explained in a study from the United Kingdom that showed mothers with earlier menarche were obese, short in height, and their daughters also had faster infant growth, EM, shorter final size and also gained fat in adolescence (Ong et al. 2007). EM causes earlier maturation of leg length and therefore, results in short stature and RSLL (Conway et al. 2012). Association of EM with higher BMI, obesity, and body fatness was also reported from the USA. (Adair and Gordon-Larsen 2001). Household socioeconomic status and lifestyle habits have been correlated with the development of an obesogenic environment and EM in girls, as reported from Chile (Amigo et al. 2012; Codner et al. 2004; Hernández et al. 2007), Iran (Pejhan et al. 2013; Shalitin and Phillip 2003), Korea (Oh et al. 2012), Poland (Wronka and Pawlinska-Chmara 2005), Portugal (Padez 2003), Spain (Labayen et al. 2009) and other countries (Al-Awadhi et al. 2013; Freedman et al. 2002, 2003; Martínez et al. 2010; Rosenfield et al. 2009). Prenatal and early childhood growth might have a larger effect on sexual maturation (Yermachenko and Dvornyk 2014) and therefore, higher body fat and early sexual maturity in terms of EM may be predicted.

Early sexual maturity among adolescent girls can be viewed as an adaptive strategy to cope with the adverse conditions of SEPE inequalities and insecurities, caused by several biocultural and environmental factors that influence the early start of reproduction, predicting lower probability of survivorship. Therefore, EM is a mismatch between biological and psychosocial maturation that can be interpreted as an alternative reproductive tactic, determined by several environmental factors, and assists a woman to gain phenotypic plasticity, alteration of behaviour. Furthermore, EM results in a life history trade-off that might be transmitted through generations (Gillette and Folinsbee 2012; Wells 2018). A study from Finland reported women were compatible with trade-offs between reproduction and growth; compromised adult height at the cost of early AM. Therefore, women gained fitness benefits by an early start of reproduction but not by taller final size (Helle 2008). Early menarche results in the growth trade-off of height and leg length in exchange of reaching reproductive age earlier, and thereby increases the risk of body fat deposit in higher relative trunk size. The results in the present study showed that EM girls in their post-menarcheal age had lower height and leg length (SLL) relative to height and sitting height in comparison with NEM peers.

The present study in a cross-sectional design limits the temporal association of EM with elevated BMI, shortened height and leg length. In addition, data of maternal phenotype (height, leg length, BMI, body fatness) were unavailable that could enrich the study. Household socioeconomic status of the participant girls was similar, and data were not used to find association with AM. Significant differences in socioeconomic status might be found in larger samples. The results need further verification in future studies representing other populations in different biocultural environmental situations.

Conclusion

In summary, the present study showed association of EM with lower body height and relative leg length that support earlier studies. Early onset of puberty and sexual maturity among adolescent girls have impacts on demographic shifts in fertility, fecundity, birth rates that are associated with biocultural environmental factors in the prenatal and postnatal stages of growth and development. Maternal capital, environmental factors, SEPE inequalities and insecurities in a woman's early life and during pregnancy, as well as nutritional status, consequently determine the qualities of offspring like birth weight, length at birth, immune response, growth and development trajectory, adult body size, relative body dimensions, and body fat that can be interpreted by the intergenerational transmission of evolutionary trade-offs in growth, maturity, and development.

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Conflict of interest

The author declares no conflict of interest.

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