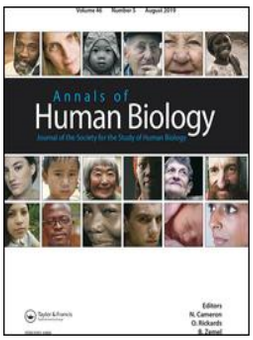


Annals of Human Biology

ISSN: 0301-4460 (Print) 1464-5033 (Online) Journal homepage: https://www.tandfonline.com/loi/iahb20

Age at menarche associated with subsequent educational attainment and risk-taking behaviours: the Pelotas 1982 Birth Cohort

Lucia M. Calthorpe, Denise P. Gigante, Bernardo L. Horta & Ken K. Ong

To cite this article: Lucia M. Calthorpe, Denise P. Gigante, Bernardo L. Horta & Ken K. Ong (2020): Age at menarche associated with subsequent educational attainment and risk-taking behaviours: the Pelotas 1982 Birth Cohort, Annals of Human Biology, DOI: 10.1080/03014460.2020.1715476

To link to this article: https://doi.org/10.1080/03014460.2020.1715476

ANNALS OF HUMAN BIOLOGY
https://doi.org/10.1080/03014460.2020.1715476

RESEARCH PAPER

Age at menarche associated with subsequent educational attainment and risk-taking behaviours: the Pelotas 1982 Birth Cohort

Lucia M. Calthorpe[a], Denise P. Gigante[b], Bernardo L. Horta[b] and Ken K. Ong[c,d]

[a]Department of Public Health and Primary Care, University of Cambridge, Cambridge, UK; [b]Federal University of Pelotas, Pelotas, Brazil; [c]MRC Epidemiology Unit, Institute of Metabolic Science, University of Cambridge, Cambridge, UK; [d]Department of Paediatrics, University of Cambridge, Cambridge, UK

ABSTRACT

Background: Earlier age at menarche (AAM), a marker of puberty timing in females, has been associated with a higher likelihood of adolescent risk-taking behaviours and variably associated with educational attainment.

Aim: To examine the association between AAM and educational attainment in the Pelotas, Brazil, 1982 Birth Cohort.

Subjects and methods: AAM was categorised as Early (7–11 years), Average (12–13 years), or Late (14+ years). Primary outcome: years of education (age 30). Secondary outcomes: risk-taking behaviours, adult income and school grade failure.

Results: In adjusted models, compared to Average AAM, Late AAM was associated with 0.64 fewer years of education (95% CI: −1.15, −0.13). Early AAM was associated with earlier age at first sexual intercourse (−0.25 years; 95% CI: −0.39, −0.12), whereas Late AAM was associated with 17% lower adult income (0.83; 95% CI: 0.71, 0.95) and 0.31 years older age at first alcohol consumption (95% CI: 0.10, 0.52).

Conclusions: Our findings confirm the association between earlier puberty timing in females and a greater likelihood of risk-taking behaviours in this setting of recent secular changes towards earlier puberty. However, the association between Late AAM and lower education was surprising and may support a psychosocial rather than biological link between puberty timing and educational outcomes.

ARTICLE HISTORY
Received 4 July 2019
Revised 16 December 2019
Accepted 3 January 2020

KEYWORDS
Menarche; puberty; precocious; risk-taking behaviour; educational attainment

Introduction

Puberty is the period of development of secondary sexual characteristics that separates childhood from adulthood and coincides with a critical period in physical, cognitive and emotional development (Biro and Chan 2018). Specifically, the timing of female puberty has been linked to a wide range of health conditions; in general, earlier puberty timing increases the risks of adverse health outcomes and all-cause mortality (Hsieh et al. 1990; Jacobsen et al. 2007; Lakshman et al. 2008; 2009). Age at menarche (AAM), a girl's first menstruation, is a well-recalled and commonly used marker of puberty timing in epidemiological studies. Its distribution varies considerably with time period, and strong social patterning is also observed. In many populations, secular trends towards earlier AAM are observed alongside improving socioeconomic conditions. A wide range of genetic and environmental factors are thought to influence AAM. Hundreds of independent genomic signals have been identified as associated with AAM, which together explain 7.4% of the variation in AAM, equivalent to ~25% of its heritability (Day et al. 2017). Other factors related to earlier AAM include higher maternal gestational weight gain, lower birthweight, higher levels of childhood nutrition and body mass index (BMI), exposure to psychological or physical trauma, and lower physical activity (Yermachenko and Dvornyk 2014). It is thought that higher childhood BMI promotes earlier AAM via cytokines secreted by body fat, such as leptin (Yermachenko and Dvornyk 2014).

In addition to the associations with longer-term adverse health outcomes, in the shorter-term, earlier AAM is associated with a wide range of adverse psychological and behavioural outcomes in adolescence, including depression, anxiety, eating and conduct disorders (Mendle et al. 2007; Copeland et al. 2010; Kågesten et al. 2015). One of the most well-established behavioural correlates of AAM is the timing of sexual activity, with earlier AAM associated with younger age at first sexual intercourse (Mendle et al. 2007; Copeland et al. 2010; Boden et al. 2011; Kågesten et al. 2015). Associations between early AAM and higher levels of substance use, including alcohol, tobacco, and illicit drugs, have also been documented (Graber et al. 2004; Mendle et al. 2007; Westling et al. 2008). Conversely, late AAM is associated with earlier age of natural menopause, coeliac disease, and asthma (Day et al. 2015).

CONTACT Lucia M. Calthorpe lucia.calthorpe@ucsf.edu 505 Parnassus Ave, San Francisco, CA 94143, USA
Supplemental data for this article is available online at https://doi.org/10.1080/03014460.2020.1715476.

It is plausible that in addition to causing adverse short-term psychological and behavioural outcomes, early puberty timing could impact educational attainment in adolescence and young adulthood, with subsequent long-term socioeconomic disadvantages. Current published literature is inconsistent regarding the association between AAM and subsequent educational attainment. Some studies have reported no such association (Koivusilta and Rimpela 2004; Copeland et al. 2010; Boden et al. 2011), but others have documented significant associations between early AAM and lower educational achievement (Stattin and Magnusson 1990; Graber et al. 2004; Johansson et al. 2005; Cavanagh et al. 2007). It is important to note the heterogeneity in study designs. Age thresholds for early AAM vary between studies or even rely on a qualitative self-perception relative to one's peers (Graber et al. 2004). Although education has often been assessed in years of completion, it has also been variably assessed by global or specific performance measures (e.g. grade point average), school absence, or the attainment of post-secondary degrees (Stattin and Magnusson 1990; Graber et al. 2004; Cavanagh et al. 2007). Additionally, studies controlled for a range of different confounders.

Different theoretical frameworks have been put forth to conceptualise the observed associations between AAM and subsequent psychological, behavioural, and educational outcomes. A "psychosocial perspective" posits that early physical maturation triggers role and social changes for which girls may be unprepared, for example, sexual activity and affiliation with older peer groups (Mendle et al. 2007). In contrast, a "biological perspective" places greater emphasis on the role of hormonal and cognitive changes associated with puberty, which may increase excitability and sensation-seeking. Negative outcomes could be a product of a lag between the emergence of these drives and the development of self-regulation (Mendle et al. 2007). Finally, "selection effects" describes a cycle where early puberty predicts negative outcomes which are transmitted to the child by exposure to chronic stress and the heritable nature of AAM (Mendle et al. 2007).

Brazil represents a unique context in which to investigate the ramifications of puberty timing, as the country has undergone a recent economic transition. Along with this transition, a secular decline in AAM has been observed during the 20th century. For example, in Rio de Janeiro mean AAM declined from 13.07 to 12.40 years when comparing women born in the 1920s with those born in the 1970s, with faster declines seen in 1960–70 than 1920–60 (Kac et al. 2017). Furthermore, the socioeconomic status (SES) patterning in AAM has undergone dramatic reversal in the last fifty years (Junqueira Do Lago et al. 2003). The downward secular trend in AAM has been greatest among lower socioeconomic status (SES) groups. While lower SES was historically associated with later AAM, it is associated with earlier AAM among those born since the late 1960s in Rio de Janeiro (Junqueira Do Lago et al. 2003). To date, no work has been published on the relationship between AAM and educational attainment in the context of a recent economic transition. Rather, much of the existing evidence on this topic comes from studies conducted in high-income nations in Europe and North America. This paper addresses this gap by describing the association between AAM and educational attainment, and with various risk-taking behaviours, in the Pelotas 1982 Birth Cohort.

Subjects and methods

Participants

The Pelotas 1982 Cohort has been described in detail elsewhere (Victora and Barros 2006). Briefly, Pelotas is a city in the state of Rio Grande do Sul in the southernmost part of Brazil. 99.2% of the births recorded in the city of Pelotas in 1982 were enrolled in the study via daily visits to the three maternity hospitals in the city (Victora and Barros 2006). This analysis is restricted to females in the cohort. In total, 5914 live born infants (2876 female) with mothers who lived in the city comprised the initial cohort. In 1984 and 1986 follow-up visits were made to all cohort members. In 2004–5 funding was obtained to visit all cohort members again at age 23 years – 2083 female members participated, yielding a follow-up of 72%. These individuals were followed up again at age 30, at which time 1912 females participated (66% of the original female cohort).

The Pelotas 1982 Birth Cohort received the approval of the Federal University of Pelotas Research Ethics Committee, affiliated to the Conselho Nacional de Ética em Pesquisa (National Research Ethics Committee – CONEP).

Variables

Age at menarche, a young woman's first menstrual bleeding, is a widely used measure for puberty timing because it is generally well-recalled without bias (Koo and Rohan 1997; Bosetti et al. 2001; Must et al. 2002). Based on the distribution of AAM in the study population, "Early AAM" was defined as 7–11 years, "Average AAM" as 12–13 years, and "Late AAM" as 14+ years.

The primary outcome was years of full-time education self-reported at age 30. Additionally, participants were asked if they had failed a grade (i.e. year in school) by age 23. School grade failure, a binary measure, was considered as a secondary outcome. Grade failure was treated as an incomplete year of education, and thus excluded from the education at age 30 variable. This avoided the appearance of higher educational attainment among individuals who failed and then repeated years of school.

We considered three categories of secondary outcomes (Table 1). Sexual behaviour outcomes included: age at first sexual intercourse (age 23), number of sexual partners (age 23), pregnancies (age 30) and abortions (spontaneous and induced, age 23). Substance use outcomes included: smoking (yes/no), age at first alcohol consumption and illicit drug use (all collected at age 23). Socioeconomic outcomes included: school grade failure (age 23) and adult income (at age 30). The confidential questionnaire included an extensive list of drug-specific questions. As few individuals reported any drug use, these items were aggregated into a single binary outcome (yes/no illicit drug use). The confidential questionnaire

Table 1. Description of the study populations followed up at ages 23 and 30 years.

Variable	23 Years $N = 2083$	30 Years $N = 1912$
Collected at Birth:		
Skin colour	White: 78.2% (1319) Black: 16.5% (279) Mixed race: 5.2% (88)	White: 79.5% (1475) Black: 15.7% (292) Mixed race: 4.7% (88)
Maternal education (years)	6.50 (6.32, 6.68)	6.59 (6.40, 6.78)
Family income at birth[a]	2.28 (2.23, 2.32)	2.28 (2.24, 2.33)
Birthweight (grams)	3162 (3140, 3183)	3157 (3134, 3180)
Gestational age (weeks)	39.4 (39.3, 39.5)	39.4 (39.3, 39.5)
Maternal smoking in pregnancy	Yes: 35.5% (739) No: 64.5% (1344)	Yes: 35.3% (675) No: 64.7% (1237)
Maternal age at birth (years)	26.12 (25.86, 26.39)	26.07 (25.80, 26.35)
Maternal parity	1.3 (1.3, 1.4)	1.3 (1.2, 1.4)
Collected at age 4:		
BMI at age 4 (WHO Z-score)	0.58 (0.53, 0.62)	0.55 (0.50, 0.59)
Collected at age 23:		
Age at menarche (years)[b]	12.39 (12.32, 12.45)	12.37 (12.30, 12.44)
Height (metres)	1.61 (1.60, 1.61)	1.61 (1.61, 1.61)
BMI (kg/m^2)	23.4 (23.2, 23.6)	23.4 (23.2, 23.7)
Age at first sexual intercourse (years)	16.51 (16.41, 16.61)	16.51 (16.40, 16.62)
Number of sexual partners	3.2 (3.1, 3.3)	3.2 (3.0, 3.3)
Abortion	Yes: 7.8% (150) No: 92.1% (1770)	Yes: 7.8% (126) No: 92.2% (1482)
Smoking	Yes: 23.6% (492) No: 76.4% (1591)	Yes: 22.9% (399) No: 77.1% (1342)
Age at first alcohol consumption (years)	15.07 (14.96, 15.18)	15.05 (14.93, 15.17)
Illicit drug use in last month[c]	Yes: 10.1% (195) No: 89.9% (1740)	Yes: 9.7% (157) No: 90.3% (1458)
School grade failure	Yes: 61.9% (1287) No: 38.1% (793)	Yes: 62.0% (1079) No: 38.0% (661)
Collected at age 30:		
Education at age 30 (years)	11.63 (11.43, 11.83)	11.72 (11.53, 11.91)
Pregnancy (by age 30)	Yes: 69.4% (1175) No: 30.6% (517)	Yes: 68.6% (1272) No: 31.3% (581)
Income at age 30 (Brazilian Real)	3172 (2986, 3359)	3179 (3003, 3355)

Arithmetic mean (95% confidence intervals), Percent (*N*).
[a]Multiples of minimum wage.
[b]For all patients, AAM was recorded at age 23. For the subset of individuals followed up at age 15 and age 19, AAM was recorded at these time points, and the earliest recording was used in the analysis.
[c]Include: marijuana, cocaine, LSD, ether, prescription drugs, crack, glue, ecstasy, benzene, and paint thinners.

was completed on paper by study participants alone, rather than elicited in conversation with an interviewer (as other data were collected) (Victora et al. 2003).

Covariates were selected based on reported evidence of their relevance as potential confounders (Junqueira Do Lago et al. 2003; Cavanagh et al. 2007; Hendrick et al. 2016). Covariates were recorded at birth (with the exception of BMI at age 4) and included: skin colour (white, black, mixed race), maternal education (years, categorised: 0–4, 5–8, 9–12, and 12+), family income (tertile), birth weight (grams), gestational age, maternal smoking in pregnancy (binary yes or no response), maternal age, maternal parity and BMI at age 4 (kg/m^2). The year of data collection for each variable used in this analysis is shown in Table 1.

Statistical analyses

Data were fit with progressive nested models by adding covariates in the following order: (1) skin colour, maternal education, family income tertile, (2) birth weight, gestational age, maternal smoking, maternal age, maternal parity, (3) BMI at age 4 years. Early AAM or Late AAM were each compared to Average AAM using multiple linear or logistic regression models for continuous or binary outcomes, respectively. Continuous outcomes included: educational attainment at age 30, age at first intercourse, number of sexual partners, number of pregnancies, age at first alcohol use, and income at age 30. Binary outcomes included: abortion, smoking, illicit drug use, grade failure and completion of secondary school (sensitivity analysis). Income at age 30 was log-transformed to improve linear model fit. As such, the parameters reported represent the percent change associated with Early or Late AAM compared to Average AAM. Sensitivity analysis for the primary outcome used a fully adjusted logistic regression model to predict the odds of terminating education prior to completion of secondary school among those with Early, Average, and Late AAM.

A complete case analysis was performed to examine the primary outcome. Individuals who were interviewed at age 30 and did not have missing values for age at menarche and covariates were retained in the analysis ($n = 1267$). 24.9% of women have missing values for AAM. Additionally, 33.5% of females in the original study sample were not interviewed at age 30, and thus have missing values for years of completed

education at this time point. The majority of these individuals also had missing values for education at 23. Therefore, the potential benefit of imputation from education at age 23 was minimal. Supplementary Table 1 provides a description of the characteristics of individuals retained in the complete case analysis vs. those with missing data. Because secondary outcomes were collected at age 23, analysis was not restricted to the above analytical cohort in order to retain individuals with complete data for each separate secondary outcome.

Results

The study variables are summarised in Table 1. Mean (SD) AAM was 12.39 (1.5) years. "Early AAM" (at 7–11 years) was reported by 24.6% of included women; "Average AAM" (12–13 years) by 55.9% and "Late AAM" (14+ years) by 19.5%. Table 2 displays bivariate associations between covariates and completed years of education at age 30 (primary outcome). With the exception of gestational age, all covariates were associated with years of education. Higher maternal parity, smoking in pregnancy, black and mixed-race were associated with lower educational attainment. In contrast, higher family income, maternal education, BMI at age 4, birthweight, and older maternal age were associated with higher educational attainment.

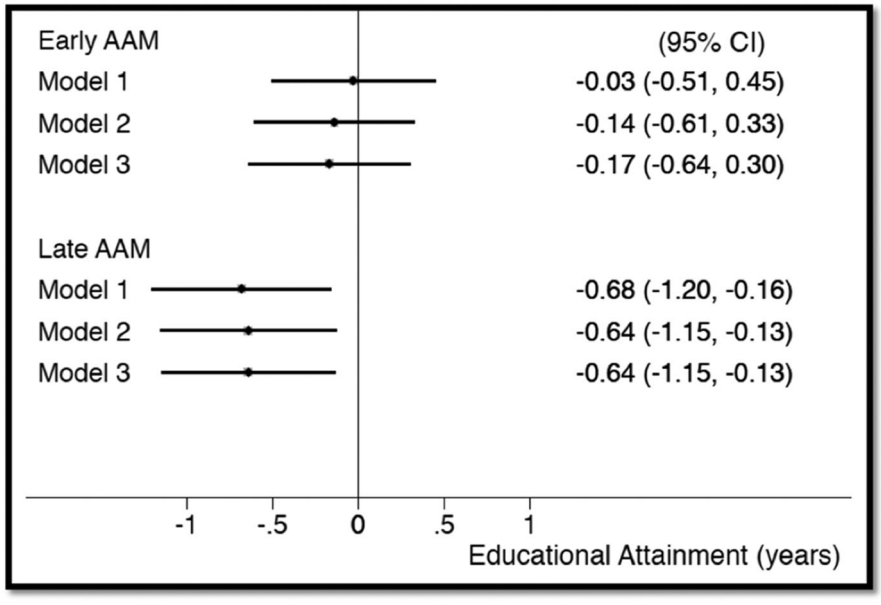
AAM associated with educational attainment

Late AAM, compared to Average AAM, was associated with lower educational attainment (−0.68 years, 95% CI: −1.20,

Table 2. Bivariate associations between covariates and educational attainment at age 30.

Variable	Effect estimate (years)	95% CI	*p*-value	*R*-squared
Linear Variables				
Birthweight (per 100 grams)	0.12	(0.08, 0.16)	$p < .001$	0.020
Gestational Age (per week)	−0.05	(−0.13, 0.03)	$p = .180$	0.001
Maternal Parity (per child)	−0.56	(−0.68, −0.46)	$p < .001$	0.053
Maternal Age at Birth (years)	0.07	(0.04, 0.10)	$p < .001$	0.012
BMI at age 4 (kg/m^2)	0.41	(0.20, 0.62)	$p < .001$	0.009
Categorical Variables				
Age at menarche	Early: −0.04	(−0.53, 0.44)	$p = .860$	0.008
"(Ref. = Average AAM)	Late: −0.97	(−1.50, −0.45)	$p < .001$	
Maternal Smoking in Pregnancy (Ref. = No)	Yes: −1.08	(−1.48, −0.68)	$p < .001$	0.015
Family Income at Birth	2nd tertile: 2.35	(1.94, 2.76)	$p < .001$	0.249
(Ref. = 1st tertile)	3rd tertile: 5.28	(4.86, 5.70)	$p < .001$	
Maternal Education	5–8: 2.29	(1.90, 2.68)	$p < .001$	0.250
(Ref. = 0–4 years)	9–11: 4.04	(3.46, 4.63)	$p < .001$	
	12+: 6.50	(5.97, 7.04)	$P < .001$	
Skin Colour	Black: −2.15	(−2.67, −1.62)	$p < .001$	0.048
(Ref. = White)	Mixed: −2.52	(−3.42, −1.62)	$p < .001$	

Results are from linear regression models.



MODEL	COVARIATES
MODEL 1	Skin colour, maternal education, family income tertile
MODEL 2	Model 1 + birthweight, gestational age, maternal smoking, maternal age, maternal parity
MODEL 3	Model 2 + BMI at age 4 years

Figure 1. Association between Early or Late (compared to Average) age at menarche and educational attainment at age 30 ($n = 1267$).

Table 3. Associations between Early or Late (compared to Average) age at menarche and secondary outcomes.

Outcome	Effect estimate (beta or odds ratio)	95% confidence interval	*p*-value	*R*-squared (pseudo)	*N*
Sexual Behaviours					
Age at first Intercourse (years)	Early: −0.25	(−.39, −.12)	$p < .001$	0.060	1407
	Late: 0.16	(.02, .31)	$p = .029$		
Sexual partners (Number)	Early: 0.04	(−.20, .28)	$p = .730$	0.019	1398
	Late: 0.21	(−.04, .47)	$p = .095$		
Pregnancies (number)	Early: 0.14	(−.05, .32)	$p = .152$	0.063	827
	Late: −0.10	(−.30, .10)	$p = .318$		
Abortions (Yes/No)	Early: OR = 1.03	(.61, 1.76)	$p = .902$	0.045	1391
	Late: OR = 1.39	(.83, 2.33)	$p = .212$		
Substance Use					
Smoking (Yes/No)	Early: OR = 0.87	(.63, 1.19)	$p = .385$	0.041	1511
	Late: OR = 1.19	(.87, 1.63)	$p = .281$		
Age at first alcohol (years)	Early: 0.09	(−.11, .29)	$p = .350$	0.052	1490
	Late: 0.31	(.10, .52)	$p = .004$		
Illicit drug use (Yes/No)	Early: OR = 1.05	(.68, 1.60)	$p = .832$	0.016	1415
	Late: OR = 1.15	(.74, 1.82)	$p = .532$		
Socioeconomic Outcomes					
Income at age 30 (% change)	Early: 0.95	(.84, 1.06)	$p = .390$	0.245	1211
	Late: 0.83	(.71, .95)	$p = .005$		
Grade failure at age 23 (Yes/No)	Early: OR = 1.07	(.82, 1.40)	$p = .606$	0.087	1508
	Late: OR = 1.27	(.95, 1.70)	$p = .103$		

All models were adjusted for the following covariates: skin colour, maternal education, family income tertile, birth weight, gestational age, maternal smoking, maternal age, maternal parity, BMI at age 4 (Model 3).

−0.16), adjusted for skin colour, maternal education, and family income tertile (Figure 1). Further adjustment for other covariables only slightly attenuated this association. In the fully adjusted model, Late AAM was associated 0.64 years lower educational attainment (95% CI: −1.15, −0.13). By contrast, Early AAM was not associated with educational attainment (−0.17 years of educational attainment, 95% CI: −0.64, 0.30).

AAM associated with risk-taking behaviours and socioeconomic outcomes

Table 3 shows the results of fully adjusted models for secondary outcomes. Early AAM, compared to Average AAM, was associated with younger age at first sexual intercourse (−0.25 years, 95% CI: −0.39, −0.12). In contrast, Late AAM was associated with older age at first sexual intercourse (0.16 years, 95% CI: 0.02, 0.31) and older age at first alcohol consumption (0.31 years, 95% CI: 0.10, 0.52). No statistically significant associations were seen between Early or Late AAM and number of sexual partners, pregnancies, abortions, smoking, or illicit drug use.

Late AAM, compared to Average AAM, was associated with ∼17% lower income at age 30 (0.83; 95% CI: 0.71, 0.95). The trend to higher odds of school grade failure in women with Late AAM compared to Average AAM did not reach statistical significance (OR = 1.27, 95% CI: 0.95, 1.70).

Sensitivity analyses

The results of sensitivity analyses, which considered education at 30 as a binary outcome (i.e. completed more than secondary education, 11+ years, or did not), were consistent with the primary analysis presented above: compared to the Average AAM group, odds of terminating school prior to the completion of secondary school was higher in the Late AAM group (OR = 1.45, 95% CI: 1.02, 2.06) but not different in the Early AAM group (OR = 0.82, 95% CI: 0.58, 1.18).

Discussion

In the fully adjusted linear model, women with Late AAM had lower education duration, by roughly two-thirds of a year compared to those with Average AAM. In contrast, the associations between Early AAM and educational attainment failed to reach statistical significance. Results of sensitivity analyses, which considered odds of completing less than secondary education, were consistent. The finding of increased odds of school grade failure in the Late AAM group (one of the secondary outcomes) is a further indication of the robust nature of the association observed in this cohort.

Results of secondary outcomes analysis revealed positive associations between AAM and both age at first sexual intercourse and age at first alcohol consumption, providing evidence of increased risk-taking behaviours in the Early AAM group. It is possible that the lack of significant association between AAM and other outcomes such as abortions and illicit drug use was due, in part, to the small number of individuals who reported these events. The observation of lower adult income in the Late AAM group is consistent with primary outcome analysis and may illustrate the long-term sequelae of reduced educational attainment.

Based on the existing body of literature, a link between early AAM and lower educational attainment would be expected (Stattin and Magnusson 1990; Graber et al. 2004; Johansson et al. 2005; Cavanagh et al. 2007). Surprisingly, our analysis found the opposite. Much of the existing literature reasons that Early AAM leads to changes in self-perception and peer relationships which impact both risk-taking behaviours and educational attainment (Graber et al.

2004; Cavanagh et al. 2007). Thus, the nature and direction of the observed associations with risk-taking behaviours (secondary outcomes), in the present analysis, has the potential to provide insight into the primary findings. Results consistent with existing literature were observed for the following risk-taking outcomes: age at first sex, alcohol consumption. In contrast, results consistent with the current findings of Late AAM and lower educational attainment were found for income at age 30 and school grade failure. Given the inherent relationships between school grade failure, education, and income, these results seem logical.

As previously noted, much of the existing evidence on this topic is from studies conducted in high-income nations in Europe and North America. Given the potential for strong social, cultural, and political influences on both an individual's understanding of puberty and the educational system to which they are exposed, it is important to acknowledge this contextual disparity. It is possible that the association between AAM and educational attainment operates via a different psychosocial mechanism in Brazil.

Contrary to most studies of puberty timing, numerous other studies have documented an association between increased maturity relative to peers and better academic performance due to season of birth within each school year (Davis et al. 1980; Hutchison and Sharp 1999; Martin et al. 2004; Verachtert et al. 2010). Such season of birth differences have been explained in terms of a difference in developmental maturity, teacher expectations, and self-confidence (Verachtert et al. 2010). Some studies have found this effect to be strongest in primary school, and to attenuate with increasing age, while others have documented ongoing effects up to university level attainment (Verachtert et al. 2010; Day et al. 2015). Hence, it is possible that perceived older maturity relative to peers contributes to better academic performance. Overall, the effect of AAM on educational attainment may depend on the context-specific balance between some advantage conferred by relative maturity, and a greater propensity for risk-taking behaviours in adolescence.

Strengths of this analysis include the prospective nature of the study design and the extensive follow-up with rich information on both maternal and participant characteristics. A relatively high retention rate was obtained (e.g. 72% follow-up after 23 years), and almost all births that occurred in the city of Pelotas in 1982 were enrolled in the study. The present analysis considers a question that has yet to be examined in the context of Brazil and thus has the potential to make an original contribution to the existing literature.

Limitations include the potential for reporting bias (particularly for substance use and sexual behaviour secondary outcomes) and residual confounding. We acknowledge the possibility of recall bias in AAM at age 23. AAM is reported to be accurately recalled in other populations (Koo and Rohan 1997; Bosetti et al. 2001; Must et al. 2002) but such data are lacking in Brazil or other economic transition settings. Only 3.5% ($n = 45$) of the analysed cohort reported menarche at age 7–9, indicating a small number of cases of very early puberty that are unlikely to have skewed the results. Additionally, it is important to consider patterns of missing data (Supplementary Table 1). Here, the group of individuals with some missing data (thus, excluded from the complete case analysis) had a lower level of educational attainment, adult income, and were more likely to have failed a grade in school. Thus, it is possible that more extreme cases were excluded due to missing data (e.g. particularly low education, income, etc.). If this were the case, the more homogenous sample retained in the complete case analysis could potentially yield a conservative estimate of any true association as a result of the reduced range of observed outcomes. We also acknowledge the possibility of residual confounding by socioeconomic status. Supplementary Table 2 shows bivariate associations between age at menarche and model covariates. Higher maternal education (but not family income at birth) was weakly inversely associated with age at menarche.

These results suggest a number of areas for further research. First, the current educational attainment findings diverge from the existing body of published literature on this topic. Thus, efforts should be made to replicate these findings in contexts of recent economic transition. Secondly, an understanding of the mechanisms linking puberty timing to educational outcomes would inform interventions to avoid barriers to optimal educational achievement. For example, qualitative studies with school-age children, parents and teachers might shed insights into the possible roles of personal (e.g. self-confidence, risk-taking) and peer-related (e.g. attractiveness to older peers) psychosocial factors and how these might differ across settings.

Overall, investigation into the association between puberty timing and educational attainment may help to clarify one of the specific mechanisms which contributes to the reciprocal relationship between health status and socioeconomic factors. Efforts should continue to be made to understand both the determinants of puberty timing and its far-reaching health, psychological, and educational implications.

Disclosure statement

The authors report no conflict of interest.

Funding

This study was funded by the Conselho Nacional de Desenvolvimento Científico e Tecnológico; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior and Medical Research Council.

ORCID

Lucia M. Calthorpe http://orcid.org/0000-0002-0496-9471

References

Biro F, Chan Y-M. 2018. Normal puberty. UpToDate; [accessed 2019 October 7]. https://www.uptodate.com/contents/normal-puberty.

Boden JM, Fergusson DM, Horwood LJ. 2011. Age of menarche and psychosocial outcomes in a New Zealand birth cohort. J Am Acad Child Adolesc Psychiatry. 50(2):132–140.

Bosetti C, Tavani A, Negri E, Trichopoulos D, La Vecchia C. 2001. Reliability of data on medical conditions, menstrual and reproductive history provided by hospital controls. J Clin Epidemiol. 54(9):902–906.

Cavanagh SE, Riegle-Crumb C, Crosnoe R. 2007. Puberty and the education of girls. Soc Psychol Q. 70(2):186–198.

Copeland W, Shanahan L, Miller S, Costello EJ, Angold A, Maughan B. 2010. Outcomes of early pubertal timing in young women: a prospective population-based study. AJP. 167(10):1218–1225.

Davis BG, Trimble CS, Vincent DR. 1980. Does age of entrance affect school achievement? Elem Sch J. 80(3):133–143.

Day FR, Elks CE, Murray A, Ong KK, Perry J. 2015. Puberty timing associated with diabetes, cardiovascular disease and also diverse health outcomes in men and women: the UK Biobank study. Sci Rep. 5(1): 11208.

Day FR, Forouhi NG, Ong KK, Perry J. 2015. Season of birth is associated with birth weight, pubertal timing, adult body size and educational attainment: a UK Biobank study. Heliyon. 1(2):e00031.

Day FR, Thompson DJ, Helgason H, Chasman DI, Finucane H, Sulem P, Ruth KS, et al. 2017. Genomic analyses identify hundreds of variants associated with age at menarche and support a role for puberty timing in cancer risk. Nat Genet. 9:834–841.

Graber JA, Seeley JR, Brooks-Gunn J, Lewinsohn PM. 2004. Is pubertal timing associated with psychopathology in young adulthood? J Am Acad Child Adolesc Psychiatry. 43(6):718–726.

Hendrick CE, Cohen AK, Deardorff J, Cance JD. 2016. Biological and sociocultural factors during the school years predicting women's lifetime educational attainment. J School Health. 86(3):215–224.

Hsieh C-C, Trichopoulos D, Katsouyanni K, Yuasa S. 1990. Age at menarche, age at menopause, height and obesity as risk factors for breast cancer: Associations and interactions in an international case-control study. Int J Cancer. 46(5):796–800.

Hutchison D, Sharp C. 1999. A Lasting Legacy? The persistence of season of birth effects. [accessed 2017 Jul 2]. http://www.leeds.ac.uk/educol/documents/000001095.htm.

Jacobsen BK, Heuch I, Kvåle G, Kvale G. 2007. Association of low age at menarche with increased all-cause mortality: a 37-year follow-up of 61,319 Norwegian women. Am J Epidemiol. 166(12):1431–1437.

Johansson TT, Ritzen EM, Ritzén EM. 2005. Very long-term follow-up of girls with early and late menarche. Endocr Dev. 8:126–136.

Junqueira Do Lago M, Faerstein E, De Souza Lopes C, Werneck GL, Pro-Saude Study (Rio de Janeiro B. 2003. Family socio-economic background modified secular trends in age at menarche: evidence from the Pro-Saude Study (Rio de Janeiro, Brazil. Ann Hum Biol. 30(3): 347–352.

Kac G, Auxiliadora De Santa Cruz Coelho M, Velasquez Melendez G. 2000. Short report: secular trend in age at menarche for women born between 1920 and 1979 in Rio de Janeiro, Brazil. Ann Hum Biol. 27(4): 423–428.

Kågesten A, Blum RW, Kagesten A, Blum RW. 2015. Characteristics of youth who report early sexual experiences in Sweden. Arch Sex Behav. 44(3):679–694.

Koivusilta L, Rimpela A. 2004. Pubertal timing and educational careers: a longitudinal study. Ann Hum Biol. 31(4):446–465.

Koo MM, Rohan TE. 1997. Accuracy of short-term recall of age at menarche. Ann Hum Biol. 24(1):61–64.

Lakshman R, Forouhi N, Luben R, Bingham S, Khaw K, Wareham N, Ong KK. 2008. Association between age at menarche and risk of diabetes in adults: results from the EPIC-Norfolk cohort study. Diabetologia. 51(5):781–786.

Lakshman R, Forouhi NG, Sharp SJ, Luben R, Bingham SA, Khaw K-T, Wareham NJ, Ong KK. 2009. Early age at menarche associated with cardiovascular disease and mortality. J Clin Endocrinol Metab. 94(12): 4953–4960.

Martin RP, Foels P, Clanton G, Moon K, Bjertness E. 2004. Season of Birth Is Related to Child Retention Rates, Achievement, and Rate of Diagnosis of Specific LD. J Learn Disabil. 37(4):307–317.

Mendle J, Turkheimer E, Emery RE. 2007. Detrimental psychological outcomes associated with early pubertal timing in adolescent girls. Dev Rev. 27(2):151–171.

Must A, Phillips SM, Naumova EN, Blum M, Harris S, Dawson-Hughes B, Rand WM. 2002. Recall of early menstrual history and menarcheal body size: after 30 years, how well do women remember? Am J Epidemiol. 155(7):672–679.

Stattin H, Magnusson D. 1990. Pubertal maturation in female development. Mahwah (NJ): Erlbaum Associates.

Verachtert P, De Fraine B, Onghena P, Ghesquière P. 2010. Season of birth and school success in the early years of primary education. Oxford Rev Educ. 36(3):285–306.

Victora CG, Barros FC, Lima RC, Behague DP, Gonçalves H, Horta BL, Gigante DP, Patrick Vaughan J. 2003. The Pelotas Birth Cohort Study, Rio Grande do Sul, Brazil, 1982-2001. [accessed2019 Feb 7]. http://www.nichd.nih.gov/despr/cohort.

Victora CG, Barros FC. 2006. Cohort Profile: The 1982 Pelotas (Brazil) Birth Cohort Study. Int J Epidemiol. 35:237–242.

Westling E, Andrews JA, Hampson SE, Peterson M. 2008. Pubertal timing and substance use: the effects of gender, parental monitoring and deviant peers. J Adolesc Health. 42(6):555–563.

Yermachenko A, Dvornyk V. 2014. Nongenetic determinants of age at menarche: a systematic review. Biomed Res Int. 2014:1–14. http://www.ncbi.nlm.nih.gov/pubmed/25050345.