Mother's age at menarche and offspring size

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Abstract

Objective—An individual’s growth trajectory is, at least in part, inherited. Mother’s early age at menarche has been associated with taller offspring height and greater body mass index (BMI) at age 9 years, suggesting that mother’s age at menarche may be an intergenerational marker of growth. We examined the association between mother’s age at menarche and childhood size at birth, and at the ages 1, 3, 4, 7, and 8 years in the Collaborative Perinatal Project (CPP).

Subjects—We examined 128,636 measurements from 31,474 Black and White children. We transformed the original measurements into z-scores. Child size was examined in mixed models, adjusted for center, child sex, race, socioeconomic index, child’s exact age at measurement (in months), mother’s age at recruitment and, depending on which measure was the outcome in the specific model, mother’s height, pre-pregnancy weight, or BMI.

Results—Compared with children whose mother had menarche at age 15 or later, children whose mothers had age at menarche before age 12 were taller from age 1 and had higher BMI at ages 7 and 8 (0.17 and 0.19 z, respectively).

Conclusions—Mother’s age at menarche is a modest predictor of their children’s growth trajectory. The mechanism is likely to be heritable, although other explanations are possible.

Keywords

Age at menarche; Body Mass Index; Growth trajectory
Evidence suggests that rapid early childhood weight gain, insulin resistance, and timing of puberty are interrelated and may recur in consecutive generations. Rapid growth in infancy or early childhood is itself a predictor of higher body mass index (BMI) in later childhood and young adulthood, although this has not been observed in all populations. A study of pedigrees suggested that the significant associations between age at menarche and obesity phenotypes were mainly attributable to shared genetic rather than environmental factors, and age at menarche appears to have a strong heritable component.

BMI before age 13 appears to have a limited value in predicting adult BMI on an individual basis, but a correlation exists at a population level. Mother’s age at menarche will be an even weaker predictor of adult BMI, but it is of interest to identify heritable markers that may interact with environmental determinants of overweight. In this paper, we examined whether the association between mother’s age at menarche and offspring growth was present in a large population of US Black and White children born from 1959 to 1966 in the Collaborative Perinatal Project.

**Methods**

The Collaborative Perinatal Project was a prospective pregnancy cohort of 58,760 pregnancies in 48,197 women who gave birth between 1959 and 1966. Women were enrolled in 12 U.S. academic medical centers during pregnancy (Baltimore, Boston, Buffalo, Memphis, Minneapolis, New Orleans, New York Columbia, New York Metropolitan, Philadelphia, Portland, Providence, and Richmond) and were followed through delivery, while their children were followed up to 7 years of age in all centers, and up to 8 years of age in approximately half the centers. Mothers self-reported their height and pre-pregnancy weight. Children were measured according to standardized procedures by trained personnel. Length/height was measured to the nearest 0.5 cm, in a supine position through 20 months age, and standing thereafter. Scales were calibrated at least semi-annually.

We included the first singleton live birth contributed by each woman during the study enrollment period (not necessarily her first child) with non-missing data on baby’s sex, birth weight, and mother’s age at menarche (n=43,037). We excluded women with race other than Black or White (n=3,553), infants with major malformations (n=3,266), and those with unlikely birth weight (n=35). Among the remaining 36,183, 4,531 children had no further weight measurements (beyond birth), thus leaving 31,652 eligible children. Finally, we excluded 3 records with mother’s age at menarche recorded as having been less than 7 years, and 175 mothers whose age at menarche was within 2 years of age at recruitment. We excluded these mothers because we wanted to be sure that menstruation had been fully established by the time of conception. As we only had age in completed years for age at recruitment, a 2 year difference was chosen to guarantee this. The final sample included 31,474 children with valid birth weight and at least one later weight measurement, with 128,636 measurements in total. Some analyses, however, include fewer individuals due to missing length/height in children or missing weight or height in mothers, as mother’s anthropometry was included as a covariate in the models. Sample size varied also by age of the children, depending on how many were measured at each point in time.
We examined the association between mother’s age at menarche and child length/height, weight, and body mass index (BMI) at birth and ages 1, 3, 4, 7, and 8 years (±2 months) using linear mixed models. Due to the relatively small number of measurement times and the nonlinear nature of child growth, we modeled age as a step function with different intercepts and different menarche slopes for each age at measurement. We also included a continuous covariate accounting for the month of measurement in each year (children could, however, be only ±2 months younger or older than the nominal age, otherwise the observation was excluded).

We considered the data both in their original scale and as z-scores calculated from the whole CPP cohort. As the z-score was sex- and age-specific, it is not influenced by age, which allowed us to easily compare the relative effects at different ages. Here, we present the results based on the z-score.

In our primary models, we categorized mother’s age at menarche as ≤11, 12, 13, 14, and 15 years or older. The categorical treatment provided us with a non-parametric assessment of the age at menarche-child size relations, which is consistent with the approach of Ong and colleagues. However, to determine if there was a significant linear relation between age at menarche and child size at different ages, we also treated age at menarche as continuous, with values, in completed years, in the range 11–15, with <11 coded as 11, and >15 coded as 15. Regardless of how we treated age at menarche, we always allowed the effect to change with child’s age in order to test for a menarche-by-year interaction.

For each measurement, our primary model (ignoring covariates) was as follows:

\[ y_{it} = \beta_0t + \beta_1t (q_{1i}) + \beta_2t (q_{2i}) + \beta_3t (q_{3i}) + \beta_4t (q_{4i}) + \beta_5t (\text{age}_{it} - t) + \varepsilon_{it}, \]

where \( y_{it} \) is the measurement (height, weight, or BMI) for child \( i \) at year \( t \), \( q_{ki} \) is an indicator variable that equals 1 if the age at menarche of the child’s mother was in the \( k \)th category \((k = 1, 2, 3, 4 \) with menarche at 15+ serving as the reference category); \( \text{age}_{it} \) is the age of the child at time of measurement in year \( t \), \( \beta_0t \), \( \beta_1t \), \( \beta_2t \), \( \beta_3t \), \( \beta_4t \), and \( \beta_5t \) are the year-specific intercept and slopes, and \( \varepsilon_{it} \) is the residual error. An unstructured covariance matrix was used to model the variances and correlations between the errors from the same child at different years. We used the Kenward-Roger method to calculate the degrees of freedom for tests of menarche effects and menarche-by-year interactions, assuming an unstructured covariance matrix for measurements obtained from the same child at different years.

We first tested whether there were significant interactions between mother’s age at menarche and children’s sex and race on their body size. We used age at menarche as a continuous variable to have a more sensitive test. When using the z-score, there was no interaction with a \( p<0.10 \), and we thus present the results for Blacks and Whites and boys and girls together (stratified results are shown in the online appendix). When using the measurements in the original scale, for weight there was a significant interaction between mother’s age at menarche and race (we present these results in the online appendix).

Estimates were adjusted for center, race (Black or White), child sex, socioeconomic index (3 levels, plus a separate category for the 3% with missing values), child’s exact age at...
measurement (in months), mother’s age at recruitment and, depending on which measure was the outcome in the specific model, mother’s height, pre-pregnancy weight, or BMI. We adjusted for mother’s anthropometry to evaluate whether an effect of age at menarche was present beyond that due to correlation with the size of the mother. In a further analysis, however, we also ran models not adjusted for mother’s anthropometry, using the total available sample (i.e., including the women with missing height and weight).

We did not treat mother’s smoking as a confounder, because smoking is likely to have started after menarche. However, because a previous analysis showed that mother’s smoking during pregnancy was associated with higher BMI in their children,16 we checked whether including smoking in the models had an impact on our estimates. SAS 9.1 (SAS Institute Inc., Cary, NC) was used for statistical analyses.

Results

As expected, women with age at menarche ≤11 were, on average, shorter and more frequently overweight than women with menarche at later ages (table 1). Table 2 shows mean length/height, weight, and BMI of the children at different ages, according to mother’s age at menarche. Especially at ages 7 and 8, children whose mother’s age at menarche was ≤11 years were slightly taller and had a higher BMI compared with children whose mother’s age at menarche was later, particularly 15 or older.

Offspring anthropometry differed according to mother’s age at menarche. Although the association between age at menarche and offspring anthropometry was statistically significant at several ages in the adjusted models, the largest and most consistent association was seen when the children were aged 7 and 8 (appendix table 1, contrasts). Figure 1 shows the difference in length/height, weight, and BMI (expressed as z scores) at the various ages as a function of mother’s age at menarche (children whose mother had menarche at ≥15 years constitute the reference category). There was a small difference in birth length with mother’s age, and the trend became stronger with age, with children born to mothers with age at menarche before 12 years being taller than children whose mothers had menarche at an older age, particularly 15+. Babies born to mothers with early age at menarche tended to be slightly lighter at birth, but the pattern reversed at 1 year and thereafter resembled the trend seen with height. The results for BMI were similar to those for weight, although a clear trend of increasing BMI among children born to women with early menarche is not seen until age 4. For reference, at age 7, a difference of 0.2 z corresponded to about 1 cm (<1% of the mean height), 0.8 kg (3% of the mean weight), and 0.4 kg/m² (approximately 2.5% of the mean BMI), respectively. (Appendix figures 1 and 2 show the results for the analogous models, stratified by sex and race, for height and BMI).

Table 3 shows the linear coefficients from the mixed models when age at menarche is treated continuously (as described above). Although the effect of each increment in mother’s age at menarche on offspring size is small, all estimates (except that for BMI at age 3) were significant (p<.05).
We saw similar results in the models where mother’s anthropometry was not included as a covariate. However, the association of age at menarche with child’s height was slightly attenuated by omitting mother’s height in the model, while the association with child’s BMI was strengthened when mother’s BMI was omitted. (Appendix figure 3 shows the results with and without adjustment).

The results were virtually identical when we further adjusted for mother’s smoking (never, former, current, and missing), and also when we reintroduced the 175 women excluded because their age at menarche was within two years of their age at enrolment (not shown).

The results were also very similar when we used the measurements in the original scale instead of the \( z \)-score (not shown). However, the relation between mother’s age at menarche and child weight in the original scale showed statistical evidence of varying according to race \((p=0.052)\). We thus report the results for weight stratified by race (appendix figure 4).

**Discussion**

In this large cohort of US children born from 1959 to 1966, we saw that children whose mothers had menarche at 11 years or younger appeared to have a faster growth trajectory than children born to mothers with later age at menarche. We saw similar results in Blacks and Whites, and in boys and girls, and we present the combined results. The estimated effects were small in absolute terms, but consistent in showing that children of women with early age at menarche were, on average, taller and had a higher BMI at ages 7 and 8 than women with later age at menarche. Our estimates were adjusted, among other factors, for mother’s anthropometry (mother’s height when child’s length/height was the outcome, etc), because we wanted to assess whether there was an association beyond that due to the mother’s own size. When we omitted mother’s anthropometry in the analysis, the results were attenuated for height and strengthened for weight and BMI. We were particularly interested in examining the effect of age at menarche on BMI. As mothers with early age at menarche were themselves heavier, we included their BMI in the model to see whether any effect remained following adjustment. The fact that inclusion of height in the models strengthened the association, rather than attenuate it, is due to the fact that mothers with earlier age at menarche were shorter than mothers with late age at menarche, while their children were taller in the age range of this study.

The larger size of children born to mothers with early menarche was more apparent at ages 4 and, especially, 7 and 8 than in earlier childhood – but such a pattern was detectable in infancy for length/height and weight. Children of mothers with menarche at \( \leq 11 \) years, although taller at age 8, are likely to end up being shorter adults, since their vertical growth stops earlier.\(^1\)

Girls with a high BMI for their age have a tendency to experience menarche earlier\(^17\) and to have higher BMI as adults\(^18\). In a study based on 597 mother-daughter pairs from the CPP with complete menstrual history available, Keim et al reported that a maternal BMI of 25 or higher predicted earlier age at menarche in their daughters, a finding symmetrical to ours\(^19\). Terry et al\(^20\) reported that, among 262 women who had been born to mothers enrolled in the...
CPP, higher percentile change in weight between 4 months and 1 year of age was associated with earlier age at menarche, after adjustment for mother’s age at menarche. Garn and colleagues have speculated that the same factors cause both fatness and early maturation and these factors may in part be genetic.

Early age at mother’s menarche predicted larger size in both boys and girls, suggesting that it may be one of many markers related to programming of overall growth, rather than being specific to female development.

Our results indicate that, when accounting for the mother’s own height, children born to mothers who had early menarche tend to be slightly taller from infancy and, by age 7, these children are taller and have higher weight and BMI than children born to mothers with later age at menarche. Although trends were, for the most part, linear, the largest difference was mostly between children born to women with menarche at age 11 or earlier and those born to women with age at menarche of 15 or older. It has been suggested that rapid growth in infancy may have a programming effect on later body composition. While this may be true, the finding of a relation between mother’s age at menarche and more rapid growth suggests that a tendency to faster growth is, at least in part, inherited. Rapid early postnatal growth, childhood adiposity, and earlier age at puberty may all have shared genetic determinants, and heritability of age at menarche has been estimated to be between 0.5 and 0.78–10. It is, however, also possible that mothers’ age at menarche is associated with non-genetic characteristics, such as nutritional status or physical activity, that also influence their children’s growth. Mothers with younger age at menarche were generally younger, tended to be of higher social class, and were more likely to be smokers (appendix table 2). We adjusted for age and socioeconomic index in our analyses, but we cannot rule out that other correlates of age at menarche, such as diet, could have produced our findings.

Adair reports that girls who were relatively long and thin at birth tended to have earlier menarche. An earlier age at first conception and higher social class had been previously reported among women with early menarche. Along similar lines, our results suggest that women with early menarche give birth to slightly longer and thinner babies.

Our study has several strengths and limitations. The cohort was large, and children were measured at various ages by trained personnel, although not all ages were equally well represented. Furthermore, we were able to adjust for several covariates, and we had a large number of Blacks. The fact that maternal age at menarche and pre-pregnancy anthropometry were self-reported constitutes a limitation of this study, as well as the absence of any information about the father’s height or age at puberty (although indicators of puberty in males are difficult to recollect). However, we saw the expected relation between mother’s age at menarche and her height and BMI. We used BMI as an outcome for infants, which may not be the best measure to assess adiposity at such an early age. Most of the influence of mother’s age at menarche was, however, observed at ages 7 and 8. Missingness of the child’s measurements at some ages was weakly associated with body size (based on the non-missing measurements). However, the estimates from the mixed model are unbiased as long as missingness is not related to the unobserved measurements. If the children’s body size determined, in some instances, their willingness to take part in later measurements, and if
these children were more likely to have mothers who themselves had a higher BMI, we may have underestimated the relation between mother’s age at menarche and children size.

Our findings, based on data collected 30 years before those in the ALSPAC Cohort, corroborate those reported by Ong et al 1, and indicate that mothers’ age at menarche is a modest predictor of their children’s size at age 7 and 8. This mechanism is likely to be heritable, although other explanations are possible.

**Supplementary Material**

Refer to Web version on PubMed Central for supplementary material.

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**References**

1. Ong KK, Northstone K, Wells JC, Rubin C, Ness AR, Golding J, Dunger DB. Earlier mother's age at menarche predicts rapid infancy growth and childhood obesity. PLoS Med. 2007; 4(4):e132. [PubMed: 17455989]
2. Dunger DB, Ahmed ML, Ong KK. Early and late weight gain and the timing of puberty. Mol Cell Endocrinol. 2006:254–255. 140–145.
3. Ong KK, Loos RJ. Rapid infancy weight gain and subsequent obesity: systematic reviews and hopeful suggestions. Acta Paediatr. 2006; 95(8):904–908. [PubMed: 16882560]
4. Monteiro PO, Victora CG. Rapid growth in infancy and childhood and obesity in later life--a systematic review. Obes Rev. 2005; 6(2):143–154. [PubMed: 15836465]
5. Baird J, Fisher D, Lucas P, Kleijnen J, Roberts H, Law C. Being big or growing fast: systematic review of size and growth in infancy and later obesity. Bmj. 2005; 331(7522):929. [PubMed: 16227306]
6. Adair LS. Child and adolescent obesity: epidemiology and developmental perspectives. Physiol Behav. 2008; 94(1):8–16. [PubMed: 18191968]
7. Wang W, Zhao LJ, Liu YZ, Recker RR, Deng HW. Genetic and environmental correlations between obesity phenotypes and age at menarche. Int J Obes (Lond). 2006; 30(11):1595–1600. [PubMed: 16568135]
8. Kaprio J, Rimpela A, Winter T, Viken RJ, Rimpela M, Rose RJ. Common genetic influences on BMI and age at menarche. Hum Biol. 1995; 67(5):739–753. [PubMed: 8543288]
9. Parent AS, Teilmann G, Juul A, Skakkebaek NE, Toppari J, Bourguignon JP. The timing of normal puberty and the age limits of sexual precocity: variations around the world, secular trends, and changes after migration. Endocr Rev. 2003; 24(5):668–693. [PubMed: 14570750]
10. Treloar SA, Martin NG. Age at menarche as a fitness trait: nonadditive genetic variance detected in a large twin sample. Am J Hum Genet. 1990; 47(1):137–148. [PubMed: 2349942]
11. Guo SS, Roche AF, Chumlea WC, Gardner JD, Siervogel RM. The predictive value of childhood body mass index values for overweight at age 35 y. Am J Clin Nutr. 1994; 59(4):810–819. [PubMed: 8147324]
12. Niswander, KB.; Gordon, M. The women and their pregnancies: the Collaborative Perinatal Study of the National Institute of Neurological Diseases and Stroke. Washington, DC: US GOvernment Print Office; 1972.
13. U.S. Department of Health E, and Welfare. Public Health Service. Manuals: Pediatric-Neurology. Vol. Part III-B. Bethesda, MD: National Institutes of Health; 1966. The collaborative study on
cerebral palsy mental retardation and other neurological and sensory disorders of infancy and childhood; p. 7720014

14. Cole, TJ. The life course plot in life course analysis. In: Pickles, A.; Maughan, A.; Wadsworth, M., editors. Epidemiological methods in life course research. New York: Oxford University Press; 2007. p. 138-155.

15. Kenward MG, Roger JH. Small sample inference for fixed effects from restricted maximum likelihood. Biometrics. 1997; 53(3):983–997. [PubMed: 9333350]

16. Chen A, Pennell ML, Klebanoff MA, Rogan WJ, Longnecker MP. Maternal smoking during pregnancy in relation to child overweight: follow-up to age 8 years. Int J Epidemiol. 2006; 35(1):121–130. [PubMed: 16260450]

17. Anderson SE, Dallal GE, Must A. Relative weight and race influence average age at menarche: results from two nationally representative surveys of US girls studied 25 years apart. Pediatrics. 2003; 111(4 Pt 1):844–850. [PubMed: 12671122]

18. Garn SM, LaVelle M, Rosenberg KR, Hawthorne VM. Maturational timing as a factor in female fatness and obesity. Am J Clin Nutr. 1986; 43(6):879–883. [PubMed: 3717062]

19. Keim SA, Brum AM, Klebanoff MA, Zemel BS. Maternal body mass index and daughters’ age at menarche. Epidemiology. 2003; 14(5):489–502. [PubMed: 18538288]

20. Terry MB, Ferris JS, Tehranifar P, Wei Y, Flom JD. Birth weight, postnatal growth, and age at menarche. Am J Epidemiol. 2009; 170(1):72–79. [PubMed: 19439580]

21. Druet C, Ong KK. Early childhood predictors of adult body composition. Best Pract Res Clin Endocrinol Metab. 2008; 22(3):489–502. [PubMed: 18538288]

22. Ong KK, Ahmed ML, Dunger DB. Lessons from large population studies on timing and tempo of puberty (secular trends and relation to body size): the European trend. Mol Cell Endocrinol. 2006:254–255. 8–12.

23. Adair LS. Size at birth predicts age at menarche. Pediatrics. 2001; 107(4):E59. [PubMed: 11335780]

24. Sandler DP, Wilcox AJ, Hornsey LF. Age at menarche and subsequent reproductive events. Am J Epidemiol. 1984; 119(5):765–774. [PubMed: 6720673]
Figure 1.
Mean length/height (95% CI), weight, and BMI at birth, 1, 3, 4, 7, and 8 years of age in children as a function of mother’s age at menarche. Estimates are adjusted differences from children born to women with menarche at age 15 obtained from mixed models1,2.

1 Adjusted for study center, race, child’s sex, socioeconomic index, child’s age at measurement, mother’s age at recruitment, and mother’s height (in the length/height model), weight (in the weight model) or BMI (in the BMI model).

2 All p-values for a linear trend were <0.05, except for BMI at age 3.
### Table 1

Mother’s anthropometry in relation to her self-reported age at menarche

| Age at menarche | Length/Height, cm | Weight, kg | BMI, kg/m² | % ≥25 |
|-----------------|-------------------|------------|------------|-------|
|                 | No.               | Mean       | SD         | No.   | Mean       | SD         | No.   | Mean       | SD         | % ≥25 |
| ≤1 yrs          | 6357              | 160.64     | 6.63       | 6608  | 60.49      | 12.52      | 6296  | 23.49      | 4.72       | 27.5  |
| 12 yrs          | 7535              | 161.33     | 6.68       | 7837  | 59.23      | 11.51      | 7450  | 22.79      | 4.28       | 21.3  |
| 13 yrs          | 8166              | 161.77     | 6.60       | 8536  | 58.71      | 11.28      | 8086  | 22.46      | 4.17       | 19.6  |
| 14 yrs          | 4041              | 162.00     | 6.75       | 4186  | 58.25      | 11.19      | 3997  | 22.25      | 4.07       | 18.2  |
| ≥15 yrs         | 3371              | 162.17     | 6.99       | 3504  | 58.40      | 11.43      | 3331  | 22.21      | 4.12       | 18.1  |
Table 2
Mean length/height, weight, and BMI in children as a function of their mother’s age at menarche.

| Age at menarche | Birth | Child's age (yrs) | N  | Mean | S.D. | N  | Mean | S.D. | N  | Mean | S.D. | N  | Mean | S.D. | N  | Mean | S.D. | N  | Mean | S.D. |
|----------------|-------|------------------|----|------|------|----|------|------|----|------|------|----|------|------|----|------|------|----|------|------|
|                |       | 1                |    |      |      | 2  |      |      | 3  |      |      | 4  |      |      | 6  |      |      | 7  |      |      | 8  |      |      |
| Length/height(cm) |      |                 |    |      |      |    |      |      |    |      |      |    |      |      |    |      |      |    |      |      |    |      |      |
| ≤1 yrs         | 6674  | 49.9             | 2.70| 6026 | 74.3| 3.18| 2688 | 94.6| 3.86| 4476 | 101.9| 4.46| 5068 | 121.7| 5.38| 2595 | 128.0| 5.54|
| 12 yrs         | 7937  | 49.9             | 2.69| 7186 | 74.3| 3.17| 3226 | 94.5| 3.90| 5234 | 101.8| 4.45| 5965 | 121.5| 5.32| 3139 | 127.7| 5.58|
| 13 yrs         | 8624  | 50.0             | 2.66| 7829 | 74.3| 3.23| 3647 | 94.4| 3.98| 5749 | 101.5| 4.45| 6578 | 121.2| 5.39| 3481 | 127.3| 5.50|
| ≥15 yrs        | 3536  | 49.9             | 2.64| 3209 | 74.2| 3.31| 1373 | 94.2| 4.08| 2349 | 101.4| 4.44| 2663 | 120.7| 5.47| 1322 | 126.8| 5.72|
| Weight (kg)    |       |                 |    |      |      |    |      |      |    |      |      |    |      |      |    |      |      |    |      |      |    |      |      |
| ≤1 yrs         | 6778  | 3.2              | 0.53| 6046 | 9.8 | 1.20| 2708 | 14.4| 1.76| 4485 | 16.6 | 2.32| 5071 | 24.0 | 4.24| 2598 | 27.0 | 5.01|
| 12 yrs         | 8068  | 3.2              | 0.52| 7206 | 9.8 | 1.20| 3251 | 14.3| 1.82| 5250 | 16.5 | 2.24| 5970 | 23.6 | 4.04| 3143 | 26.5 | 4.77|
| 13 yrs         | 8742  | 3.2              | 0.52| 7847 | 9.8 | 1.20| 3681 | 14.2| 1.77| 5766 | 16.4 | 2.19| 6579 | 23.4 | 3.94| 3486 | 26.2 | 4.64|
| ≥15 yrs        | 3598  | 3.2              | 0.53| 3223 | 9.7 | 1.23| 1382 | 14.1| 1.88| 2352 | 16.3 | 2.29| 2665 | 23.0 | 3.92| 1324 | 25.8 | 5.04|
| BMI (kg/m²)    |       |                 |    |      |      |    |      |      |    |      |      |    |      |      |    |      |      |    |      |      |    |      |      |
| ≤1 yrs         | 6674  | 12.7             | 1.60| 6026 | 17.7| 1.68| 2688 | 16.1| 1.43| 4476 | 16.0 | 1.57| 5068 | 16.1 | 2.07| 2595 | 16.4 | 2.25|
| 12 yrs         | 7937  | 12.7             | 1.55| 7186 | 17.7| 1.68| 3226 | 16.0| 1.43| 5234 | 15.9 | 1.52| 5965 | 15.9 | 1.95| 3139 | 16.2 | 2.13|
| 13 yrs         | 8624  | 12.7             | 1.46| 7829 | 17.7| 1.69| 3647 | 15.9| 1.39| 5749 | 15.9 | 1.52| 6578 | 15.9 | 1.93| 3481 | 16.1 | 2.11|
| ≥15 yrs        | 3536  | 12.7             | 1.49| 3209 | 17.6| 1.77| 1373 | 15.9| 1.55| 2349 | 15.8 | 1.58| 2663 | 15.7 | 1.92| 1322 | 15.9 | 2.21|
Table 3

Estimated effect of continuous mother’s age at menarche (in completed years) on children’s size from birth to age 8$^1$.

| Age  | Height, cm  | Weight, kg  | BMI, kg/m$^2$ |
|------|-------------|-------------|---------------|
|      | Estimate    | SE          | DF            | p   | Estimate    | SE          | DF            | p   | Estimate | SE          | DF            | p   |
| Birth| −0.013      | 0.0045      | 28131         | 0.00280      | 0.018 | 0.0041    | 30843        | 0.00000      | 0.015 | 0.0045   | 28995       | 0.00060      | 0.00280 |
| 1    | −0.033      | 0.0045      | 27515         | 0.00000      | 0.0016 | 0.0046    | 29974        | 0.00030      | −0.011 | 0.0049   | 27250       | 0.02320      | 0.00000 |
| 3    | −0.045      | 0.0052      | 21609         | 0.00000      | −0.020 | 0.0050    | 25091        | 0.00010      | −0.008 | 0.0058   | 18297       | 0.14580      | 0.00000 |
| 4    | −0.050      | 0.0047      | 25560         | 0.00000      | −0.029 | 0.0046    | 28746        | 0.00000      | −0.016 | 0.0048   | 24921       | 0.00120      | 0.00000 |
| 7    | −0.063      | 0.0047      | 25430         | 0.00000      | −0.047 | 0.0046    | 28081        | 0.00000      | −0.039 | 0.0048   | 25773       | 0.00000      | 0.00000 |
| 8    | −0.069      | 0.0050      | 23890         | 0.00000      | −0.055 | 0.0052    | 24224        | 0.00000      | −0.046 | 0.0057   | 19831       | 0.00000      | 0.00000 |

$^1$ Adjusted for study center, race, child’s sex, socioeconomic index, child’s age at measurement, mother’s age at recruitment, and mother’s height (in the length/height model), weight (in the weight model) or BMI (in the BMI model).