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Prenatal and childhood environmental tobacco smoke exposure and age at menarche

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Abstract

Previous studies have reported mixed results regarding the association between age at menarche and environmental tobacco smoke exposure, both prenatally and during early childhood; however, few studies have had data available during both time periods. The present study examined whether exposure to prenatal tobacco smoke (PTS) via maternal smoking during pregnancy or childhood environmental tobacco smoke (ETS) was associated with age at menarche in a multi-ethnic birth cohort. With the uniquely available prospectively collected data on body size and growth at birth and in early life, we further examined whether the association between PTS and ETS exposure and age at menarche was mediated by these variables. From 2001 to 2006, we recruited 262 women born between 1959 and 1963 who were enrolled previously in a New York City site of the National Collaborative Perinatal Project. Mothers who smoked during pregnancy vs. those who did not were more likely to be White, younger, have more education and have lower birthweight babies. Daughters with heavy PTS exposure (≥ 20 cigarettes per day) had a later age at menarche (>12 years vs. ≤ 12 years), odds ratio (OR) = 2.1 [95% confidence interval (CI) 0.9, 5.0] compared with daughters with no PTS. Daughters exposed to only childhood ETS had a later age at menarche, OR = 2.1 [95% CI 1.0, 4.3], and those exposed to PTS and ETS combined had a statistically significant later age at menarche, OR = 2.2 [95% CI 1.1, 4.6] compared with daughters with no PTS and no ETS. These results did not change after further adjustment for birthweight and postnatal growth suggesting that exposure to PTS and ETS is associated with later age at menarche even after considering possible relationships with growth.

Keywords

menarche; puberty; maternal prenatal smoking; childhood environmental tobacco smoke

Introduction

Understanding factors that influence the age at menarche is important for many reasons, including breast cancer risk. Accumulating research has high-lighted the importance of body size, at birth and during childhood, and growth early in life in the timing of menarche.^{1–10}

Studies have consistently shown an association between larger childhood body size [weight, height and body mass index (BMI)] and earlier age at menarche^{4,11–17} and recent research has revealed an association between rapid growth early in life and early age at menarche.^{3,10} Additionally, research has consistently shown a strong correlation between mother's and daughter's age at menarche, suggesting a possible genetic influence.^{1,15,18}

The hypothalamo-pituitary-gonadal axis plays a role in the initiation of puberty¹⁹ and substances that alter the endocrine or central nervous system may subsequently affect the onset of menarche.¹⁸ Cigarette smoke contains more than 4000 chemical compounds including nicotine and polycyclic aromatic hydrocarbons and has been shown to be associated with an earlier age at menopause in smokers compared with non-smokers, and reduced fertility among current smokers compared with non-smokers or those only exposed to second-hand smoke.^{20,21}

Although the constituents of prenatal tobacco smoke (PTS) exposure may be different from the constituents of childhood environmental tobacco smoke (ETS) exposure, for ease of terminology we considered PTS exposure to be a form of ETS exposure. Research on the association between PTS and ETS exposure and age at menarche has been limited and most studies have either focused on PTS or ETS but not both. Two studies that examined ETS found that such exposure was associated with earlier menarche^{22,23}; however, exposure to PTS was not examined in these studies. Four studies have examined PTS exposure and age at menarche;^{18,24–26} however, only two of these studies also had measures of ETS.^{18,24} For the two studies with only PTS data, one found PTS exposure to be associated with earlier age at menarche,²⁶ while the other reported PTS exposure to be associated with later age at menarche.²⁵ For the other two studies with both PTS and ETS exposure data, one reported no association between PTS or ETS exposure and age at menarche,²⁴ while the other found both PTS and ETS exposure to be associated with earlier age at menarche.¹⁸ Given these conflicting findings and the overall limited research in this area, further research is needed to determine the influence of PTS and ETS exposure on age at menarche.

Given the correlation between PTS and ETS exposure, it is necessary to have studies that assess both, in order to understand whether exposure during these separate time periods are each associated with age at menarche. Furthermore, it is necessary to consider infant and childhood growth measures as these factors are both important to age at menarche and may be affected by PTS and ETS exposure. Thus, we undertook a study to examine the association between PTS and ETS exposure and age at menarche using information from a multi-ethnic New York City birth cohort with detailed prospectively collected data on body size and growth at birth, early infancy and childhood. With data on body size and postnatal growth, we were further able to determine whether the association between PTS and ETS exposure and age at menarche was mediated by effects on birthweight, postnatal body size and growth.

Methods

Study population

The New York Women's Birth Cohort was an adult follow-up study conducted from 2001 to 2006 in a cohort of women enrolled previously in a New York City site of the National Collaborative Perinatal Project (NCPP) born between 1959 and 1963.^{27,28} Mothers were enrolled in the NCPP during their second or third trimester and were followed throughout pregnancy and delivery and their offspring were followed until the age of 7 years. We attempted to trace the 841 daughters who participated in a New York City site of the NCPP and were successfully followed until the age of 7 years. A total of 375 (45%) daughters were successfully traced and expressed interest in participating, and of those, 262 (70%)

completed the adult follow-up questionnaire and provided consent forms. The average age of women at the time of the adult data collection was 41.8 years (range 38–46).

Measures

The NCPP used a standardised protocol to collect self-reported and prospective data. At enrolment mothers provided information on age, race/ethnicity, occupation, pre-pregnancy weight, smoking history and age at menarche. Information was collected prospectively throughout pregnancy and delivery on maternal weight gain in pregnancy, pre-eclampsia status, infant race, birthweight, placental weight, length at birth, gestational age and birth order. Childhood anthropometric measurements were prospectively taken at age 4 months, 1 year, 7 years and 3–4 years for a subgroup of participants. Maternal and infant race were recorded at the time of registration and delivery using the following categories: White, Black, Puerto Rican, Asian and Other. Socio-economic status (SES) was determined from data on maternal and paternal education, occupation and income at enrolment and when the child was 7 years old. Information on income, education, and occupation for the head of the household or the main wage earner (most frequently the father) was combined into a continuous SES index with higher scores indicating higher or more privileged SES.^{29,30} Further details of the NCPP are published elsewhere.²⁷ PTS exposure information was collected at the NCPP enrolment from the mothers during their pregnancy by self-report of the current number of cigarettes smoked per day. ETS exposure information was self-reported by the daughters in the adult follow-up questionnaire by asking ‘As a child, did any member of your household, including caregivers, smoke in your presence?’ Age at menarche was also ascertained in the adult follow-up questionnaire by asking the daughters ‘How old were you when you had your first menstrual period?’ and responses were recorded in discrete years. The study was approved by the Institutional Review Board at Columbia Medical Center.

Statistical analysis

We examined bivariable associations between maternal smoking status during pregnancy and prenatal and early life variables using ANOVA for continuous variables and χ^2 -tests for categorical variables. For regression analyses we categorised PTS exposure into four levels: 0 (no PTS), 1–9 cigarettes smoked per day (light PTS), 10–19 cigarettes smoked per day (medium PTS) and ≥ 20 cigarettes smoked per day (heavy PTS). Participants with no PTS exposure were used as the reference group. In addition, we created a total smoke exposure variable based on PTS and ETS. We categorised PTS and ETS exposure into four levels: no PTS + no ETS, any PTS + no ETS, no PTS + any ETS and any PTS + any ETS. The level no PTS + no ETS was used as the reference group. The number of participants in the category, any PTS + no ETS, was very small ($n = 3$); therefore, we were unable to analyse this group separately.

We used linear regression models to examine the unadjusted and adjusted associations between levels of PTS exposure, ETS exposure alone and PTS combined with ETS exposure in relation to age at menarche (continuous). In addition, we used unconditional logistic regression models to assess this association, predicting the odds of later age at menarche compared with earlier age at menarche, using age at menarche dichotomised at the median (>12 years and ≤ 12 years). We evaluated potential covariates based on the 10% criterion: any potential covariate that changed the parameter estimate for the association between PTS exposure or PTS combined with ETS exposure and age at menarche by more than 10% was included in the final parsimonious models. Once the parsimonious models were established, we then re-evaluated the potential covariates that were excluded and assessed them again using the 10% criterion. We examined the following potential covariates for inclusion in the final model: prenatal and early life variables (maternal age at pregnancy, age at menarche,

pre-pregnancy BMI, weight gain during pregnancy, education, occupation, pre-eclampsia, father presence in the home, gestational age, birth order, race/ethnicity and family SES at age 7 years). Furthermore, we examined potential mediation of the association between PTS exposure and PTS combined with ETS exposure and age at menarche by examining models before and after adjustment for infant and childhood body size and growth measures (birthweight, birth length, placental weight, percentile change of weight and height from birth to 4 months, 4 months to 1 year and 1 to 7 years). In addition, final parsimonious models were stratified by race/ethnicity in order to examine effect modification by race. All statistical methods were carried out using SAS (version 9.1).

Results

Approximately 39% of mothers smoked during pregnancy and the median number of cigarettes smoked per day was 10 with a range of 1–40 cigarettes. Women who smoked during pregnancy were more likely to be White, to have more years of education, to be younger, to have lower birthweight and shorter birth length babies, and to have a lower pre-pregnancy BMI (Table 1). In addition, women who smoked were more likely to have daughters exposed to childhood ETS. Specifically, 97% of mothers who smoked during pregnancy had daughters exposed to childhood ETS.

There were 11 participants (4.2%) with missing data on age at menarche; however, no statistically significant differences were found in PTS or ETS exposure between those missing and those not missing menarche data ($P = 0.44$ and $P = 0.74$, respectively). The median age at menarche was 12 years with a range of 8–19 years. We previously reported bivariable associations between age at menarche and prenatal and early life growth variables.¹⁰ Women with an earlier age at menarche were more likely to be heavier at age 7 ($P = 0.01$), have a lower family SES at age 7 ($P = 0.01$), have a mother with an earlier age at menarche ($P = 0.05$) and fewer years of education ($P = 0.06$).¹⁰

Table 2 presents the unadjusted and adjusted linear regression results for the association between level of PTS exposure and age at menarche. In the unadjusted model, participants with heavy PTS exposure had an average age at menarche 0.66 years later [95% CI 0.01, 1.31] than participants with no PTS exposure. After adjusting for race, birthweight, maternal education and maternal pre-pregnancy BMI, participants with heavy PTS exposure experienced an average age at menarche 0.54 years later [95% CI −0.17, 1.24] than participants with no PTS exposure; however, this result was no longer statistically significant. We also examined the effects of having ETS exposure alone, having PTS and ETS exposure combined and having neither PTS nor ETS exposure on age at menarche. After controlling for race, birthweight and maternal pre-pregnancy BMI, participants with only ETS exposure and no PTS exposure had an average age at menarche 0.55 years later [95% CI −0.05, 1.15] than participants with no PTS and no ETS exposure. Participants with both PTS and ETS exposure combined had an average age at menarche 0.53 years later [95% CI −0.07, 1.13] than participants with no PTS and no ETS exposure. We further assessed whether the amount of PTS exposure had an impact on the association between PTS and ETS exposure and age at menarche in these same models by separately examining heavy PTS exposure (≥ 20 cigarettes per day) and ETS exposure and light/medium PTS exposure (1–19 cigarettes per day) and ETS exposure. Daughters with heavy PTS and ETS exposure had a statistically significant later average age at menarche by 0.99 years [95% CI 0.20, 1.79]; daughters with light/medium PTS and ETS exposure had a much lower increase in average age at menarche by 0.33 years [95% CI −0.31, 0.97]. We examined the possible mediating effects of placental weight, birthweight, birth length, percentile change in weight and height from birth to 4 months, 4 months to 1 year and 1 to 7 years and weight at age 7 by examining the final parsimonious models with and without these variables. We found no

substantial differences between these models. Specifically, the parameter estimates for PTS and ETS exposure and age at menarche did not change by more than 10% (data not shown).

Table 3 presents results from the logistic regression models of the association between levels of PTS exposure, ETS exposure alone and PTS combined with ETS exposure and later age at menarche (>12 years vs. ≤12 years). The unadjusted odds ratio (OR) for the association between participants with heavy PTS exposure and later age at menarche was 2.1 [95% CI 1.0, 4.6], compared with participants with no PTS exposure. The OR was similar after adjusting for race, birthweight, maternal education and maternal pre-pregnancy BMI [OR = 2.1, 95% CI 0.9, 5.0]. After controlling for race, birthweight and maternal pre-pregnancy BMI, having ETS exposure alone was associated with a later age at menarche [OR = 2.1, 95% CI 1.0, 4.3], compared with participants with no PTS and no ETS exposure. Having both PTS and ETS exposure was statistically significantly associated with a later age at menarche [OR = 2.2, 95% CI 1.1, 4.6], compared with participants with no PTS and no ETS exposure.

In our cohort, Puerto Ricans had the earliest age at menarche (mean = 12.1 years, SD = 1.3), followed by Whites (mean = 12.5 years, SD = 1.8) and Blacks had the latest age at menarche (mean = 12.7 years, SD = 1.9). We formally tested the interaction between race and PTS exposure, but it was not statistically significant ($P = 0.27$).

Discussion

In our study, ETS exposure, either prenatally or during childhood, was associated with a later age at menarche of approximately 6 months. This finding remained even after adjusting for birthweight, birth length and postnatal early childhood growth, showing that our results were not influenced by body size and growth during these periods. To our knowledge, this is the second study to report an association between PTS exposure and later age at menarche.²⁵ If these results are replicated in larger prospective studies, they suggest that exposure to cigarette smoke may have complex associations with reproductive function that may depend on timing of exposure. As most participants with PTS exposure also reported ETS exposure (97%), we were unable to disentangle the effects of PTS exposure alone. However, when looking at the amount of PTS exposure we did observe a stronger association for daughters with heavy PTS and ETS exposure compared with daughters with light/medium PTS and ETS exposure. In addition, we were able to examine the effects of ETS alone on age at menarche and similar results were found between any PTS and ETS and ETS alone. Daughters exposed to ETS, but not PTS, had a later age at menarche compared with daughters with no ETS and no PTS exposure.

Results from previous research on the association between PTS exposure and age at menarche have been mixed. A study by Fried *et al.* found no association between PTS exposure and age at menarche; however, they were limited by a small sample size.²⁴ Windham and colleagues conducted a larger study using a California birth cohort and found that PTS and ETS exposure were associated with an earlier age at menarche, although their results were not statistically significant.¹⁸ Another study by Windham and colleagues using data from the Baltimore, Providence and Philadelphia sites of the NCPP found that PTS exposure was associated with a later age at menarche. They described differences between the California cohort in their first study and the NCPP Baltimore, Providence and Philadelphia cohorts in their second study, including having a mostly White population, higher SES and fewer pregnant working mothers in the California cohort, compared with a mostly Black population, with lower SES and more pregnant working mothers in the NCPP Baltimore, Providence and Philadelphia cohorts. This may have contributed to these reported differences.²⁵

Using data from a New York City site of the NCPP, our results were consistent with the recent Windham *et al.* study²⁵ in that PTS exposure was associated with later age at menarche. Although we had a smaller sample size, the overall mean age at menarche (12.5 years) was similar to the mean age at menarche reported in that study (12.7 years). Our study population had a slightly lower percentage of mothers who reported smoking during pregnancy at the baseline interview (39%) compared with the Windham *et al.* study (48%).²⁵ The NCPP cohorts used in both studies were multi-ethnic; however the sample used by Windham *et al.* primarily included Whites and Blacks, while our study had a large proportion of Puerto Rican participants. We examined the association between PTS exposure and age at menarche by race/ethnicity and found few differences; however, these analyses were limited due to small sample sizes in the stratified categories. Similar to the NCPP cohorts used by Windham *et al.*,²⁵ our cohort tended to have a lower SES.

Our study was strengthened by the collection of childhood ETS exposure data, which is often unavailable in studies of PTS exposure. This information allowed us to examine the effects of ETS exposure during different time periods. We found that daughters with only ETS exposure and no PTS exposure, had a later age at menarche compared with those with no PTS and no ETS exposure. These results contradict previous studies that have examined the association between ETS exposure and age at menarche.^{22,23} These studies found that ETS exposure was associated with an earlier age at menarche; however, they did not have data on PTS exposure.

In our analyses we further examined measures of body size and growth in early life and childhood to empirically evaluate whether the observed association between PTS and age at menarche was mediated by infant and childhood body size and growth patterns. Recently we reported that higher birthweight was associated with an earlier age at menarche in our study cohort.¹⁰ In addition, previous research has shown that exposure to PTS is associated with decreased birthweight,^{31–33} which may in turn affect age at menarche. It is also possible that low birthweight is associated with increased childhood weight, which may affect age at menarche.¹⁸ Previous work has also revealed that in addition to birthweight, early life growth plays an important role in the timing of menarche.^{3,10} However, we found similar overall findings for the association between exposure to PTS and combined exposure to PTS and ETS and age at menarche before and after adjusting for infant and childhood growth measures. This suggests that the association between PTS and ETS exposure and age at menarche is independent of any effect that PTS may have on growth.

The mechanism by which tobacco smoke exposure influences age at menarche is still unclear; however, both animal and human studies provide evidence that cigarette smoke and nicotine may affect developmental reproductive biology. There is laboratory evidence in both rats and mice that cigarette smoke and nicotine affect the female reproductive system. Specifically, in a study of mice, cigarette smoke exposure *in utero* reduced the number of primordial oocytes in the offspring,³⁴ and in a study of rats, nicotine influenced ovarian steroidogenesis.³⁵ Human studies have shown that cigarette smoking has anti-oestrogenic effects in women,³⁶ affecting ovulatory function. In a study by Windham and colleagues, heavy smokers were found to have shorter and more variable cycle lengths and more variable menses lengths.³⁷ Research has also shown that women who smoke have an earlier age at menopause, compared with nonsmokers.^{37–41} Given that these studies suggest that smoking is related to disruption of the menstrual cycle and cessation of menses, it is therefore possible and plausible that smoking may be related to a delayed age at menarche.

The NCPP was conducted between 1959 and 1965 when there was little stigma attached to the reporting of smoking during pregnancy; therefore, the reporting of pregnancy smoking is likely to be valid and subject to less information bias than a retrospective assessment.

Furthermore, a validation study comparing cotinine levels with self-reported cigarette smoking of women in the NCPP found that women reported their smoking status accurately during pregnancy ($k = 0.83$).⁴² As we were limited to retrospective collection of ETS data, we were unable to collect detailed information on the number of smokers in the home or the frequency and duration of smoking. Similarly, participants may have reported age at menarche with error, as they were asked to recall an event that occurred many years ago. However, previous research has shown that age at menarche is reliably reported many years after the event ($r = 0.60$ – 0.79).^{22–28} Because of the number of years that elapsed between menarche and the adult follow-up questionnaire, it was not feasible to collect month data for age at menarche. It is possible that our measure of age at menarche, which was in discrete years, was not detailed enough to detect a difference in mean age at menarche by a few months. The lack of precision in reporting the outcome variable affects both exposed and unexposed populations, therefore suggesting that the true association between PTS and ETS exposure and age at menarche may be stronger than was observed.

Although we had a high participation rate among the daughters who were successfully traced, we had a low percentage of successful tracing. We assessed differences between women who participated in the adult follow-up compared with those who were not traced and/or were traced but did not participate. We found no statistically significant differences between these groups in terms of the maternal number of cigarettes smoked during pregnancy, maternal age at menarche, maternal pregnancy variables, birth size, or any postnatal height or weight changes.²⁸

In summary, using data from a multi-ethnic birth cohort, we observed a positive association between PTS and ETS exposure and age at menarche. The prospective data collection in the NCPP allowed us to examine whether these associations were independent of infant and childhood body size and growth patterns. If these results are replicated in larger cohort studies, further laboratory research will be needed to explain the biological mechanisms underlying these associations.

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References

1. Adair LS. Size at birth predicts age at menarche. *Pediatrics*. 2001; 107:E59. [PubMed: 11335780]
2. Cooper C, Kuh D, Egger P, Wadsworth M, Barker D. Childhood growth and age at menarche. *British Journal of Obstetric Gynaecology*. 1996; 103:814–817.
3. dos Santos Silva I, De Stavola BL, Mann V, Kuh D, Hardy R, Wadsworth ME. Prenatal factors, childhood growth trajectories and age at menarche. *International Journal of Epidemiology*. 2002; 31:405–412. [PubMed: 11980804]
4. Frisch RE, Revelle R. Height and weight at menarche and a hypothesis of menarche. *Archives of Disease in Childhood*. 1971; 46:695–701. [PubMed: 5118059]
5. Koziel S, Jankowska EA. Effect of low versus normal birthweight on menarche in 14-year-old Polish girls. *Journal of Paediatrics and Child Health*. 2002; 38:268–271. [PubMed: 12047695]
6. Persson I, Ahlsson F, Ewald U, Tuvemo T, Qingyuan M, von Rosen D, et al. Influence of perinatal factors on the onset of puberty in boys and girls: implications for interpretation of link with risk of long term diseases. *American Journal of Epidemiology*. 1999; 150:747–755. [PubMed: 10512428]

7. Romundstad PR, Vatten LJ, Nilsen TI, Holmen TL, Hsieh CC, Trichopoulos D, et al. Birth size in relation to age at menarche and adolescent body size: implications for breast cancer risk. *International Journal of Cancer*. 2003; 105:400–403.
8. Sloboda DM, Hart R, Doherty DA, Pennell CE, Hickey M. Age at menarche: influences of prenatal and postnatal growth. *Journal of Clinical Endocrinology and Metabolism*. 2007; 92:46–50. [PubMed: 17062767]
9. Tam CS, de Zegher F, Garnett SP, Baur LA, Cowell CT. Opposing influences of prenatal and postnatal growth on the timing of menarche. *Journal of Clinical Endocrinology and Metabolism*. 2006; 91:4369–4373. [PubMed: 16926251]
10. Terry MB, Ferris JS, Tehranifar P, Wei Y, Flom JD. Birth weight, postnatal growth, and age at menarche. *American Journal of Epidemiology*. 2009; 170:72–79. [PubMed: 19439580]
11. Blell M, Pollard TM, Pearce MS. Predictors of age at menarche in the newcastle thousand families study. *Journal of Biosocial Science*. 2008; 40:563–575. [PubMed: 18198007]
12. Britton JA, Wolff MS, Lapinski R, Forman J, Hochman S, Kabat GC, et al. Characteristics of pubertal development in a multi-ethnic population of nine-year-old girls. *Annals of Epidemiology*. 2004; 14:179–187. [PubMed: 15036221]
13. Koprowski C, Ross RK, Mack WJ, Henderson BE, Bernstein L. Diet, body size and menarche in a multiethnic cohort. *British Journal of Cancer*. 1999; 79:1907–1911. [PubMed: 10206312]
14. Moisan J, Meyer F, Gingras S. A nested case-control study of the correlates of early menarche. *American Journal of Epidemiology*. 1990; 132:953–961. [PubMed: 2239910]
15. Petridou E, Syrigou E, Toupadaki N, Zavitsanos X, Willett W, Trichopoulos D. Determinants of age at menarche as early life predictors of breast cancer risk. *International Journal of Cancer*. 1996; 68:193–198.
16. St George IM, Williams S, Silva PA. Body size and the menarche: the Dunedin Study. *Journal of Adolescent Health*. 1994; 15:573–576. [PubMed: 7857956]
17. Biro FM, Khoury P, Morrison JA. Influence of obesity on timing of puberty. *International Journal of Andrology*. 2006; 29:272–277. [PubMed: 16371114]
18. Windham GC, Bottomley C, Birner C, Fenster L. Age at menarche in relation to maternal use of tobacco, alcohol, coffee, and tea during pregnancy. *American Journal of Epidemiology*. 2004; 159:862–871. [PubMed: 15105179]
19. Ebling FJ. The neuroendocrine timing of puberty. *Reproduction*. 2005; 129:675–683. [PubMed: 15923383]
20. Foster WG, Neal MS, Han MS, Dominguez MM. Environmental contaminants and human infertility: hypothesis or cause for concern? *Journal of Toxicology and Environmental Health. Part B, Critical Reviews*. 2008; 11:162–176.
21. Harlow BL, Signorello LB. Factors associated with early menopause. *Maturitas*. 2000; 35:3–9. [PubMed: 10802394]
22. Kolasa E, Hulanicka B, Waliszko A. Does exposure to cigarette smoke influence girls maturation? *Przegląd Epidemiologiczny*. 1998; 52:339–350. [PubMed: 9919929]
23. Reynolds P, Hurley SE, Hoggatt K, Anton-Culver H, Bernstein L, Deapen D, et al. Correlates of active and passive smoking in the California Teachers Study cohort. *Journal of Women's Health (Larchmt)*. 2004; 13:778–790.
24. Fried PA, James DS, Watkinson B. Growth and pubertal milestones during adolescence in offspring prenatally exposed to cigarettes and marihuana. *Neurotoxicology and Teratology*. 2001; 23:431–436. [PubMed: 11711245]
25. Windham GC, Zhang L, Longnecker MP, Klebanoff M. Maternal smoking, demographic and lifestyle factors in relation to daughter's age at menarche. *Paediatric and Perinatal Epidemiology*. 2008; 22:551–561. [PubMed: 19000293]
26. Rubin C, Maisonet M, Kieszak S, Monteilh C, Holmes A, Flanders D, et al. Timing of maturation and predictors of menarche in girls enrolled in a contemporary British cohort. *Paediatric and Perinatal Epidemiology*. 2009; 23:492–504. [PubMed: 19689500]
27. Broman, S. The Collaborative Perinatal Project: an overview. *Handbook of Longitudinal Research*. Mednick, SA.; Harway, M.; Finello, KM., editors. Vol. Vol. 1. New York: Praeger Publishers; 1984. p. 185–227.

28. Terry MB, Flom J, Tehranifar P, Susser E. The role of birth cohorts in studies of adult health: the New York women's birth cohort. *Paediatric and Perinatal Epidemiology*. 2009; 23:431–445. [PubMed: 19689494]
29. U.S. Bureau of the Census. Methodology and scores of socioeconomic status. Washington, DC: 1963. Working Paper No 15
30. Myrionthopoulos NC, French KS. An application of the U.S. Bureau of the Census socioeconomic index to a large, diversified patient population. *Social Science & Medicine*. 1968; 2:283–299.
31. de Waard F, Thijssen JH. Hormonal aspects in the causation of human breast cancer: epidemiological hypotheses reviewed, with special reference to nutritional status and first pregnancy. *Journal of Steroid Biochemistry and Molecular Biology*. 2005; 97:451–458. [PubMed: 16230007]
32. Potischman N, Troisi R. In-utero and early life exposures in relation to risk of breast cancer. *Cancer Causes & Control*. 1999; 10:561–573. [PubMed: 10616825]
33. Windham GC, Eaton A, Hopkins B. Evidence for an association between environmental tobacco smoke exposure and birthweight: a meta-analysis and new data. *Paediatric and Perinatal Epidemiology*. 1999; 13:35–57. [PubMed: 9987784]
34. Vahakangas K, Rajaniemi H, Pelkonen O. Ovarian toxicity of cigarette smoke exposure during pregnancy in mice. *Toxicology Letters*. 1985; 25:75–80. [PubMed: 3922090]
35. Holloway AC, Kellenberger LD, Petrik JJ. Fetal and neonatal exposure to nicotine disrupts ovarian function and fertility in adult female rats. *Endocrine*. 2006; 30:213–216. [PubMed: 17322582]
36. Shiverick KT, Salafia C. Cigarette smoking and pregnancy I: ovarian, uterine and placental effects. *Placenta*. 1999; 20:265–272. [PubMed: 10329346]
37. Windham GC, Elkin EP, Swan SH, Waller KO, Fenster L. Cigarette smoking and effects on menstrual function. *Obstetrics and Gynecology*. 1999; 93:59–65. [PubMed: 9916957]
38. Hiatt RA, Fireman BH. Smoking, menopause, and breast cancer. *Journal of the National Cancer Institute*. 1986; 76:833–838. [PubMed: 3457970]
39. Midgette AS, Baron JA. Cigarette smoking and the risk of natural menopause. *Epidemiology*. 1990; 1:474–480. [PubMed: 2090286]
40. Walsh RA. Effects of maternal smoking on adverse pregnancy outcomes: examination of the criteria of causation. *Human Biology*. 1994; 66:1059–1092.
41. Windham GC, Hopkins B, Fenster L, Swan SH. Prenatal active or passive tobacco smoke exposure and the risk of preterm delivery or low birth weight. *Epidemiology*. 2000; 11:427–433. [PubMed: 10874550]
42. Klebanoff MA, Levine RJ, Clemens JD, DerSimonian R, Wilkins DG. Serum cotinine concentration and self-reported smoking during pregnancy. *American Journal of Epidemiology*. 1998; 148:259–262. [PubMed: 9690362]

Table 1

Mean and proportion of maternal and child variables by maternal smoking status during pregnancy, New York Women's Birth Cohort^a

Maternal and child variables	Maternal smokers during pregnancy (n = 101)			Maternal non-smokers during pregnancy (n = 159)			p ^b
	n	Mean/%	[SD]	n	Mean/%	[SD]	
Prenatal							
Maternal pre-pregnancy BMI (kg/m ²)	96	22.0	[3.6]	141	22.9	[3.7]	0.06
Maternal pregnancy weight gain (kg)	98	10.1	[5.0]	147	10.8	[5.0]	0.27
Maternal age at menarche	101	12.8	[1.5]	158	13.0	[1.6]	0.14
Maternal age at pregnancy	101	25.2	[5.7]	158	27.1	[6.2]	0.02
Maternal education (years)	99	11.6	[2.0]	157	10.4	[2.8]	<0.01
Maternal pre-eclampsia							
Yes	7	6.9%		14	9.0%		0.56
No	94	93.1%		142	91.0%		
Maternal occupation							
No work outside home	14	13.9%		15	9.5%		0.28
Work outside home	87	86.1%		143	90.5%		
Race							
White	45	44.6%		53	33.5%		0.03
Black	41	40.6%		60	38.0%		
Puerto Rican	15	14.9%		45	28.5%		
Father of baby in the home							
Present	89	88.1%		146	92.4%		0.25
Absent	12	11.9%		12	7.6%		
Early life							
Gestation at delivery (weeks)	101	39.2	[2.8]	158	39.6	[2.5]	0.23
Birthweight (kg)	101	3.0	[0.4]	158	3.2	[0.5]	0.01
Weight at 4 months (kg)	100	6.1	[0.9]	156	6.1	[0.7]	0.56
Weight at 1 year (kg)	99	9.6	[1.1]	153	9.6	[1.1]	0.86
Weight at 7 years (kg)	101	23.9	[5.3]	158	23.8	[4.7]	0.89
Birth length (cm)	100	49.7	[2.0]	156	50.2	[2.4]	0.09
Length at 4 months (cm)	100	61.7	[3.0]	156	61.6	[2.8]	0.81
Length at 1 year (cm)	101	73.7	[3.2]	151	73.9	[2.9]	0.59
Height at 7 years (cm)	101	122.0	[5.1]	156	121.4	[5.4]	0.35
Family SES index at age 7	94	55.5	[18.9]	151	52.7	[21.4]	0.28
Birth order							
Not first-born	64	65.3%		94	59.5%		0.35
First-born	34	34.7%		64	40.5%		
Child environmental tobacco smoke							
Yes	98	97.0%		95	60.1%		

Maternal and child variables	Maternal smokers during pregnancy (<i>n</i> = 101)			Maternal non-smokers during pregnancy (<i>n</i> = 159)			<i>p</i> ^{<i>b</i>}
	<i>n</i>	Mean/%	[SD]	<i>n</i>	Mean/%	[SD]	
No	3	3.0%		63	39.9%		<0.01

^{*a*}Three participants (1.1%) were missing PTS exposure data.

^{*b*}*P*-values calculated using ANOVA test for linear variables and χ^2 -test for categorical variables.

BMI, body mass index; SES, socio-economic status.

Table 2

Coefficients from unadjusted and adjusted linear regression models of age at menarche (years) according to prenatal and combined prenatal and childhood environmental tobacco smoke exposure, New York Women's Birth Cohort

Passive smoke exposure	<i>n</i>	Unadjusted model b [95% CI]	Adjusted for infant body size ^a b [95% CI]	Adjusted for infant body size and childhood growth ^b b [95% CI]	Parsimonious model ^c b [95% CI]
Prenatal (no. cigarettes smoked per day by mother during pregnancy)					
None: 0	150	1.00 Reference	1.00 Reference	1.00 Reference	1.00 Reference
Light: 1–9	38	−0.08 [−0.70, 0.53]	−0.18 [−0.81, 0.45]	−0.08 [−0.70, 0.55]	−0.13 [−0.77, 0.51]
Medium: 10–19	27	0.23 [−0.48, 0.94]	0.18 [−0.54, 0.89]	0.16 [−0.55, 0.87]	0.20 [−0.53, 0.93]
Heavy: 20+	33	0.66 [0.01, 1.31]	0.60 [−0.06, 1.25]	0.61 [−0.05, 1.26]	0.54 [−0.17, 1.24]
Time of exposure					
No prenatal + no childhood	61	1.00 Reference	1.00 Reference	1.00 Reference	1.00 Reference
No prenatal + childhood	90	0.45 [−0.11, 1.01]	0.39 [−0.18, 0.97]	0.38 [−0.20, 0.95]	0.55 [−0.05, 1.15]
Prenatal + no childhood	3	–	–	–	–
Prenatal + childhood	95	0.52 [−0.03, 1.08]	0.43 [−0.15, 1.00]	0.45 [−0.12, 1.02]	0.53 [−0.07, 1.13]

^aBoth prenatal model and time of exposure model adjusted for: birthweight, birth length.

^bBoth prenatal model and time of exposure model adjusted for: birthweight, birth length, percentile change in weight from 4 months, 4 months to 1 year, 1 to 7 years.

^cPrenatal model adjusted for: race, birthweight, maternal education, maternal pre-pregnancy BMI; time of exposure model adjusted for: race, birthweight, maternal pre-pregnancy BMI.

Table 3

Odds ratios from unadjusted and adjusted logistic regression models of later age at menarche (>12 years vs. ≤12 years) according to prenatal and combined prenatal and childhood environmental tobacco smoke exposure, New York Women's Birth Cohort

Passive smoke exposure	Age at menarche		Unadjusted model OR [95% CI]	Parsimonious model ^a OR [95% CI]
	>12 years <i>n</i>	≤12 years <i>n</i>		
Prenatal (no. cigarettes smoked per day by mother during pregnancy)				
None: 0	68	82	1.0 Reference	1.00 Reference
Light: 1–9	19	19	1.2 [0.6, 2.5]	1.3 [0.6, 2.8]
Medium: 10–19	13	14	1.1 [0.5, 2.5]	1.1 [0.5, 2.6]
Heavy: 20+	21	12	2.1 [1.0, 4.6]	2.1 [0.9, 5.0]
<i>P</i> for trend			0.09	0.17
Time of exposure				
No prenatal + no childhood	23	38	1.0 Reference	1.0 Reference
No prenatal + childhood	45	45	1.7 [0.9, 3.2]	2.1 [1.0, 4.3]
Prenatal + no childhood	2	1	–	–
Prenatal + childhood	51	44	1.9 [1.0, 3.7]	2.2 [1.1, 4.6]

^a Prenatal model adjusted for: race, birthweight, maternal education, maternal pre-pregnancy BMI; time of exposure model adjusted for: race, birthweight, maternal pre-pregnancy BMI.