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Environmental tobacco smoke exposure in pregnancy is associated with earlier delivery and reduced birth weight

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Abstract

The association between maternal smoking and preterm birth (PTB) has been known for more than 50 years but the effect of passive smoking is controversial. This retrospective cohort study in Bristol, UK, examines the effect of environmental tobacco smoke exposure (ETSE) on gestational age at delivery, birth weight, PTB and small-for-gestational age (SGA). ETSE was defined by either self-report or exhaled carbon monoxide (eCO) levels; exposed women were compared with unexposed controls. Two models were used: The first included all women with adjustment for maternal smoking, the second considered non-smokers alone. Both models were further adjusted for maternal age, BMI, parity, ethnicity, employment status, socioeconomic position, asthma, pre-eclampsia and offspring sex. Logistic regression and likelihood ratio tests were used to test for any association between exposure and the binary outcomes (PTB and SGA), whilst linear regression and F-tests were used to test for associations between exposure and the continuous outcomes. There were 13359 deliveries in 2012-2014, with complete data for 5066 and 4793 women in the self-reported and eCO-measured exposure groups, respectively. Self-reported exposure was associated with earlier delivery (-0.19 weeks; 95% CI: -0.32 to -0.05) and reduced birth weight (-56 g, 95% CI: -97 to -16 g) but no increase in the risk of PTB or SGA. There was no evidence for an association between eCO-measured exposure and any of the outcome measures. This information is important when advising women and their families, and adds further support to continued public health efforts to reduce exposure to tobacco smoke.

Keywords: passive smoking, birth weight, preterm/premature birth, carbon monoxide, pregnancy outcome

Introduction

The association between maternal smoking, reduced birth weight and preterm birth (PTB) has been known for more than 50 years[1]. Maternal smoking increases the risk of PTB by around 27%[2] and a dose-response relationship has been described in which heavier smoking is associated with a higher risk[2,3]. Proposed mechanisms for the adverse perinatal outcomes include reduced fetal oxygenation secondary to increased carbon monoxide and nicotine-induced vasoconstriction[4]. Previous studies have demonstrated the deleterious effect of active smoking during pregnancy, but the extent of the effects of passive smoking is still uncertain[5-7]. Complications related to prematurity account for more than one million deaths each year worldwide [8]. The survivors often face severe morbidity into childhood and beyond[9]. There are serious negative psychosocial and emotional effects on the family and important resource implications for society[9]. Preterm birth is the leading cause of perinatal mortality and morbidity and its prevention is a global priority[8].

Cigarette smoking during pregnancy is one of the few preventable causes of adverse pregnancy outcomes and focusing on smoking cessation should be a way to reduce the incidence of PTB. Despite a 20 to 40% reduction in smoking rates in pregnancy over the past 30 years[10], between 11% and 13% of women continue to smoke throughout their pregnancy[10-13]. The introduction of anti-smoking legislation has reduced PTB birth rates by around 10%[14]. This is most likely mediated by a reduction in the number of women smoking during their pregnancies, but there is emerging evidence that environmental exposure to tobacco smoke, known as passive smoking, may also affect PTB rates. It has been estimated that 11-50% of *non-smoking* pregnant women are exposed to environmental tobacco smoke[5,7,15-17] and this exposure has been associated with reduced birth weight[5].

Currently there is conflicting evidence on the effects of ETSE (environmental tobacco smoke exposure) on PTB. Several meta-analyses[5-7] have failed to show an association between the two, but existing studies are limited by residual confounding factors and the difficulties of accurately

determining exposure. In this paper we have addressed these limitations by designing a study with correction for confounding factors and by evaluating the use of a recently introduced routine measure of exposure in the first trimester, namely exhaled carbon monoxide (eCO) levels. The levels of eCO have been shown to correlate with the number of cigarettes smoked[18] and are affected by ETSE[19-21]. The objective of this study was to investigate whether ETSE is an independent risk factor for shortened gestation and preterm birth, using both self-report and eCO, as an objective measure of exposure, in a large obstetric population.

Methods

Study design and sample

We performed a retrospective cohort study of all women with singleton pregnancies of at least 23 weeks gestation delivering at the University Hospitals Bristol NHS Foundation Trust between April 2012 and September 2014. Women were identified using the computerised Maternity Medway Database which records details of all women delivering within the Trust. At the first antenatal appointment, usually before 12 weeks gestation, the community midwife enters relevant obstetric and medical history into the database including the woman's smoking status, eCO level, her partner's smoking status and the presence of any other smokers in the household. Information about the birth is added to this computerised record immediately after delivery.

Multiple births often have obstetric complications that result in a higher incidence of preterm birth. The analysis was restricted to singleton births. Due to the referral nature of our hospital, women were referred from across the region for a variety of serious pregnancy complications. These 'out-of-area' women had a higher background risk of preterm birth because of these complications and were excluded from the study population in order to improve the representativeness of the study.

Ethical approval for this study was obtained from the University of Bristol Research Ethics Committee (ref. 2120).

Outcomes

The primary outcomes for this study were gestational age at delivery and preterm birth (<37 weeks' gestation). Gestational age at delivery (in weeks) was calculated from antenatal ultrasound scan (USS; usually during the first trimester), or last menstrual period where USS had not taken place. Secondary outcomes included birth weight and small-for-gestational age (defined as less than the population gestation-specific 10th centile).

Exposures

Exposure to environmental tobacco smoke was assessed in two ways. First, by self-report; a binary variable was created where pregnant women were coded as exposed if they reported that either their partner or another member of the household smoked. We refer to this as 'household smoking'. Second, by objective measurement; exhaled CO was measured at the first antenatal appointment (usually during the first trimester) using a hand-held Bedfont piCO+ Smokerlyzer (Bedfont Scientific, UK, http://www.bedfont.com). Women were asked to inhale and hold their breath for 15 seconds before exhaling into the analyser. The first reading was recorded.

Potential confounders

We assessed several potential confounders, identified from the literature and univariate analyses, in logistic regression models. These include maternal smoking, maternal age at delivery, body mass index (BMI = weight (kg) /height (m)^2), fetal sex, parity, ethnicity, a diagnosis of asthma[22] or pre-eclampsia[23], employment status, and socioeconomic position as determined by postcode-linked Index of Multiple Deprivation scores which have been shown to be a useful marker of socioeconomic status[24]. Age at delivery, fetal sex and any current pregnancy diagnosis of pre-

eclampsia were recorded at delivery, whilst self-reported maternal smoking status and the other variables were recorded at the first antenatal appointment, usually in the first trimester.

Analysis

A range of summary statistics was used to describe the women in the study. We used z-tests and chi-squared tests to compare the characteristics of women in the analysis samples with those eligible but excluded from the analysis due to a missing value on one or more of the covariables.

Analysis strategy and models

To check the external validity of the hospital database, we first examined the associations between self-reported maternal smoking and each outcome to ensure they were comparable to previously reported estimates. Next we considered the effect of ETSE. Both *self-reported* household smoking and *measured* eCO were used as indicators of ETSE. Two analysis models were used: The first included all women and adjusted for maternal smoking. The second considered only the non-smoking women. Both models were adjusted for maternal age, BMI, parity, ethnicity, employment status, socioeconomic position, asthma, pre-eclampsia and offspring sex.

These models were fitted for each of the outcomes. Logistic regression was used for binary outcomes (preterm birth (PTB) and small for gestational age (SGA)) and linear regression for continuous outcomes (gestational age at delivery and birth weight). Likelihood ratio tests (for logistic regression models) and F-tests (for linear regression models) were used to test for any association between the exposures and outcomes.

The eCO cut-off value at which exposure to environmental tobacco smoke can be determined is uncertain. Several authors have suggested cut off values between 2 ppm[25] and 4 ppm[26,27] when distinguishing smokers from non-smokers; a value of 2 ppm giving a sensitivity of 86% and specificity of 90%[25]. To examine whether our results were robust to the choice of cut off and way in which eCO was classified, we repeated the analysis using 4 ppm and 6 ppm as cut offs instead of 2ppm. We also

modelled the relationship between eCO and the outcomes as a linear continuous variable, and as a shape-free cubic spline to see whether there was a particular form of relationship that was missed by our main parameterisation.

STATA version 13.1 was used for all analyses.

Results

Sample description

We documented 13359 eligible deliveries at gestations greater than 23 weeks, after excluding multiple pregnancies (450 deliveries) and one case with no gestational age at delivery recorded (Figure 1). For the analyses involving self-reported exposure there were 5066 deliveries (38%) with complete data and for the analyses involving objective exposure (eCO) there were 4793 cases (36%) with complete data.

A comparison of the characteristics of the complete cases (see figure 1) and those eligible but with at least one piece of missing data is shown in Table 1. The median age was 30 years and the majority of women were white and employed. Approximately 42% of all women reported the presence of a smoker in their household and the median eCO was 1 ppm. The proportion of exposed *non-smokers* increased from 17.8%, when considering partner smoking alone, to 28.0% when considering all household members. In the analysis group, the incidence of preterm birth was 6.3%. This rate was slightly lower among those with missing information. Paradoxically, those missing some information on covariables, and therefore not included in the analysis, were more likely to report living with a smoker. Women reporting as non-smokers were more likely to have information on household smoking and eCO readings missing. The gestational age at booking was not significantly different between the exposed and unexposed women.

Association of exposures and outcomes with confounders

Generally, women from more deprived postal areas and women unemployed or unfit to work were more likely to live with smokers, have higher eCO readings, and a higher risk of preterm birth and SGA baby. The distributions of household smoking, eCO and outcomes were also patterned to a varying extent by the other potential confounders (maternal age, parity, BMI, ethnicity and asthma) (data not shown). Smoking was associated with a lower risk of pre-eclampsia (OR 0.68 95% CI 0.50 – 0.93).

Maternal smoking: Prevalence and association with perinatal outcomes

Of the 13094 women whose smoking status was known, 2946 women reported smoking in the early part of their pregnancy (22.5%). Of these smokers, 1043 (35.4%) stopped before their first antenatal appointment, leaving 14.5% of women reporting as smokers at the first antenatal appointment.

After adjustment for maternal age, BMI, ethnicity, parity, employment status, socioeconomic status, fetal sex, paternal smoking, pre-eclampsia and asthma, maternal smoking was associated with a more than two-fold increased risk of preterm birth (OR: 2.16; 95% CI 1.56 – 2.99, p<0.001), a reduction in gestational length of 0.6 weeks (95% CI -0.7 to -0.4, p<0.001), a mean reduction in birth weight of 350 g (CI -399 to -302, p<0.001), and a three times greater risk of SGA (OR 3.06, 95% CI 2.33 – 4.03, p<0.001) when compared to non-smoking women. Compared to eCO readings of zero, eCO values ≥2 ppm were associated with an increased risk of preterm birth (OR 1.63, 95% CI 1.14-2.32, p=0.017) and SGA (OR 1.76, 95% CI 1.34-2.32, p<0.001), a shorter gestation (-0.29 weeks; 95% CI -0.45 to -0.12, p=0.003) and a mean reduction in birth weight (-166 g; 95% CI -214 to -118 g, p<0.001).

There was no evidence that women who stopped smoking between conception and their first antenatal appointment were at any additional risk of PTB, reduced gestational length, lower birth weight babies or SGA when compared to non-smokers.

ETSE and perinatal outcomes

Self-reported exposure

After adjustment for maternal smoking, women who reported themselves as exposed to ETS gave birth to their babies earlier. These associations persisted when considering only the non-smoking women and after adjustment for confounding factors including pre-eclampsia (Table 2); babies were born on average 0.19 weeks earlier (95% CI: -0.32 to -0.05) among non-smoking women that reported a smoker in the house compared with non-smokers with no household exposure.

We found a crude association between self-reported exposure to household smoking and preterm birth: The odds of preterm birth were 31% higher (95% CI: 0 to 72%) among women living with smokers (after adjusting for maternal smoking), but this weakened to 22% (95% CI: -9 to 62%) after adjustment for other potential confounders, providing no evidence of an independent association between self-reported ETSE and preterm birth (Table 3).

There was strong evidence that babies born to mothers who lived with smokers had lower birth weights when compared to the babies born to unexposed mothers, after adjustment for maternal smoking and other confounders (Table 4). This association remained consistent when considering only the non-smoking mothers. Babies born to non-smoking mothers who reported a smoker in their household were on average 56g lighter (95% CI: -97 to -16g).

Self-reported ETSE was not associated with a change in the risk of SGA. (Table 5).

Exhaled carbon monoxide measurement as an objective measure of ETSE

When an eCO level greater than 2 ppm was used to define ETSE there was no association between ETSE and gestational age at delivery, preterm birth, birth weight or risk of SGA. This was the case when considering all women with adjustment for maternal smoking and when considering non-smoking women alone.

Sensitivity analysis

There is some controversy about the best value for eCO to define ETSE[26,27]. When replacing ≥2 ppm with ≥4 ppm as a cut off category for eCO, as suggested elsewhere,[26,27] there was some weak evidence of an association between preterm birth and eCO-measured ETSE. For example the odds ratio for preterm birth adjusting for maternal smoking and confounders was 1.7 (95% CI: 1.04 to 2.8) in all women and 2.04 (95% CI: 0.9 to 4.64) in non-smoking women. When ≥6 ppm was used as the cut-off for eCO-determined ETSE the associations were stronger than for 2 ppm although there was no statistical evidence of an association with preterm birth. The results for SGA were fairly consistent regardless of choice of cut-off. For gestational age and birth weight, the associations were generally stronger when a higher eCO cut-off was used, making the results more similar to those where ETSE was determined by self-report (results available on request). When eCO was treated as a linear continuous variable there was no evidence for an association between eCO-measured ETSE and preterm birth, SGA, birthweight or gestational age.

Discussion

This is the first large cohort study to consider the effect of ETSE on preterm birth and gestational age at delivery using eCO as an objective measure of exposure. When smoking women were included in the analysis, elevated eCO levels were strongly associated with preterm birth, reduced gestational age at delivery, reduced birth weight and increased risk of SGA. However when the smokers were excluded or controlled for, elevated eCO readings were not significantly associated with any of the outcome measures. Self-reported ETSE was strongly associated with reduced gestational age at delivery and reduced birth weight, but not with an increased risk of SGA or PTB.

Strengths & Limitations

This population-based study includes over 13000 women of which more than a third were non-smoking women with complete information on their environmental smoke exposure. The proportion

of women exposed to environmental tobacco smoke varies in the literature depending upon how exposure is defined, the country studied, and the time of the study, because smoking prevalence has changed over recent decades[10]. Traditional family structures and living circumstances have changed considerably over the last few decades. Whilst ETSE from work is now less common because of anti-smoking legislation, women are still at risk of ETSE if their partner or any member of the household smokes. Our study is strengthened by our use of a combined measure of exposure; simply considering the smoking status of a woman's partner, as many studies have done, may be inadequate in assessing her exposure. We have shown that the proportion of exposed non-smokers increased from 17.8%, when considering partner smoking alone, to 28.0% when considering all household members.

Self-reported smoking behaviour has generally been found to be reliable when it has been validated with biochemical measures[28]. However, some evidence suggests self-reporting of both active and passive smoking may be less reliable in pregnancy[29-31], perhaps because of the additional social stigma associated with smoking in pregnancy and the desire to make a good impression to healthcare professionals. The use of an objective measure is a strength of our study. Many objective measures of exposure have been used previously; nicotine and cotinine, the major metabolite of nicotine[32], can be measured in serum[30], saliva[33] hair[31], meconium[34] and urine[27]. Measuring eCO levels has the advantage of being cheap, non-invasive, and giving immediate results; eCO levels correlate well with other biochemical measures of exposure[18,20]. Whilst a number of studies have considered the role of eCO in determining a woman's smoking status[18,25,27,35,36], none have used eCO to define exposure when considering the effect of ETSE on gestational age at delivery. A cut-off of 2 ppm was chosen after recent data suggested specificity of 90% and sensitivity of 86% at this level when distinguishing between smokers and non-smokers[25]. Since asthma[22] and pre-eclampsia[37] have been reported to affect eCO levels, we ensured these confounders were included when adjusting the models.

Whilst most studies have adjusted for possible confounding factors such as maternal age, parity, race and socioeconomic status[2], adjustments for pre-eclampsia have not been made previously[5]. Pre-eclampsia is a common reason for elective preterm birth. Active maternal smoking appears to decrease the risk pre-eclampsia by approximately 30%[23,38]. A similar trend for passive smoking has been reported[39]. This complex interplay requires that pre-eclampsia is considered when determining the effect of smoking, active or passive, on preterm birth rates, in order to avoid under-estimating the true effect of smoking. The correction for pre-eclampsia as a confounding factor is another strength of our study and may explain the greater risk of preterm birth for smokers that we observed (OR 2.16) compared to the more conservative estimate in a recent meta-analysis (OR 1.27)[2].

The prospective way in which exposure information was collected reduces the risk of reporting bias. However, the study is restricted by the large proportion of missing data, especially exposure information. Although women's smoking status was well recorded (98%), their partner's status and the presence of other smokers in the household were less frequently recorded (54% and 49% of cases respectively). Despite national recommendations in the UK that all women, regardless of their smoking status, have eCO readings taken at their first antenatal appointment[40], readings were only recorded in 42% cases. Women with incomplete data were excluded from the analyses (figure 1) possibly introducing selection bias, although no consistent differences in associations were observed in this 'missing data' cohort and the analysis group, and there was no systematic reason for data not being available.

Our objective measure of ETSE has its limitations: CO has a short half-life (around 1-4 hours)[36] and the time since exposure affects readings; eCO may not accurately represent exposure in some women. This and the considerable overlap in eCO readings for ETSE compared with active maternal smoking may have made it difficult to detect a relationship between ETSE (when defined by eCO readings) and perinatal outcomes. The association observed between preterm birth and higher eCO

levels (>4 ppm) could represent more heavily exposed non-smokers or perhaps smokers reporting as non-smokers.

Seasonal variation in birth patterns including the outcomes considered here has been described[41], although few studies on perinatal outcomes adjust for this. Additionally, seasonal variation in ETSE is possible, with women potentially more exposed at times of the year with poorer weather. Our data had insufficient information to make seasonal adjustments but we recommend further research on the effect of ETS consider these issues where possible.

In this study smoking rates in pregnancy (14.5%) were similar to those previously reported in the literature (11-16%)[10,12,16]; interestingly the proportion of *non-smoking* women reporting exposure to ETS (28%) was more than twofold higher than recent reports for other UK and European populations (11-13%)[7,16] and probably reflects the inclusion of women living with smokers as well as those whose partners smoke (most studies only consider exposure from partner smoking). It is also possible that the addition of an objective measure of exposure (eCO reading) may encourage disclosure or even some smokers to self-report as exposed non-smokers.

Biochemical measures of exposure may alleviate some of the problems associated with inaccurate self-reporting. However, the use of biochemical measures is not without problems; differentiating between light active smokers and heavily-exposed passive smokers remains difficult[42] and adjustment for maternal smoking requires reliance on maternal reports of smoking behaviour. Whilst knowing the effects of lower levels of exposure is important (whether that is from environmental or lighter active smoking) the success of programmes aimed at changing smoking behaviour will depend upon knowing to *whom* interventions should be targeted. We recommend that biochemical measures of exposure are used in conjunction with self-reporting.

Self-reported ETSE was strongly associated with reduced gestational age at delivery, a relationship which has previously been debated[5,6]. Although this mean reduction (0.2 weeks) is small

at an individual level, at a population level this may shift the distribution to the left resulting in a significant burden; further, active maternal smoking only reduced gestation by 0.6 weeks on average and yet more than doubled the rate of preterm birth. The deleterious effect of ETSE on perinatal outcomes is also emphasised by the finding of a strong association with reduced birth weight of a similar magnitude to that previously reported[5,6,16]. Our study shows that ETSE is associated with both shorter gestation and reduced birth weight, but it was not associated with an increased risk of either SGA or PTB. A larger number of participants may be required to study the associations of ETSE with non-continuous, rarer outcomes such as preterm birth and SGA.

Conclusions

Pregnant women reporting household exposure to environmental tobacco smoke deliver their babies at earlier gestations and with lower birth weights when compared to unexposed women. The value of eCO as an objective measure of exposure and in quantifying the risk of adverse perinatal outcomes remains to be determined. This information is important in advising women and their families and further supports public health efforts to reduce exposure to tobacco smoke.

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Conflict of interests

The authors declare that there is no conflict of interest.

Contribution to authorship

Details of ethics approval

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Table/Figure caption list

Figure 1   Participant flow chart and derivation of the analysis sample

Table 1   A comparison of the characteristics of the cases included in the analysis samples and those excluded due to missing data.

Table 2   Association between gestational age at delivery and exposure to environmental tobacco smoke (as captured by self-report of household smokers (HH), and measured eCO). Regression coefficients were estimated in the whole sample and in the non-smoking women

Table 3   Association between preterm birth and exposure to environmental tobacco smoke (as captured by self-report of household smokers (HH), and measured eCO). Odds ratios were estimated in the whole sample and in the non-smoking women

Table 4   Association between birth weight and exposure to environmental tobacco smoke (as captured by self-report of household smokers (HH), and measured eCO). Regression coefficients were estimated in the whole sample and in the non-smoking women.

Table 5   Association between SGA and exposure to environmental tobacco smoke exposure (as captured by self-report of household smokers (HH), and measured eCO). Odds ratios were estimated in the whole sample and in the non-smoking women.
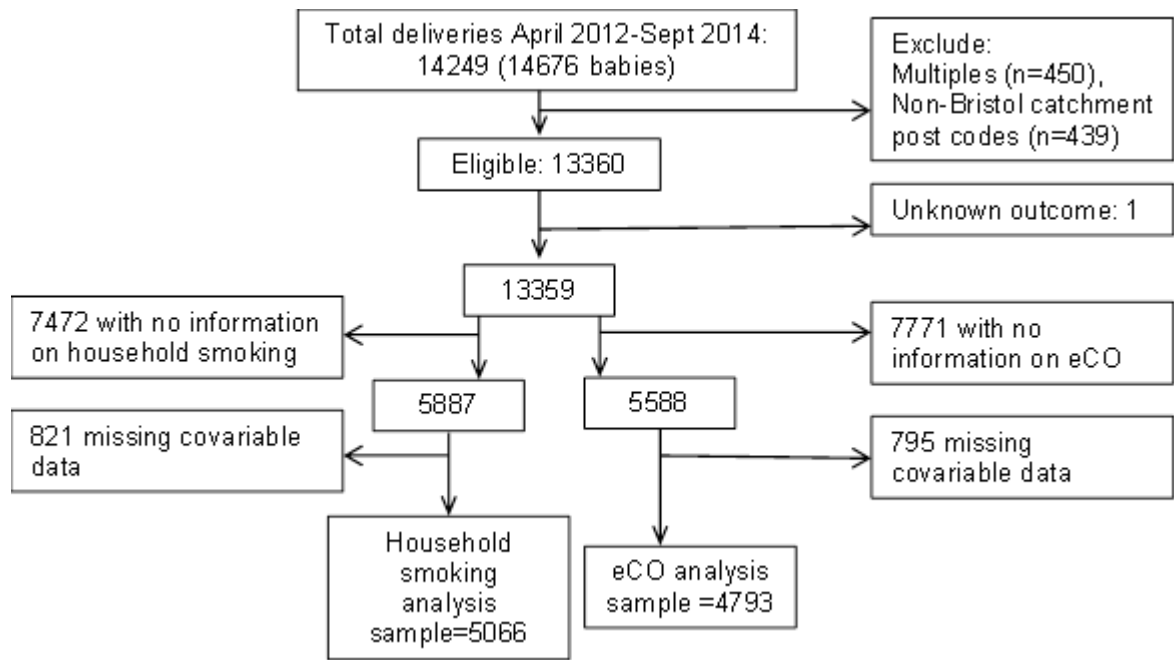
Figure 1. Participant flow chart and derivation of the analysis sample.

Table 1. A comparison of the characteristics of the cases included in the analysis sample for self-reported ETSE and others who were eligible but excluded due to missing data.

| Variable | SELF-REPORTED EXPOSURE | | | eCO-MEASURED EXPOSURE | | |
| | Included in analysis sample (n=5066) | Excluded from analysis due to one or more missing variables | | Included in analysis sample (n=4793) | Excluded from analysis due to one or more missing variables | |
	N (%) or median (IQR)	N (%) or median (IQR)	No. of cases with data available	N (%) or median (IQR)	N (%) or median (IQR)	No. of cases with data available
Age (y)	30 (26, 34)	30 (26, 34)	8133	30 (26, 34)	30 (26, 34)	8409
BMI (kg/m2)	24.4 (21.7, 28.3)	24.4 (21.8, 28.2)	7568	24.4 (21.8, 28.4)	24.4 (21.8, 28.1)	7843
Parity						
0	2210 (43.6)	3727 (45.7)		2071 (43.2)	3866 (45.8)	
1	1750 (34.5)	2650 (32.5)	8165	1613 (33.7)	2787 (33.0)	8438
≥2	1106 (21.8)	1788 (21.9)		1109 (23.1)	1785 (21.2)	
Ethnicity						

White	4179 (82.5)	6020 (81.4)		3924 (81.9)	6275 (81.9)	
Afro-Caribbean	333 (6.6)	595 (8.1)		332 (6.9)	596 (7.8)	
Asian	333 (6.6)	484 (6.6)	7392	311 (6.5)	506 (6.6)	7665
Mixed	147 (2.9)	205 (2.8)		161 (3.4)	191 (2.5)	
Other	74 (1.5)	88 (1.2)		65 (1.4)	97 (1.3)	
Employment status						
Employed	3258 (64.3)	3160 (66.5)		3073 (64.1)	3345 (66.6)	
Unemployed	1644 (32.5)	1453 (30.6)	4749	1567 (32.7)	1530 (30.5)	5022
In education	128 (2.5)	117 (2.5)		122 (2.6)	123 (2.5)	
Medically unable to work	36 (0.7)	19 (0.4)		31 (0.7)	24 (0.5)	
Deprivation score (/100)‡	24.8 (13.9, 43.3)	21.8 (12.5, 38.9)	8106	25.2 (13.7, 47.4)	21.6 (12.5, 36.8)	8379
Asthma	460 (9.1)	617 (7.4)	8293	450 (9.4)	627 (7.3)	8566
Pre-eclampsia	197 (3.9)	247 (3.0)	8293	168 (3.5)	276 (3.2)	8566
Booking gestational age (weeks)	10.1 (9, 11.3)	10.1 (9, 11.9)	7484	10.1 (9, 11.9)	10.1 (9, 11.9)	7796
Offspring sex (female)	2495 (49.3)	4050 (48.9)	8286	2365 (49.3)	4180 (48.8)	8559

Smoking during pregnancy						
Non-smoker	3661 (72.3)	6487 (80.8)		3484 (72.7)	6664 (80.3)	
Smoker	889 (17.6)	1014 (12.6)	8028	845 (17.6)	1058 (12.8)	8301
Quit after conception	516 (10.2)	527 (6.6)		464 (9.7)	579 (7.0)	
Household smokers	2122 (41.9)	411 (50.1)	821	1449 (42.1)	1084 (44.4)	2445
eCO (ppm)						
0				2022 (42.2)	370 (46.5)	
0 to 2				1569 (32.7)	211 (26.5)	795
>2				1202 (25.1)	214 (26.9)	
Median (IQR)				1 (0, 2.6)	1 (0, 3)	
Preterm	319 (6.3)	478 (5.8)	8293	300 (6.3)	497 (5.8)	8566
Gestational age (weeks)	40 (39, 40.9)	40 (39, 41)	8293	40 (39, 40.9)	40.1 (39, 41)	8566
SGA	537 (10.6)	796 (9.6)	8284	513 (10.7)	820 (9.6)	
Birth weight (kg)	3.41 (3.06, 3.74)	3.43 (3.10, 3.76)	8290	3.40 (3.06, 3.73)	3.43 (3.10, 3.76)	8563

‡Index of Multiple Deprivation score (2007)

Table 2. Association between gestational age at delivery and exposure to environmental tobacco smoke (as captured by self-report of household smokers (HH), and measured eCO). Regression coefficients were estimated in the whole sample and in the non-smoking women.

		Crude*		Adjusted[†]	
All women		Mean difference (95% CI)	p	Mean difference (95% CI)	P
HH smokers (n=5066)	No	Reference		Reference	
	Yes	-0.2 (-0.32, -0.07)	0.002	-0.15 (-0.28, -0.02)	0.020
eCO (ppm) (n=4793)	0	Reference		Reference	
	0 to 1.99	0.03 (-0.10, 0.16)		-0.01 (-0.15, 0.12)	
	≥2	-0.10 (-0.29, 0.08)	0.39	-0.13 (-0.32, 0.06)	0.380
Non-smoking women					
HH smokers (n=3661)	No	Reference		Reference	
	Yes	-0.21 (-0.34, -0.08)	0.001	-0.19 (-0.32, -0.05)	0.007
eCO (ppm) (n=3484)	0	Reference		Reference	
	0 to 1.99	0.01 (-0.12, 0.14)		-0.03 (-0.16, 0.11)	
	≥2	-0.01 (-0.22, 0.20)	0.98	-0.07 (-0.28, 0.14)	0.8

*adjusted for maternal smoking in the models using all women. [†]adjusted for maternal age, BMI, parity, ethnicity, employment status, socioeconomic position, asthma, pre-eclampsia plus maternal smoking in the models using all women

Table 3. Association between preterm birth and exposure to environmental tobacco smoke (as captured by self-report of household smokers (HH), and measured eCO). Odds ratios were estimated in the whole sample and in the non-smoking women.

		Crude*		Adjusted[†]	
All women		OR (95% CI)	p	OR (95% CI)	P
HH smokers (n=5066)	None	Reference		Reference	
	Yes	1.31 (1.0, 1.72)	0.05	1.22 (0.91, 1.62)	0.18
eCO (ppm) (n=4793)	0	Reference		Reference	
	0 to 1.99	1.00 (0.74, 1.36)		1.06 (0.78, 1.45)	
	≥2	1.27 (0.86, 1.88)	0.40	1.36 (0.91, 2.03)	0.31
Non-smoking women					
HH smokers (n=3661)	None	Reference		Reference	
	Yes	1.20 (0.86, 1.66)	0.28	1.15 (0.81, 1.63)	0.43
eCO (ppm) (n=3484)	0	Reference		Reference	
	0 to 1.99	0.94 (0.68, 1.31)		0.99 (0.70, 1.40)	
	≥2	1.18 (0.73, 1.92)	0.68	1.24 (0.75, 2.05)	0.80

*adjusted for maternal smoking in the models using all women. [†]adjusted for maternal age, BMI, parity, ethnicity, employment status, socioeconomic position, asthma,

pre-eclampsia plus maternal smoking in the models using all women

Table 4. Association between birth weight and exposure to environmental tobacco smoke (as captured by self-report of household smokers (HH), and measured eCO). Regression coefficients were estimated in the whole sample and in the non-smoking women

		Crude*		Adjusted[†]	
All women		Mean difference (95% CI)	p	Mean difference (95% CI)	P
HH smokers (n=5066)	None	Reference		Reference	
	Yes	-61 (-97, -24)	0.001	-49 (-86, -13)	0.008
eCO (ppm) (n=4793)	0	Reference		Reference	
	0 to 1.99	47 (9, 86)		26 (-11, 64)	
	2+	-10 (-64, 44)	0.02	-28 (-80, 25)	0.095
Non-smoking women					
HH smokers (n=3661)	None	Reference		Reference	
	Yes	-56 (-96, -15)	0.007	-56 (-97, -16)	0.006
eCO (ppm) (n=3484)	0	Reference		Reference	
	0 to 1.99	37 (-2, 77)		13 (-25, 52)	
	2+	47 (-16, 110)	0.106	24 (-37, 85)	0.65

*adjusted for maternal smoking in the models using all women.

†adjusted for maternal age, BMI, parity, ethnicity, employment status, socioeconomic position, asthma, pre-eclampsia plus maternal smoking in the models using all

women

Table 5. Association between SGA and exposure to environmental tobacco smoke exposure (as captured by self-report of household smokers (HH), and measured eCO). Odds ratios were estimated in the whole sample and in the non-smoking women

		Crude*		Adjusted[†]	
All women		OR (95% CI)	P	OR (95% CI)	P
HH smokers (n=5066):	None	Reference		Reference	
	Yes	1.09 (0.88, 1.36)	0.42	1.10 (0.88, 1.39)	0.39
eCO (ppm) (n=4793):	0	Reference		Reference	
	0 to 1.99	0.83 (0.66, 1.05)		0.89 (0.70, 1.13)	
	≥2	0.98 (0.72, 1.33)	0.28	1.05 (0.76, 1.44)	0.46
Non-smoking women					
HH smokers (n=3661):	None	Reference		Reference	
	Yes	1.01 (0.78, 1.32)	0.91	1.06 (0.80, 1.40)	0.7
eCO (ppm) (n=3484):	0	Reference		Reference	
	0 to 1.99	0.92 (0.71, 1.18)		0.99 (0.76, 1.29)	
	≥2	0.66 (0.42, 1.04)	0.19	0.70 (0.44, 1.29)	0.31

*adjusted for maternal smoking in the models using all women.

[†]adjusted for maternal age, BMI, parity, ethnicity, employment status, socioeconomic position, asthma, pre-eclampsia plus maternal smoking in the models using all women