

Published in final edited form as:

J Epidemiol Community Health. 2011 December ; 65(12): 1145–1150. doi:10.1136/jech.2009.095802.

Maternal smoking during pregnancy and criminal offending among adult offspring

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Abstract

Background—Although a number of previous studies have reported an association between maternal smoking during pregnancy (MSP) and externalising behaviour problems among offspring, it has been suggested that this relationship is spurious due to the failure of these studies to properly account for important confounding factors.

Methods—The relationship between MSP and adult criminal offending was examined using data from 3766 members of the Providence, Rhode Island, cohort of the Collaborative Perinatal Project. Information on MSP and most potential confounders was collected prospectively throughout pregnancy. In 1999–2000 all offspring had reached 33 years of age and an adult criminal record check was performed. Because previous research has been criticised for not properly accounting for confounding influences, our primary aim was to determine whether the MSP–criminal offending relationship held after efficiently adjusting for a wide range of sociodemographic and family background characteristics using propensity score methods.

Results—The association between MSP and adult criminal offending remained after controlling for propensity scores. Offspring of mothers who smoked heavily during pregnancy (≥ 20 cigarettes per day) had the greatest odds of an adult arrest record (OR 1.31, 95% CI 1.06 to 1.62). Findings also suggest that MSP may be an independent risk factor for adult criminal histories marked by multiple arrests. Lastly, our findings show that the impact of MSP operates similarly across both genders.

Conclusion—Results from this study provide evidence of an association between heavy MSP and long-term criminal offending. Any causal association is likely to be weak to moderate in strength.

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Competing interests None.

Patient consent Obtained.

Ethics approval This study was conducted with the approval of Brown University and Harvard University.

Provenance and peer review Not commissioned; externally peer reviewed.

Previous research suggests that maternal smoking during pregnancy (MSP) is associated with externalising behaviour problems among offspring ranging from hyperactivity and aggression in early childhood^{1–5} to conduct disorder and delinquency during adolescence.^{6–10} Evidence also suggests that MSP is related to adult antisocial behaviour (ASB), such as criminal offending, although fewer investigations have been conducted.^{11–14} Yet it remains unclear whether the relationship between MSP and ASB among offspring is causal. It has been suggested that the association is spurious due to uncontrolled or residual confounding in prior work.^{7, 12, 15–19} The goal of the current investigation was to determine whether the MSP–adult criminal behaviour association remained after controlling for a range of potential confounders and, if so, to further characterise the nature of this relationship. For example, current evidence suggests (a) that central nervous system deficits, such as inattention and impulsivity, mediate the relationship between MSP and externalising behaviour,^{20–24} and (b) that neuropsychological impairments may be a specific risk factor for chronic and violent offending.²⁵ Given this, if MSP does indeed influence ASB through neurobehavioural pathways, it may only be predictive of particular patterns of criminal behaviour, such as violent or chronic offending.

The current research has several strengths, including the use of prospectively collected, chemically validated, reports of MSP; a follow-up period of four decades; and the efficient control of confounders through propensity score methods. Study hypotheses are:

1. The association between MSP and criminal behaviour among adult offspring would be attenuated but remain after controlling for a large set of potential confounders.
2. Those exposed to the highest levels of MSP would be most likely to engage in adult criminal offending.
3. The association between MSP and criminal offending would be: (a) stronger for violent than non-violent crimes; and (b) more pronounced for arrest histories marked by multiple versus a limited number of arrests.

METHODS

Participants

Subjects were offspring of mothers enrolled in the Providence, Rhode Island, site of the Collaborative Perinatal Project (CPP)²⁶: a multicentre study of prenatal and perinatal antecedents of childhood mental, neurological and physical abilities. In Providence, approximately 50% of obstetric patients at participating hospitals were randomly selected and 4140 pregnancies were enrolled from 1959–1966.

By 1999–2000 all offspring had reached 33 years of age (mean=37, range=33–40). An adult criminal record check was performed for each subject known to be alive at age 7 years (n=3826; 91.4% of the original cohort). Arrest data were obtained via the Inmate Facility Tracking System at the Rhode Island Department of Corrections, Planning and Development unit. Arrests were confirmed by matching the subject's name, date of birth and, when possible, social security number.²⁷ Analyses include 3766 participants with valid data on MSP.

A subset of individuals (n=1303) also participated in adult follow-up studies (age range=30–42 years).^{28–30} Of these subjects, 1294 (99.3%) had information on MSP and were included in supplementary analyses. During standardised, structured, interviews participants reported whether they had been arrested since age 18 years. By using these data, we attempted to replicate observed associations between MSP and official arrests using self-reports. Analyses limited to individuals with both official and self-reported arrest data used

robust standard errors to appropriately account for the sampling design of the follow-up studies.³¹ The institutional review boards of Brown and Harvard Universities approved the follow-up studies; written informed consent was obtained from participants.

Measures

Maternal smoking during pregnancy—At the first prenatal visit, women reported whether they currently smoked and, if so, the number of cigarettes they smoked per day. Questions pertaining to smoking behaviours were repeated at each subsequent prenatal visit until delivery. From these measurements, the maximum number of cigarettes smoked at any point during pregnancy was determined. In addition to a binary indicator of MSP (any/none), women were classified into one of three categories based on the maximum number of cigarettes smoked on any pregnancy day: (1) never smoked during pregnancy ('none'; 37.8%); (2) smoked less than one pack (1–19 cigarettes, 'moderate smokers'; 26.0%); and (3) smoked a pack or more (≥ 20 cigarettes, 'heavy smokers'; 36.2%).

A prior analysis of CPP participants demonstrated agreement ($\kappa=0.83$) between serum cotinine and maternal reports of smoking providing biochemical validation.³² Our selected indicator of MSP, the maximum number of cigarettes smoked, was correlated with the mean number of cigarettes smoked ($r=0.94$) and a measure of the total number of cigarettes smoked in which mothers' reports were extrapolated over the entire gestational period ($r=0.92$).¹⁰

Adult criminal offending—Of the 3766 Providence cohort members alive through age 7 years with valid data on MSP, 624 (16.6%) had an official adult arrest record (table 1). Information regarding the type of criminal offence(s) was available for most of these participants ($n=493$, 79.0%) and each offence was classified as either violent or non-violent. In accord with previous studies,^{11–13} homicide, robbery, sexual offences and assault were defined as violent offences; all others were coded as non-violent. Arrest counts were available for most participants with an official record ($n=546$, 87.5%). Consistent with prior research,^{27–33} individuals with five or more arrests were classified as multiple offenders.

Only self-reported arrests ($n=466/1294$, 36.0%) occurring through 2000 were considered to match the timeframe for which official records were available.

Potential confounders—Potential confounders were identified from the extant literature. Data on most factors were collected prospectively using standardised procedures.

Information ascertained during prenatal visits and at birth was used to categorise participants on the following: child's sex (male/female), child's race (white/non-white), maternal age at pregnancy (in years), maternal education (<high school/ high school), maternal and paternal employment (yes/no), maternal marital status (unmarried/married) and a large sibship (≥ 4) at the child's birth (yes/no). Parental socioeconomic status at the time of pregnancy was calculated using methods developed by the US Census Bureau.³⁴ Study parents were compared to national data and assigned a percentile rank for education and occupation of the head of household and household income. The composite measure represents an average of these percentiles; higher percentiles indicate higher relative standing (range=0–99). An indicator of residential instability (≥ 1 moves/year over the previous 7 years (yes/no)) was created from maternal reports gathered when their children were age 7 years.

Maternal IQ was measured when offspring were 4 years old, using the Science Research Associates, Inc, non-verbal form.³⁵ Parental mental illness was assessed during maternal interviews at study enrolment and the child's 7 year evaluation. Mothers and fathers were separately categorised as having a history of mental health problems if psychiatric

hospitalisation or outpatient treatment for a mental health issue or substance abuse was reported by the mother at either time point.

Subjects participating in one of the adult follow-ups (n=720) reported on parental ASB (whether either parent was ever the type of person who could not hold a job for long, got into physical fights or got into trouble with the law).

Maternal attitudes toward child-rearing and family life (hostile, controlling) were measured at the 8-month and 4-year child assessments using an abbreviated version of the Parental Attitude Research Instrument.³⁶ Information from the 4-year assessment was used when data were unavailable from the earlier assessment. After observing mother–child interactions at the 4-month examination, psychologists rated whether each mother was responsive to her child's needs (unresponsive/responsive).

Additional variables were considered for inclusion but dropped because they were either highly correlated with other covariates (eg, paternal age) or had an extremely low prevalence (eg, problematic alcohol or drug use during pregnancy).

Statistical analysis

Missing data—Although most covariates had missing values for only a small number of subjects (<10%), the cumulative effect of missing data was substantial. A complete case approach would include only 37.3% of the eligible participants, substantially decreasing the precision of the estimated effect of MSP. To reduce the number of omitted observations and obtain an indicator of parental ASB for the entire sample, multiple imputation was used.³⁷ 38 Ten imputed data sets were created using PROC MI in SAS version 9.0 (SAS, Inc). Standard analyses were then performed on each completed data set and results combined to yield a single overall analysis with inferences appropriately accounting for the uncertainty associated with the imputed data.³⁷

Propensity score models

Due to the sizeable number of sociodemographic and family background characteristics considered, propensity scores were used to efficiently control for confounding.³⁹ 40 For the binary MSP variable, logistic regression was used to calculate the predicted probability of any MSP conditional on a full set of potential confounders. Gender was included since initial analyses showed that the MSP–criminal offending relationship did not differ for males and females. All other variables listed in table 2 were included except the parenting and parental ASB variables. Since information on parenting collected during infancy and early childhood may reflect reactions to problems in temperament resulting from MSP, we wanted to directly examine how the addition of these factors impacted the effect estimate for MSP.

After propensity scores were estimated, observations were divided in to quintiles based on the overall distribution of scores.⁴⁰ To examine whether initial imbalances of background factors across smoking groups were corrected, we examined the distribution of each confounder across the exposure groups before and after controlling for propensity score quintiles. Analyses of variances (ANOVAs) were used to examine covariate balance for continuous confounders and logistic regression models were used with binary confounders.⁴¹ As shown in table 2, balance was achieved on all covariates.

For the three-level MSP variable, we fit two separate logistic regressions to estimate the predicted probability of either moderate or heavy MSP. The first model was limited to offspring whose mothers were moderate smokers or non-smokers; the second model included offspring of heavy smokers and non-smokers. Observations were divided into

quintiles based on the distribution of scores from these separate models. Initial imbalances were corrected (not shown).

Regression models for the MSP–adult criminal offending association

A series of logistic regression models examined the relationship between MSP and criminal offending. Crude models, controlling for participant age, provided an unadjusted effect estimate. Next, propensity scores were added to the model (in quintiles), followed by the parental ASB and parenting variables. Multi-nomial logistic regression models examined whether the MSP–adult criminal offending relationship differed by (1) type of offence (any violent, only non-violent, no offences) and (2) degree of criminal offending (multiple, limited, no arrests). To investigate the relationship between the extent of MSP and criminal behaviour, two sets of regression models were conducted. In each, either the moderate or heavy group was compared to those with no prenatal exposure.

RESULTS

Table 1 shows the proportions arrested among the maternal smoking categories. Table 3 presents data summarising the strength of the relationship between MSP and criminal offending. While initial models showed that the offspring of mothers who smoked during pregnancy had 1.39 times the odds of having a criminal record (95% CI 1.16 to 1.67), efficiently controlling for a range of potential confounders led to an attenuation of this estimate (OR 1.25, 95% CI 1.04 to 1.51). Results were unchanged when the parental ASB and parenting variables were added to the adjusted model.

In crude analyses treating MSP as an ordinal variable, both moderate (OR 1.37, 95% CI 1.10 to 1.71) and heavy (OR 1.40, 95% CI 1.14 to 1.72) exposure compared to no prenatal exposure increased the odds of an adult arrest. Yet, in the fully adjusted analyses only the effect for the highest exposure group remained significant (heavy vs none: OR 1.31, 95% CI 1.06 to 1.62).

Analyses did not support the hypothesis that the MSP–criminal offending relationship was specific to violent offences (table 4). However, the relationship between MSP, particularly heavy smoking, and adult offending was more strongly related to criminal histories marked by multiple rather than a limited number of arrests. The offspring of mothers who smoked heavily during pregnancy had a 47% increased odds of multiple versus no arrests (OR 1.47, 95% CI 1.01 to 2.14).

Finally, we conducted analyses to determine whether MSP had a similar association with self-reported arrests using the representative subsample participating in adult follow-up studies. The propensity score adjusted effect of MSP was somewhat higher for self-reported (OR 1.35, 95% CI 1.05 to 1.75) compared to official arrests (OR 1.17, 95% CI 0.85 to 1.61). To appropriately account for the correlation between the two outcome variables, bivariate logistic regression^{42 43} was used to empirically test whether the strength of the association between prenatal exposure and adult offending differed significantly by source of data on arrests (official records vs self-reports). The difference in the strength of the effects was not statistically significant ($\chi^2=1.38$, $df=1$, $p=0.24$).

DISCUSSION

In our prospective study we found a robust association between MSP and criminal offending among adult offspring after efficiently controlling for a range of potential confounders using propensity score methods. This suggests that the elevated risk of offending is independent of other family attributes more common among women who smoke during pregnancy, such as

a history of mental illness and lower socioeconomic status, and may be directly attributable to the smoking exposure. Yet the current work also suggests that any potential causal effect of MSP on adult offending is likely to be weaker than suggested in some previous work with adults.^{11 12} Although a direct comparison of our results with those of other investigations is complicated by methodological variations across studies, it is likely that differences in findings may reflect uncontrolled or residual confounding not addressed in previous work.

Our primary results should also be placed in the broader context of developmentally informed research into the influence of MSP on offspring behavioural problems. Although many studies have observed a significant link between MSP and externalising behavioural problems (eg, aggression, conduct disorder), a growing number of recent well-conducted studies focussing on childhood and adolescent antisocial outcomes, including our own, suggest that this association fades or is entirely eliminated after proper adjustment for family and background characteristics.^{16 18 44}

In our study, we find that the effect of MSP, while attenuated, remains after accounting for a comprehensive set of confounding variables. One difference between this study and previous work is our focus on adult criminal offending rather than child or adolescent externalising behaviour. Coupled with research conducted on younger age groups, our data suggest that heavy MSP may have a weak to moderate independent effect on only the most serious forms of ASB (eg, chronic criminal offending) that are persistent across the life-course.

In our effort to further characterise the nature of the MSP–criminal offending relationship, we found support for the hypothesis that the increased risk of later criminal behaviour is greatest among individuals with the heaviest prenatal exposure. Our results for moderate MSP are not as conclusive. Although those exposed to lower levels of MSP were not at a statistically elevated risk for adult arrests when compared to those with no prenatal exposure, results are also consistent with alternative conclusions (eg, a potential dose-response relationship).

In keeping with our third hypothesis, we found that heavy prenatal exposure may be more closely related to criminal histories marked by a multiple arrests. Evidence suggests that neuropsychological deficits mediate the relationship between MSP and externalising behaviour.^{22–24} Prenatal exposure has been found in humans to increase the risk for neurobehavioural difficulties, including inattention, impulsivity and motor hyperactivity.^{21–24} Animal studies indicate that these problems likely result from the biological effects of nicotine on the developing brain through its effects on neurotransmitter receptors and, ultimately, altered synaptic activity.⁴⁵ Consistent with the hypothesis that MSP influences ASB through neurobehavioural pathways, we found that the MSP–criminal offending relationship may be specific to recurrent offending. Chronic offenders, in particular, are known to suffer from neuropsychological impairments.²⁵

Lastly, while many prior studies have focused solely on male offspring,^{11–13} our findings show that the impact of MSP operates similarly across both genders.

Limitations and strengths

In this study we adjusted for a more comprehensive set of covariates than most prior research. Yet it remains possible that we overestimated the true relationship between MSP and adult criminal offending. Although data on most confounders were collected prospectively using valid and reliable procedures, we most likely missed important variables (eg, genetic factors, use of alcohol and drugs during pregnancy) and incompletely measured others (eg, maternal parenting). Due to the potential for unmeasured and residual

confounding, our results likely reflect the upper boundary of any true effect of MSP on adult ASB.

It is also important to note that information on parental ASB was collected retrospectively. However, we do not believe that this greatly impacted our results. Since the CPP was initiated at a time when smoking during pregnancy was the norm (62% of CPP mothers smoked while pregnant), maternal ASB may not be as influential of a confounder as in more recent investigations. It is likely that, since the time of the study, MSP has become increasingly concentrated among women with tendencies toward ASB as smoking has become less prevalent and less socially desirable.

The current study has important strengths enabling us to address limitations of prior investigations. Information on MSP was prospectively collected during a historical time when there was less social stigma surrounding maternal smoking reducing measurement bias. Maternal reports were also validated using serum cotinine levels.³² The use of both official and self-reported information on arrests is also notable. Given that official arrest data were collected only in Rhode Island, we were concerned about underestimates. Yet the magnitude of the MSP–criminal offending relationship did not significantly depend on whether the outcome was assessed by self-reports or official records. Nonetheless, it will be important for other rigorously conducted studies to use outcomes based on alternative definitions of ASB, including self-reported engagement in offending behaviours. Arrest records may reflect only a small subset of actual criminal behaviour and may be influenced by individual characteristics (intelligence, impulsiveness, substance use) leading to differential misclassification.

CONCLUSION

While we cannot definitively conclude that MSP (particularly heavy MSP) is a causal risk factor for adult criminal offending, the current findings do support a modest causal relationship. Additional study is needed to examine whether the effect of MSP varies across the phases of pregnancy and examine whether smoking cessation (or reduction) can decrease the likelihood of antisocial outcomes among offspring. Lastly, it should be noted that this study focused only on the overall effect of MSP. Future studies should investigate whether there are particular subgroups that are more susceptible to MSP.

What is already know on this subject

Maternal smoking during pregnancy has been associated with a range of externalising behaviour problems among the offspring from early childhood to adulthood. However, much prior literature may suffer from methodological concerns, including considerable residual confounding.

What this study adds

- ▶ Our findings suggest that the relationship between maternal smoking during pregnancy (MSP) and adult criminal offending is causal. The elevated risk of criminal offending identified here was found to be independent of a comprehensive set of family attributes that are more common among women who smoke during pregnancy.
- ▶ Increased risk of later criminal behaviour may be strongest among individuals with the heaviest prenatal exposure.

- Results also suggest that maternal smoking, particularly heavy MSP, may be a specific risk factor for chronic criminal offending.

Acknowledgments

Funding This work was supported by a National Research Service Award (grant number T32 MH17119) from the Harvard Training Program in Psychiatric Epidemiology and Biostatistics; the Flight Attendant Medical Research Institute; grant number R01 AG023397-02 from the National Institute on Aging; Transdisciplinary Tobacco Use Research Center grant (number P50 CA084719) from the National Institutes of Health; the Robert Wood Johnson Foundation; and the National Science Foundation (grant number YR4-CCRP1) to the National Consortium on Violence Research. Dr Koenen is supported by grants K08 MH070627 and MH078928 from the National Institute of Mental Health.

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Table 1

Prevalence of adult criminal offending by maternal smoking during pregnancy among the full sample and the subsample with self-reported arrests

	<u>Maternal smoking during pregnancy</u>			Total
	None	Moderate (0–19)	Heavy (20)	
	n (%)	n (%)	n (%)	n (%)
Full sample	1423	979	1364	3766
Any official arrest record	197 (13.8)	176 (18.0)	251 (18.4)	624 (16.6)
If any official arrest				
Type of offence *				
Any violent	78 (5.6)	80 (8.4)	90 (6.9)	248 (6.8)
Only non-violent	79 (6.7)	66 (7.0)	100 (7.7)	245 (6.7)
Chronicity of offending †				
Multiple offender (5 arrests)	55 (3.9)	74 (5.6)	74 (5.6)	183 (5.0)
Limited offender (<5 arrests)	119 (8.5)	103 (10.7)	141 (10.6)	363 (9.8)
Subsample with self-reported arrests	505	323	466	1294
Any official arrest record	78 (15.4)	61 (18.9)	91 (19.5)	230 (17.8)
Any self-reported arrest	154 (30.5)	119 (36.8)	193 (41.4)	466 (36.0)

Note: Arrests include only those occurring since the respondent's 18th birthday.

* Information was not available for 131 subjects. Of the sample with available data, the prevalence of maternal smoking during pregnancy was as follows: 1383=none, 949=moderate, 1303=heavy.

† Information was not available for 78 subjects. Of the sample with available data, the prevalence of maternal smoking during pregnancy was as follows: 1400=none, 960=moderate, 1328=heavy.

Table 2

Relationship between any maternal smoking during pregnancy and potential confounders (n=3766)

Potential confounders	Maternal smoking during pregnancy		Pre-adjustment group differences*	Post-adjustment group differences†
	Yes (n = 2343)	No (n = 1423)		
Child's sex, % male	50.0	49.5	1.02 (0.89 to 1.16)	1.00 (0.88 to 1.15)
Child's race, % white	79.7	74.9	1.32 (1.15 to 1.51)	0.99 (0.84 to 1.18)
Maternal age at pregnancy, mean (SD)	23.8 (5.9)	25.0 (6.4)	-1.14 (-1.54 to -0.74)	-0.01 (-0.36 to 0.38)
Socioeconomic status, mean (SD)	43.2 (19.5)	48.1 (20.9)	-4.91 (-6.23 to -3.59)	-0.26 (-1.38 to 0.82)
Mother <high school education, %	73.6	57.7	2.04 (1.77 to 2.36)	1.13 (0.89 to 1.44)
Mother currently employed, %	7.4	10.9	0.65 (0.51 to 0.82)	0.95 (0.74 to 1.20)
Father unemployed at child's birth, %	22.5	18.6	1.27 (1.00 to 1.53)	1.01 (0.86 to 1.21)
Unmarried at child's birth, %	16.3	13.3	1.27 (1.05 to 1.54)	1.03 (0.85 to 1.26)
Large sibship size at birth, %	20.8	22.9	0.89 (0.75 to 1.05)	1.02 (0.86 to 1.20)
Residential instability, %	3.8	2.3	1.68 (1.11 to 2.56)	1.08 (0.70 to 1.67)
Maternal IQ, mean (SD)	90.8 (17.5)	91.9 (17.9)	-1.07 (-2.23 to 0.10)	-0.09 (-1.24 to 1.09)
Maternal mental illness, %	11.7	7.9	1.56 (1.24 to 1.97)	1.05 (0.82 to 1.36)
Paternal mental illness, %	5.2	4.4	1.17 (0.86 to 1.61)	1.01 (0.74 to 1.40)
Parental antisocial behaviour‡, %	4.5	3.2	1.44 (0.66 to 3.14)	
Maternal parenting‡				
Hostile, mean (SD)	41.0 (7.8)	40.6 (8.0)	0.40 (-0.12 to 0.73)	
Controlling, mean (SD)	41.2 (9.5)	41.3 (9.8)	-0.16 (-0.80 to 0.48)	
Unresponsive to child's needs, %	7.3	5.9	1.25 (0.95 to 1.66)	

* For continuous variables, mean differences (95% CIs) on the potential confounding variables across the maternal smoking groups from analyses of variances (ANOVAs) are presented; for binary variables, ORs (95% CIs) from logistic regression models are provided.

† For continuous variables, adjusted mean differences (95% CIs) on the potential confounding variables across the maternal smoking groups from ANOVAs are presented; for binary variables, adjusted ORs (95% CIs) from logistic regression models are provided. Analyses are adjusted for the propensity score quintiles.

‡ The parental antisocial behaviour and maternal parenting variables were not included in propensity score models; they were adjusted for in regression analyses modelling the maternal smoking during pregnancy–criminal offending relationship.

Table 3

Relationship between maternal smoking during pregnancy and any official record of adult criminal offending (n=3766)

Logistic regression models		
	Crude OR (95% CI)*	Propensity score adjusted OR (95% CI)[†]
Any maternal smoking during pregnancy	1.39 (1.16 to 1.67)	1.25 (1.04 to 1.51)
By category of maternal smoking		
None	Reference	Reference
Moderate (1–19)	1.37 (1.10 to 1.71)	1.15 (0.91 to 1.44)
Heavy (≥ 20)	1.40 (1.14 to 1.72)	1.31 (1.06 to 1.62)

* Adjusted for participants' age at the time the official arrest records were obtained.

[†] Adjusted for participants' age and 5 strata of propensity scores.

Table 4

Relationship between maternal smoking during pregnancy and type (n=3635) and number (n=3688) of adult criminal offences

	Response variable in propensity score adjusted multinomial logistic regression models*			
	Model 1: Type of offence(s)		Model 2: Number of offences	
	Violent vs none	Non-violent vs none	Multiple vs none[†]	Limited vs none[‡]
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Any maternal smoking during pregnancy	1.28 (0.96 to 1.70)	1.20 (0.90 to 1.60)	1.35 (0.97 to 1.88)	1.18 (0.93 to 1.49)
By category of maternal smoking				
None	Reference	Reference	Reference	Reference
Moderate (1–19)	1.31 (0.94 to 1.83)	1.07 (0.75 to 1.51)	1.22 (0.82 to 1.82)	1.13 (0.85 to 1.50)
Heavy (≥ 20)	1.27 (0.92 to 1.75)	1.26 (0.91 to 1.72)	1.47 (1.01 to 2.14)	1.20 (0.92 to 1.56)

* Adjusted for participants' age at the time the official arrest records were obtained and 5 strata of propensity scores.

[†] Multiple offences=5+ arrests in adulthood.

[‡] Limited offences=1–4 arrests in adulthood.