

# Does maternal smoking during pregnancy predict the smoking patterns of young adult offspring? A birth cohort study

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## ABSTRACT

**Objective:** To examine the association between maternal smoking during pregnancy and the development of smoking behaviour patterns among young adult offspring.

**Method:** Data were from the Mater-University of Queensland Study of Pregnancy (MUSP), a birth cohort of 7223 mothers and children enrolled in Brisbane, Australia, in 1981. The development of smoking behaviours (early or late onset, or combination of onset and prevalence patterns) among offspring at age 21 years with different patterns of maternal smoking (never smoked, smoked before or after pregnancy but not during pregnancy, or smoked during pregnancy) were compared. Maternal smoking information was derived from the prospectively collected data from the beginning of pregnancy until the child was 14 years of age. Analyses were restricted to the 3058 mothers and children whose smoking status was reported.

**Results:** The proportion of young adults who smoked regularly, either with early onset or late onset, was greater among those whose mothers had smoked during pregnancy compared with those whose mothers had never smoked. The smoking patterns among those adolescent offspring whose mothers stopped smoking during pregnancy, but who then smoked at other times during the child's life, were similar to those whose mothers had never smoked. This association was robust to adjustment for a variety of potential covariates.

**Conclusions:** The findings provide some evidence for a direct effect of maternal smoking in utero on the development of smoking behaviour patterns of offspring and provide yet another incentive to persuade pregnant women not to smoke.

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**Abbreviations:** FCV, first clinical visit; MUSP, Mater-University of Queensland Study of Pregnancy, SES, socioeconomic status

In the natural history of smoking, there seems to be two critical periods for the development of nicotine dependence: in utero exposure and adolescence.<sup>1-3</sup> Offspring of mothers who smoked during pregnancy experience many health and cognitive behavioural problems including asthma,<sup>4</sup> respiratory infections,<sup>5</sup> attention deficit and

hyperactivity disorders,<sup>6</sup> and difficulty with reading, mathematics and related skills.<sup>7</sup> They are also more likely to smoke and become nicotine dependent.<sup>8,9</sup> Most adolescent smokers continue to smoke as adults and those who start smoking early are more likely to continue smoking, to become daily smokers, to smoke heavily, to remain chronic heavy smokers and to become nicotine dependent.<sup>10</sup> As the health effects of smoking are cumulative and substantial across the life course, identifying the origins of the development of smoking behaviours is of considerable public health importance.

Nicotine passes through the placenta and may act directly on the developing fetal brain. Possibly, during a critical prenatal period of brain development, nicotine might modify the dopaminergic system implicated in the reinforcing effects of various classes of drugs including nicotine<sup>11,12</sup> and change the response of this system to the effects of nicotine later in life. Prenatal exposure to nicotine is linked by both direct and indirect pathways to childhood hyperactivity, aggression and disruptive behaviour problems<sup>13-15</sup> that increase the likelihood of smoking during adolescence. The indirect effects of nicotine on the fetus may also be secondary to poor maternal nutrition, exposure to carbon monoxide and restriction of blood flow to the placenta.<sup>16</sup>

With respect to the development of smoking behaviours, a few studies have found that in utero smoking predicts offspring smoking<sup>1,17-20</sup> and nicotine dependence.<sup>8,9,21</sup> These studies suggest a positive association between maternal smoking during pregnancy and risk of smoking and nicotine dependence among offspring. To our knowledge, no studies have examined whether prospectively measured maternal smoking during pregnancy predicts different patterns of smoking in offspring (eg, occasional or more regular smoking), whether it predicts early or late onset, or whether it is influential in predicting a combination of onset and prevalence of smoking. With respect to reducing the public health burden of adolescent and young adult smoking, it is important to know whether in utero smoking is causally associated with these different patterns of smoking.

One way to discern whether maternal smoking during pregnancy has a direct or indirect effect on patterns of offspring smoking is to compare the smoking patterns of offspring whose mothers smoked during pregnancy with those whose mothers smoked at times other than during pregnancy, and those who never smoked. If smoking during pregnancy directly affects later development of offspring smoking, then we would expect patterns of smoking among those whose mothers stopped smoking during pregnancy but smoked at other times during the child's life to be more like those whose mothers never smoked. Alternatively, if the effects were indirect, via childhood hyperactivity, aggression and disruptive behaviour problems, then the effect of in utero smoking on offspring smoking would be mediated by these childhood factors. Consequently, if a mother gave up smoking during pregnancy but was otherwise a smoker, the smoking pattern of her offspring might differ from that of women who continued to smoke throughout pregnancy. A further possibility is that the effect results primarily through social modelling during adolescence, rather than being mediated by childhood behaviour problems.

The aim of this study is to understand the mechanisms linking maternal smoking during pregnancy to the development of smoking behaviours among young adult offspring. The study involves different patterns of maternal smoking derived from

prospectively collected data from the beginning of pregnancy until the child was 14 years of age.

## **METHODS**

### **Participants**

The Mater-University of Queensland Study of Pregnancy and its outcomes (MUSP) is a prospective study of 7223 women and their offspring. The women received antenatal care at a major public hospital in Brisbane between 1981 and 1984, and delivered a live singleton child who was not adopted before leaving hospital. The study was approved by the Mater Hospitals and University of Queensland Ethics Committees. Written consent was obtained from the mother at each stage of follow-up, and from the youth at 21 years.

All details of the study participants, measurements and attrition rates have been reported previously.<sup>22-24</sup> In this paper, analyses are restricted to the 3058 mothers for whom we had prospective self-reports of smoking from before pregnancy to 14 years after delivery and their offspring participants who had attended follow-up examinations at ages 14 and 21 years and reported their smoking status.

### **Outcome measurements**

At 21-years follow-up, the young adult was asked, "At what age did you start smoking?" Early onset of smoking was defined as initiation of smoking before or at age 14 years, whereas late onset was defined as reporting initiation of smoking at age 15 years or after. Participants were also asked "Which of the following best describes your smoking status now?", with response options as follows: I have never smoked; I used to smoke; I now smoke occasionally; and I now smoke regularly. Combining the young adult report on initiation and smoking status at 21-years follow-up, we created a composite indicator of smoking patterns as follows: never smoked; early onset and used to smoke or smoked occasionally; early onset and smoked regularly; late onset and used to smoke or smoked occasionally; and late onset and smoked regularly. This composite indicator was the main outcome for all analyses.

### **Measurements of exposure**

At the first clinical visit (FCV) when the women were on average at 18 weeks of gestation, then at 3-5 days after delivery, at 6-months, 5-years and 14-years follow-up, mothers were asked to record whether they smoked (yes or no). If they smoked, they were asked to report the frequency and quantity of tobacco use in the previous week. In addition, at the FCV women were asked about whether and how much they smoked before they became pregnant. At 3-5 days after delivery, mothers were asked to recall their smoking level during the last trimester.

For in utero smoking, we combined the two smoking variables from early pregnancy and late pregnancy to define those who were "never smokers" throughout pregnancy and "smokers at either stage". We defined smoking status as: never smoked (responded "no" at all stages of the study), smoked throughout pregnancy (responded "yes" to smoking at FCV or "yes" to smoking in the third trimester) and smoked before or after pregnancy but not during pregnancy (women who responded "no" to smoking at FCV and third trimester but "yes" either to smoking before pregnancy or at

any stage of follow-up to the 14-years follow-up). These categories are mutually exclusive.

## Measurements of confounders and mediators

The following maternal characteristics during pregnancy, reported at FCV, were considered to be potential confounding factors on the basis of their potential association with maternal smoking during pregnancy and offspring smoking: maternal age (exact age), family income (low: <AUS \$10 399; medium: AUS \$10 400–20 799; high: >AUS \$26 000), maternal education (did not complete secondary school, completed secondary school, completed further/higher education), maternal depression (using the Delusions Symptoms States Inventory<sup>25</sup>; depressed v non-depressed), quality of marital relationship (using Spanier's<sup>26</sup> Dyadic Adjustment Scale: good relationship v not good relationship) and maternal alcohol consumption (abstainer, light or  $\geq 1$  glasses/day). The child's characteristics that were considered as potential confounders were breastfeeding (categorised into three groups: never, <4 months and  $\geq 4$  months, recorded at 6-months follow-up), exact age in days at which they reported smoking status, sex and number of children in the family at 5-years follow-up. Finally, we considered child behaviour,<sup>27</sup> measured using selected items from the Child Behavior Checklist of Achenbach and Edelbrock,<sup>28</sup> as the possible mediating factors. This shortened version of the Child Behavior Checklist has three scales: internalising, externalising, and social, attention and thought problems. Each scale was categorised as nil, borderline and case. Behavioural problems were based on maternal reports at 5-years follow-up.

## Statistical analyses

Our a priori hypothesis was that there is be an association between maternal smoking categorised into three different mutually exclusive groups and young adult smoking patterns. To test this, we first tabulated the different patterns of young adult smoking by maternal smoking at each follow-up and identified different patterns of maternal smoking categorised into three mutually exclusive exposure groups (table 1). The outcomes in these exposure groups were compared by computing a  $\chi^2$  test (tables 1 and 2).

**Table 1: Prevalence of maternal smoking from before pregnancy to 14-years follow-up**

Maternal smoking status by stage of life course up to 14 years (non-mutually exclusive categories)	n = 3058	Prevalence (%)
Before pregnancy		42.9
Early or middle of pregnancy		31.8
Late pregnancy		33.3
6-months follow-up		37.8
5-years follow-up		32.8
14-years follow-up		26.6
Maternal smoking status in the three mutually exclusive categories used in this study		
Never smoked	1623	53.1
Smoke before or after pregnancy but NOT during pregnancy	348	11.4
Smoked before, after and during pregnancy	1087	35.6

**Table 2: Young adult smoking patterns by three mutually exclusive categories of maternal smoking status**

Young adults smoking pattern reported at 21 years	n	Maternal smoking status in the three mutually exclusive categories			p Value*
		Never smoked (n = 1623)	Smoked before or after pregnancy but NOT during pregnancy (n = 348)	Smoked before, after and during pregnancy (n = 1087)	
<b>Onset of smoking</b>					<0.001
Never smoked	1568	57.21	50.29	42.78	
Early onset	441	11.53	17.24	17.85	
Late onset	1048	31.26	32.47	39.37	
<b>Smoking category</b>					<0.001
Never smoked	1563	57.18	50.00	42.41	
Used to smoke/smoke occasionally	761	24.89	28.45	23.74	
Smoke regularly	734	17.93	21.55	33.85	
<b>Smoking patterns</b>					<0.001
Never smoked	1570	57.24	50.29	42.87	
Early onset and used to smoke or smoked occasionally	196	6.28	8.91	5.80	
Early onset and smoked regularly	244	5.24	8.33	11.96	
Late onset and used to smoke or smoked occasionally	558	18.55	19.25	17.48	
Late onset and smoked regularly	490	12.69	13.22	21.90	

\*Three smoking categories were compared by computing a  $\chi^2$  test.

Statistical evidence for a difference in effect between men and women was assessed by computing a likelihood ratio test of the interaction with sex. We found statistical evidence that the effect differed between the sexes ( $p = 0.03$ ). As the size of this difference was not substantial, results are presented for men and women combined to increase the statistical precision of the estimate.

We fitted a series of multinomial regression models to assess the association between young adult smoking patterns by maternal smoking status in the three mutually exclusive categories, taking into account potential confounding factors. In the first model, none of the confounders was included. In the second model, age (continuous variable), sex and socioeconomic status (SES; income, education, maternal age) at birth were added. In the third model, age (continuous variable), sex, SES, maternal depression, dyadic adjustment and alcohol consumption were added. In the fourth model, age, sex, SES and breastfeeding were added. In the fifth model, age, sex, SES, child externalising, internalising and social, attention and thought problem behaviours

were added. In the final model, all potential covariates mentioned above were included.

Participants lost to follow-up were more likely to have weighed  $\leq 2.50$  kg, at birth, to be males and of Asian or Aboriginal/Torres Strait Islander background (all p values  $<0.001$ ). Their mothers were more likely to be teenagers, less educated, single or cohabitating, have  $\geq 3$  children, use tobacco and alcohol during pregnancy and be anxious and depressed at their first antenatal visit (all p values  $<0.001$ ). To determine whether this affected the validity of our findings, we undertook a weighted analysis using inverse probability (of having missing outcome data) weights.<sup>29</sup> The probability weights were computed by using a logistic regression model with the outcome being complete data or not. The influence of all other covariates used in our primary analyses on having complete data or not was assessed in combination in a logistic regression model. The regression coefficients from this model were then used to determine probability weights for the covariates in the main analyses. The results using these inverse weightings did not differ from those presented here. All analyses were undertaken using Stata V.9.0.

## RESULTS

Of 3058 women, 35.6% reported smoking at some stage of pregnancy, 11.4% reported smoking before or after pregnancy but NOT during pregnancy, and the rest (53.1%) reported never smoking (table 1). There were no women who smoked throughout pregnancy but not at any other time.

Table 2 shows the young adult smoking patterns by maternal smoking throughout the 14-years follow-up. The proportion of young adults who started smoking from age 15 years, or who smoked regularly, was higher for those whose mothers smoked during pregnancy than for those whose mothers never smoked, or smoked at other times but not during pregnancy. Combining smoking onset and status, the proportion of offspring who smoked regularly, either with early or late onset, was higher for those whose mothers smoked during pregnancy than for those whose mothers never smoked or smoked at any other times but not during pregnancy.

Table 3 presents the maternal and child characteristics by maternal smoking throughout the 14-years follow-up. In comparison to mothers who either never smoked or smoked before or after pregnancy but not during pregnancy, mothers who smoked during pregnancy were younger, were less likely to have completed secondary education, had lower family income, were more likely to be depressed, had lower-quality partner relationships, and were more likely to consume alcohol during pregnancy. In comparison to others, offspring of mothers who smoked during pregnancy were from families with more children, were less likely to breastfeed, and had experienced more externalising, social, behaviour and thought problems at 5 years.

**Table 3 - Maternal and child characteristics by three categories of maternal smoking status over the 14-years follow-up**

Maternal and child characteristics	n	Maternal smoking status in the three mutually exclusive categories			p Value*
		Never smoked	Smoked before or after pregnancy but NOT during pregnancy	Smoked before, after and during pregnancy	
<b>Sex</b>					0.157
Male	1467	49.23	43.68	47.47	
Female	1591	50.77	56.32	52.53	
Maternal age at pregnancy (years)	3058	26.66	24.50	24.68	<0.001
<b>Gross family income</b>					<0.001
Poor	816	22.37	27.30	32.93	
Middle	1722	61.68	53.45	49.22	
High	380	12.32	14.08	12.05	
Missing	140	3.64	5.17	5.80	
<b>Maternal education</b>					
Did not complete secondary	463	12.82	13.22	19.39	<0.001
Completed secondary	1943	62.04	65.52	65.84	
Completed further or higher	640	25.14	21.26	14.77	
<b>Depression</b>					
Not depressed	2764	94.51	92.06	87.56	<0.001
Depressed	248	5.49	7.94	12.44	
<b>Dyadic adjustment</b>					
Good adjustment	2610	90.18	84.88	80.06	<0.001
Not good adjustment	426	9.82	15.12	19.94	
<b>Maternal alcohol consumption at pregnancy</b>					
Abstainer	1457	51.73	46.55	42.03	<0.001
Light or $\geq$ 1/day	1598	48.27	53.45	57.97	
<b>Number of children in the family at 5-years follow-up</b>					
<4	2537	80.35	88.51	85.10	<0.001
>4	521	19.65	11.49	14.90	
<b>Breastfeeding</b>					
Never	503	13.32	14.41	22.00	<0.001
<4 months	1155	31.54	39.19	47.13	
$\geq$ 4 months	1385	55.14	46.40	30.87	
<b>Internalising behaviour</b>					
Nil	2321	77.76	76.08	74.40	
Borderline	384	11.96	12.39	13.73	
Case	334	10.29	11.53	11.87	0.383
<b>Externalising behaviour</b>					
Nil	2424	82.46	78.96	76.07	
Borderline	300	8.99	11.24	10.76	
Case	314	8.56	10.83	13.17	0.001
<b>SAT</b>					

Nil	2258	77.50	71.76	70.47	
Borderline	438	12.34	18.73	16.16	
Case	341	10.17	9.51	13.37	<0.001

SAT, social, attention and thought problems.

\*Three smoking categories were compared by computing a  $\chi^2$  test.

Table 4 shows the multivariable association between the three categories of maternal smoking and offspring smoking patterns. These results are for the 2948 young adults and their mothers with complete data on all variables included in the models. In model 2 (adjusted for age, sex and SES), young adults whose mothers smoked during pregnancy were 2.74 (95% CI 2.01 to 3.75) times more likely to start smoking before 14 years and to smoke regularly, and 2.11 (95% CI 1.68 to 2.66) times more likely to start smoking after 14 years and to smoke regularly than young adults whose mothers never smoked. Maternal smoking at other times, but not during pregnancy, was also associated with early onset and regular smoking among offspring, although the association was weaker than that observed with smoking during pregnancy. The association remained consistent, with further adjustments for other factors mentioned in Methods. The association was not mediated when we further adjusted for child behavioural problems (model 5) and parenting style at 5 years, maternal depression at 14 years and family communication at 14 years (results are not shown). When we repeated the analyses using weights for factors that predicted non-response, the results did not differ from those presented here.

**Table 4 Adjusted odds ratios of offspring smoking patterns, comparing mothers who smoked throughout pregnancy or smoked before or after pregnancy but not during pregnancy compared with those who never smoked (n = 2984)**

Young adults smoking status	Early onset and used to smoke or smoked occasionally	Early onset and smoked regularly	Late onset and used to smoke or smoked occasionally	Late onset and smoked regularly
<b>Model 1—unadjusted</b>				
Never smoked	1.00	1.00	1.00	1.00
Smoked before or after pregnancy but NOT during pregnancy	1.57 (1.00 to 2.49)	1.92 (1.21 to 3.04)	1.21 (0.88 to 1.66)	1.28 (0.89 to 1.84)
Smoked before, after and during pregnancy	1.21 (0.87 to 1.70)	3.13 (2.30 to 4.24)	1.24 (1.00 to 1.54)	2.32 (1.86 to 2.90)
<b>Model 2—adjusted by age, sex, SES (family income, maternal education)</b>				
Never smoked	1.00	1.00	1.00	1.00
Smoked before or after pregnancy but NOT during pregnancy	1.46 (0.93 to 2.30)	1.77 (1.10 to 2.83)	1.23 (0.89 to 1.54)	1.23 (0.85 to 1.77)
Smoked before, after and during pregnancy	1.11 (0.79 to 1.57)	2.74 (2.01 to 3.75)	1.23 (0.98 to 1.54)	2.11 (1.68 to 2.66)
<b>Model 3—adjusted by age, sex, SES, depression, dyadic adjustment, alcohol consumption</b>				
Never smoked	1.00	1.00	1.00	1.00
Smoked before or after pregnancy but NOT during pregnancy	1.42 (0.90 to 2.22)	1.69 (1.06 to 2.71)	1.21 (0.88 to 1.67)	1.20 (0.83 to 1.74)
Smoked before, after and during pregnancy	1.05	2.52	1.20	2.03



pregnancy (0.74 to 1.49) (1.83 to 3.46) (0.96 to 1.50) (1.61 to 2.57)

**Model 4—adjusted by age, sex, SES, number of children in the family at 5-years follow-up, breastfeeding**

Never smoked	1.00	1.00	1.00	1.00
Smoked before or after pregnancy but NOT during pregnancy	1.45 (0.92 to 2.27)	1.78 (1.11 to 2.85)	1.22 (0.89 to 1.69)	1.23 (0.85 to 1.78)
Smoked before, after and during pregnancy	1.07 (0.75 to 1.52)	2.70 (1.96 to 3.72)	1.22 (0.97 to 1.53)	2.10 (1.66 to 2.65)

**Model 5—adjusted by age, sex, SES, child internalising, externalising behaviours and SAT**

Never smoked	1.00	1.00	1.00	1.00
Smoked before or after pregnancy but NOT during pregnancy	1.44 (0.92 to 2.27)	1.75 (1.10 to 2.81)	1.22 (0.89 to 1.69)	1.23 (0.85 to 1.78)
Smoked before, after and during pregnancy	1.08 (0.76 to 1.53)	2.68 (1.95 to 3.66)	1.22 (0.98 to 1.53)	2.09 (1.66 to 2.63)

**Model 6—adjusted by all covariates mentioned before**

Never smoked	1.00	1.00	1.00	1.00
Smoked before or after pregnancy but NOT during pregnancy	1.39 (0.88 to 2.18)	1.72 (1.07 to 2.76)	1.21 (0.88 to 1.67)	1.22 (0.84 to 1.76)
Smoked before, after and during pregnancy	0.97 (0.68 to 1.39)	2.46 (1.78 to 3.40)	1.20 (0.95 to 1.51)	2.00 (1.57 to 2.53)

SES, socioeconomic status; SAT, social, attention and thought problems.

**DISCUSSION**

In this prospective longitudinal study of mothers and their offspring, we found that the proportion of regular smokers, either with early onset or late onset, was greater among those whose mothers had smoked during pregnancy compared with those whose mothers had never smoked. With the exception of early-onset regular smoking, the smoking patterns among those adolescent offspring whose mothers stopped smoking during pregnancy, but who then smoked at other times during the child's life were similar to those whose mothers had never smoked. A multivariable analysis (model adjusted by age, sex and SES) showed that offspring of mothers who smoked during pregnancy were 2.74 (95% CI 2.01 to 3.75) times more likely to start smoking before age 14 years and to smoke regularly, and 2.11 (95% CI 1.68 to 2.66) times more likely to start smoking after 14 years and to smoke regularly than young adults whose mothers never smoked. This association was robust to adjustment for a variety of potential covariates including SES, maternal depression, marital relationship, alcohol consumption and breastfeeding. These findings provide some evidence for a direct effect of maternal smoking in utero on the development of smoking behaviours among offspring.

Participants who were lost to follow-up were more likely to be from poorer backgrounds and mothers were likely to have had low education and to be of Asian or Aboriginal/Torres Strait Islander descent. Our results would be biased if the associations we have assessed were non-existent or in the opposite direction in non-participants. However, as most studies find that children of mothers who smoked during pregnancy exhibit a range of poorer physical and mental health outcomes,<sup>30-32</sup> this is unlikely. To further assess whether those lost to follow-up produced bias in our

results, we attached inverse probability weighting to persons included in the analyses to restore the representation of those lost to follow-up. We followed the method suggested by Hogan et al<sup>29</sup> and used robust standard error estimates in these models. We found no difference between the weighted and unweighted results, which suggests that attrition is unlikely to have substantively biased our findings.

Although the study has several strengths including the use of prospective measures of smoking during pregnancy, control for many social and contextual factors, and measures of offspring smoking at 21 years of age when nicotine dependence could be expected to have developed, several limitations also need to be considered. One important limitation of our study and others in this area is the use of maternal self-reports of smoking status. Several steps were taken to elicit accurate self-reports (eg, assurances of confidentiality, the clinical setting, detailed questions and trained interviewers). However, as smoking throughout pregnancy has been discouraged for some decades, the most likely direction of measurement error would be for some mothers who did actually smoke during pregnancy to deny this and to be categorised with those who smoked at other times but not during pregnancy. The effect of this measurement error on our results would be to attenuate them. Thus, the effect of smoking during pregnancy on offspring smoking could actually be greater than we have estimated here.

Further limitations include the possibility that factors that were not measured in the current study may explain the associations reported. Such factors include peer influences on the development of smoking behaviours,<sup>8,29</sup> genetic influences and personality factors that may characterise mothers who gave up smoking while pregnant and serve to indirectly influence the association between maternal and child smoking.

The adjusted odds ratios for maternal smoking before or after pregnancy were considerably different from never smoked for offspring early onset and smoked regularly. Possible explanations of this finding involve a sensitive period for brain development and the effect of behavioural modelling. Brain development continues at a rapid pace throughout the first 2 years and continues into late adolescence; so it is possible that during this perinatal period the brain is sensitive to the effects of smoking in a way that it is during pregnancy.

The results are consistent with previous studies reporting that maternal smoking during pregnancy predicts offspring smoking<sup>1,13,17-19</sup> or nicotine dependence.<sup>8,9,10,21</sup> However, results of this study extend the existing evidence by showing that offspring of mothers who smoked during pregnancy have patterns of smoking different from those of mothers who did not smoke during pregnancy, or who smoked at other times but not during pregnancy. The critical period of in utero exposure predicts young adults' regular smoking, irrespective of time of onset.

Behavioural problems and learning difficulties were also examined in the current study owing to their potential role in the causal pathway from prenatal exposure to offspring smoking. As noted by Goldman,<sup>33</sup> variations in the core neurobiological basis of addiction may be inherited and may be mediated by pathways involving factors such as reward responses and behavioural control. Despite further adjustments with these patterns, in the multivariable model, the relationship between maternal

smoking during pregnancy and offspring smoking patterns remained distinctive and consistent.

Particular classification of early and late trimester maternal smoking in relation to offspring smoking is complex. Some women may quit smoking before pregnancy and some may quit soon after realising that they are pregnant. Because of the nature of the questions asked at the first antenatal clinic visit, it is not possible to ascertain the exact time when a woman who quit smoking during or before pregnancy did so. It would not be possible to classify this effect using the MUSP data because of the different gestational ages at entry time of the women at their first antenatal clinic visits. The mean gestational age at entry was 18 weeks and only 10% of women entered into the cohort by the first trimester of their gestation.

In conclusion, using a longitudinal analysis of a mother and offspring cohort, we have found that adolescent offspring of mothers who reported smoking during pregnancy were more likely to smoke regularly, either with early onset or late onset, than those whose mothers did not smoke during pregnancy or smoked at other times. Our findings suggest a direct effect of maternal smoking during pregnancy on young adults' development of regular smoking and provide yet another incentive to persuade pregnant women not to smoke and to discourage young women from ever taking it up.

### **What this paper adds**

With respect to the development of smoking behaviours, a few studies have found that in utero smoking predicts offspring smoking, and nicotine dependence. To our knowledge, no studies have examined whether prospectively collected maternal smoking during pregnancy predicts different patterns of smoking in offspring (eg, occasional or more regular smoking), whether it predicts early or late onset, or whether it is influential in predicting a combination of onset and frequency of smoking.

In this prospective longitudinal study of mothers and their offspring, we found that the proportion of regular smokers, either with early onset or later onset, was greater among those whose mothers had smoked during pregnancy compared to those whose mothers had never smoked. The smoking patterns among those adolescent offspring whose mothers stopped smoking during pregnancy, but who then smoked at other times in the child's life were similar to those whose mothers had never smoked. Our findings suggest a direct effect of maternal smoking and provide yet another incentive for pregnant women to be persuaded not to smoke and young women encouraged never to take it up.

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## REFERENCES

1. Cornelius MD, Leech SL, Goldschmidt L, *et al.* Prenatal tobacco exposure: is it a risk factor for early tobacco experimentation? *Nicotine Tob Res* 2000;2:45–52.
2. Kelder SH, Perry CL, Klepp KI, *et al.* Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors. *Am J Public Health* 1994;84:1121–6.
3. Schooling M, Kuh D. A lifecourse perspective on women's health behaviours. In Kuh D, Hardy R, eds. *A life course approach to women's health*. Oxford: Oxford University Press, 2002:279–303.
4. Gilliland FD, Li YF, Peters JM. Effects of maternal smoking during pregnancy and environmental tobacco smoke on asthma and wheezing in children. *Am J Respir Crit Care Med* 2001;163:429–36.
5. Young S, Sherrill DL, Arnott J, *et al.* Parental factors affecting respiratory function during the first year of life. *Pediatr Pulmonol* 2000;29:331–40.
6. Thapar A, Fowler T, Rice F, *et al.* Maternal smoking during pregnancy and attention deficit hyperactivity disorder symptoms in offspring. *Am J Psychiatry* 2003;160:1985–9.
7. Batstra L, Hadders AM, Neeleman J. Effect of antenatal exposure to maternal smoking on behavioural problems and academic achievement in childhood: prospective evidence from a Dutch birth cohort. *Early Hum Dev* 2003;75:21–33.
8. Buka SL, Shenassa ED, Niaura R. Elevated risk of tobacco dependence among offspring of mothers who smoked during pregnancy: a 30-year prospective study. *Am J Psychiatry* 2003;160:1978–84.
9. Lieb R, Schreier A, Pfister H, *et al.* Maternal smoking and smoking in adolescents: a prospective community study of adolescents and their mothers. *Eur Addict Res* 2003;9:120–30.
10. Kandel DB, Chen K, Warner L, *et al.* Prevalence and demographic correlates of symptoms of dependence on cigarettes, alcohol, marijuana and cocaine in the U.S. population. *Drug Alcohol Depend* 1997;44:11–29.
11. Balfour DJ. The neurobiology of tobacco dependence: a preclinical perspective on the role of the dopamine projections to the nucleus accumbens. 2004;6: 899–912 (Erratum in *Nicotine Tob Res* 2005;7, 307; Review. Erratum in *Nicotine Tob Res* 2004;6 :899–912.

12. Hyman SE. Addiction: a disease of learning and memory. *Am J Psychiatry* 2005;162:1414–22.
13. Cornelius MD, Day NL. The effects of tobacco use during and after pregnancy on exposed children: relevance of findings for alcohol research. *Alcohol Res Health* 2000;224:242–9.
14. Wakschlag LS, Pickett KE, Cook E Jr, *et al.* Maternal smoking during pregnancy and severe antisocial behavior in offspring: a review. *Am J Public Health* 2002;92:966–74.
15. Weitzman M, Gortmaker SL, Sobol AM. Maternal smoking and behavior problems of children. *Pediatrics* 1992;90:342–9.
16. Ernst M, Moolchan ET, Robinson ML. Behavioral and neural consequences of prenatal exposure to nicotine. *J Am Acad Child Adolesc Psychiatry* 2001;40:630–41.
17. Griesler P, Kandel D, Davies M. Maternal smoking in pregnancy, child behavior problems and adolescent smoking. *J Res Adolesc* 1998;8:159–85.
18. Lawlor DA, O’Callaghan M, Mamun AA, *et al.* The association of maternal smoking throughout pregnancy, parental education and socio-economic position at birth with adolescent smoking: findings from the Mater-University Study of Pregnancy and its outcomes. *Paediatr Perinat Epidemiol* 2005;19:377–87.
19. Roberts KH, Munafo MR, Rodriguez D, *et al.* Longitudinal analysis of the effect of prenatal nicotine exposure on subsequent smoking behavior of offspring. *Nicotine Tob Res* 2005;7:801–8.
20. Cornelius MD, Leech SL, Goldschmidt L, *et al.* Is prenatal tobacco exposure a risk factor for early adolescent smoking? A follow-up study. *Neurotoxicol Teratol* 2005;27:667–76.
21. Fergusson DM, Woodward LJ, Horwood LJ. Maternal smoking during pregnancy and psychiatric adjustment in late adolescence. *Arch Gen Psychiatry* 1998;58:721–7.
22. Najman JM, Bor W, O’Callaghan M, *et al.* Cohort profile: The Mater-University of Queensland Study of Pregnancy (MUSP). *Int J Epidemiol* 2005;34:992–7.
23. Lawlor D, Najman JM, Sterne J, *et al.* Associations of parental, birth and early life characteristics with systolic blood pressure at age 5: findings from the Mater-University study of pregnancy and its outcomes. *Circulation* 2004;110:2417–23.
24. Keeping JD, Najman JM, Morrison J, *et al.* A prospective longitudinal study of social, psychological and obstetric factors in pregnancy: response rates and demographic characteristics of the 8556 respondents. *Br J Obstet Gynaecol* 1989;96:289–97.

25. Bedford A, Foulds GA. *Delusions symptoms states inventory: state of anxiety and depression (manual)*. Berkshire, England: NFER Publishing, 1978.
26. Spanier GB. Measuring dyadic adjustment—new scales for assessing quality of marriage and similar dyads. *J Marriage Fam* 1976;38:15–28.
27. Williams GM, O’Callaghan M, Najman JM, *et al*. Maternal cigarette smoking and child psychiatric morbidity: a longitudinal study. *Pediatrics* 1998;102:E11.
28. Achenbach TM, Edelbrock C. *Manual for the child behavior checklist and revised child behavior profile*. Burlington, VT: University of Vermont, Department of Psychiatry, 1983.
29. Hogan JW, Roy J, Korkontzelou C. Handling drop-out in longitudinal studies. *Stat Med* 2004;23:1455–97.
30. Lawlor DA, Bor W, O’Callaghan MJ, *et al*. Intrauterine growth and intelligence within sibling pairs: findings from the Mater-University study of pregnancy and its outcomes. *J Epidemiol Community Health* 2005;59:279–82.
31. Stathis SL, O’Callaghan DM, Williams GM, *et al*. Maternal cigarette smoking during pregnancy is an independent predictor for symptoms of middle ear disease at five years’ postdelivery. *Pediatrics* 1999;104:301–7.
32. Williams GM, O’Callaghan M, Najman JM, *et al*. Maternal cigarette smoking and child psychiatric morbidity: a longitudinal study. *Pediatrics* 1998;102:e11.
33. Goldman D, Oroszi G, Ducci F. The genetics of addictions: uncovering the genes. *Nat Rev Genet* 2005;6:521–32.