

Maternal Smoking During Pregnancy and School Performance at Age 15

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Background: Smoking during pregnancy has been suggested to have long-term consequences for neuropsychologic development in the offspring, including behavioral problems, attention deficit disorders, and antisocial behavior. Also, findings from several studies indicate an association with impaired cognitive function in the children.

Methods: In a population-based Swedish cohort study, we examined possible associations between maternal smoking in pregnancy and educational achievement in the offspring at age 15 years among more than 400,000 male and female students born 1983 through 1987. Generalized estimating equation models were used to evaluate associations of maternal smoking, other maternal characteristics, and birth characteristics with school performance. Odds ratios (ORs) were used as a measure of risk.

Results: In a model adjusted for maternal characteristics, maternal smoking compared with no tobacco use during pregnancy was associated with an increased risk of poor scholastic achievement: for 1–9 cigarettes per day, the OR was 1.59 (95% confidence interval = 1.59–1.63) and for 10 or more cigarettes per day, the OR was 1.92 (1.86–1.98). These risks remained unchanged when we also adjusted for smoking-related pregnancy outcomes such as fetal growth restriction and preterm birth. However, if the mother had smoked in her first pregnancy, but not in her second pregnancy, the younger sibling was also at increased risk of poor school performance.

Conclusion: Observed associations between maternal smoking during pregnancy and poor cognitive performance in the offspring might not be causal. We suggest that associations reported in earlier studies may instead reflect the influence of unmeasured characteristics that differ between smokers and nonsmokers.

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Smoking is probably the most important preventable risk factor for unsuccessful pregnancy outcomes. Maternal smoking is causally linked to fetal growth restriction, and

possibly also to placental abruption, preterm birth, and still-birth.¹ In addition, smoking during pregnancy has been suggested to have long-term consequences for neuropsychologic development in the offspring, including behavioral problems,^{2,3} attention deficit disorders,^{4,5} and antisocial behavior.^{6,7} Also, findings from several studies indicate an association with impaired cognitive function in children of smoking mothers, whether measured by IQ tests^{8,9} or as reflected in poor scholastic achievement at different ages.^{3,10–14} Proposed underlying biologic mechanisms include intrauterine hypoxia, or direct toxic effects of nicotine or other products of cigarette smoke on the developing fetal brain.¹⁵ However, it remains unclear whether reported associations between in utero exposure to tobacco smoke and measures of cognitive function are causally related, mediated by passive smoking after birth, or explained by socioeconomic or other characteristics of smoking mothers.^{16,17}

We used data from population-based Swedish registers to examine possible associations between maternal smoking in pregnancy and educational achievement in the offspring at age 15 years among more than 400,000 students. The data allowed adjustments for birth characteristics and some potential sociodemographic confounders. We were also able to compare risks of poor school performance in first- and second-born siblings whose mothers reported various permutations of smoking habits across successive pregnancies.

METHODS

The study was based on data from 4 Swedish population-based registers: the Medical Birth Register, the Education Register, the 1990 Census database, and the National School Register. Each register includes a national registration number, an individually unique identifier that facilitates record linkage.

Information on maternal smoking (the main exposure variable), age, parity, and birth characteristics was obtained from the Medical Birth Register. The Education Register and the Population and Housing Census of 1990 both provided information on sociodemographic background factors. Outcome data (school performance) was obtained from the National School Register, which records individual grades in 9th grade for up to 16 school subjects.

The Medical Birth Register

The Swedish Medical Birth Register started in 1973 and includes more than 99% of all births in Sweden.¹⁸ During pregnancy and delivery, information is prospectively recorded on standardized records. After delivery, copies of these records

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are forwarded to the Birth Register, in which data are computerized.

Beginning in 1983, information on smoking habits has been recorded by the midwife at a woman's first visit to antenatal care. More than 95% of the Swedish pregnant population attends antenatal care before the 15th gestational week.¹⁹ Information on maternal age and parity and infant birth weight and length, gestational age, sex, and Apgar score is collected at the time of delivery. Pregnancy and delivery complications are noted by the obstetrician when the woman is discharged from the hospital.

The 1990 Census

The Swedish Population and Housing Census of 1990 includes questions about household size, type of housing, employment, occupation, and income. In addition, data on country of origin, citizenship, immigration, and emigration were retrieved from a national population register and added to the Census file.

The Education Register

The Education Register provides information on highest attained educational level for all residents of Sweden who were alive in 1985 or later. A validation study has shown that the highest level of formal education is correctly reported for 83% of the population.²⁰

The National School Register

The National School Register is administered jointly by the Swedish School Authority (Skolverket) and Statistics Sweden. The database encompasses information on individual educational achievements (grades by subject as well as summary scores) for all students graduating from class 9 in public schools since 1988. Nonpublic schools, which comprise fewer than 5% of all Swedish schools, have been included since 1993. The quality of the data in the National School Register is high and summary statistics are published regularly.²¹

The population for this study was defined as individuals registered in the National School Register who were born between 1983 and 1987. Data from the School Register indicate that children with 2 foreign-born parents are at higher risk of poor school performance, possibly due to language barriers. Also, twin membership may be associated with a disadvantageous fetal environment. We therefore restricted our investigation to single-born children with a Swedish-born mother by excluding twins ($n = 8765$) and students with a mother born outside Sweden ($n = 48,193$). The final study population encompassed 401,365 students.

The study was approved by the Research Ethics Committee at Karolinska Institutet.

Risk Factors

Maternal Characteristics

Maternal smoking was categorized into 3 groups: non-smokers (nondaily smoking), moderate smokers (1–9 cigarettes daily), and heavy smokers (10 or more cigarettes per day). Other maternal factors included were maternal age and parity. We also retrieved information on mother's level of

formal education, socioeconomic index category, and home ownership. The socioeconomic index variable, a commonly used indicator for socioeconomic status in Sweden, is based on occupational group.²²

Birth Characteristics

We examined the following birth characteristics: sex, birth weight, birth length, head circumference, gestational age, and Apgar score at 5 minutes. Birth weight, birth length, and head circumference for gestational age were expressed in standard deviation scores for gestational age according to Swedish standards.²³

School Performance

School performance was assessed by a grade-point summary score, which equals the sum of the numeric values of the grades in 16 different subjects (pass = 10; pass with distinction = 15; and pass with honors = 20). A student can obtain a maximum summary score of 320. The mean score in 2003 was 205. We defined poor school performance as a summary score below 160, ie, the mean grade of the individual was below "pass." In a separate step, we also assessed the grade-point summary score in continuous form.

Statistical Analysis

To control for the dependence between siblings, we used generalized estimating equation models²⁴ to evaluate associations of maternal smoking, other maternal characteristics, and birth characteristics with school performance. Odds ratios (ORs) were used as a measure of risk with 95% confidence intervals (CIs).

First, we estimated the associations of maternal factors and birth characteristics with school performance in both univariate and multivariate analyses. Second, we assessed the association between smoking and educational achievement adjusting separately for maternal factors and birth characteristics. In a third step, both maternal factors and birth characteristics were included in a full model. Subsequently, the modifying effect of maternal social status on the association between smoking and scholastic achievement was examined. Finally, we wanted to investigate whether changes in maternal smoking habits from one pregnancy to another influenced risk of poor school performance. Using logistic regression models, we estimated risks in first- and second-born siblings by different permutations of maternal smoking (0/1–9 cigarettes/10+ cigarettes) across successive pregnancies.

RESULTS

The grade-point summary scores were not normally distributed but skewed toward higher values. For the whole period under study, the mean score was 204. There was a trend in mean score with exposure to maternal smoking (no smoking 214; 1–9 cigarettes 187; 10+ cigarettes 175).

Table 1 presents the associations between maternal and sociodemographic characteristics and risks of poor school performance, defined as grade-point summary score <160. Low maternal age at birth, high parity, low maternal education, low socioeconomic status, and renting one's home (vs ownership)

TABLE 1. Maternal Characteristics and the Risk of Poor School Performance (Grade-Point Summary Score <160)

	Total No.	Low Grades		Crude OR (95% CI)	Adjusted* OR (95% CI)
		No.	%		
Mother's age (yrs)					
≤16	538	227	42	4.45 (3.74–5.29)	2.72 (2.06–3.59)
17–19	11,665	3893	33	2.98 (2.86–3.11)	2.15 (2.03–2.29)
20–24	95,584	19,488	20	1.62 (1.59–1.66)	1.43 (1.38–1.47)
25–29†	150,027	19,559	13	1.00	1.00
30–39	137,198	15,264	11	0.83 (0.81–0.85)	0.82 (0.79–0.84)
40+	6352	868	14	1.02 (0.95–1.10)	0.77 (0.70–0.86)
Missing	1	0	0		
Parity					
1†	166,748	22,359	13	1.00	1.00
2	144,247	20,330	14	1.08 (1.06–1.10)	1.42 (1.38–1.46)
3	66,452	11,073	17	1.29 (1.26–1.32)	1.89 (1.83–1.96)
4	23,918	5537	23	1.88 (1.81–1.94)	2.52 (2.39–2.66)
Mother's education					
9-yr compulsory	51,825	14,856	29	1.76 (1.72–1.81)	1.37 (1.32–1.41)
Secondary school 2 yr†	156,744	28,985	19	1.00	1.00
Secondary school 3 yr	48,474	5,844	12	0.60 (0.58–0.62)	0.72 (0.69–0.74)
Higher education <3 yr	68,546	4897	7	0.34 (0.33–0.35)	0.59 (0.56–0.62)
Higher education ≥3 yr	71,134	3737	5	0.24 (0.23–0.25)	0.46 (0.44–0.49)
Missing	4642	980	21		
Mother's socioeconomic category					
Unskilled blue collar worker†	112,412	24,049	21	1.00	1.00
Skilled blue collar worker	44,762	6365	14	0.61 (0.59–0.63)	0.76 (0.74–0.79)
Low-level white collar worker	60,399	6615	11	0.45 (0.44–0.46)	0.64 (0.62–0.66)
Intermediate-level white collar worker	74,189	4206	6	0.22 (0.21–0.23)	0.54 (0.52–0.57)
High-level white collar worker	26,056	1156	4	0.17 (0.16–0.18)	0.48 (0.45–0.52)
Self-employed	12,180	1325	11	0.45 (0.42–0.48)	0.64 (0.60–0.69)
Missing	71,367	15,583	22		
Mother's housing					
Own†	295,439	33,846	12	1.00	1.00
Rent	87,015	21,181	24	2.49 (2.44–2.54)	1.92 (1.87–1.97)
Other	5018	811	16	1.50 (1.38–1.62)	1.31 (1.18–1.45)
Missing	13,893	3461	25		

*Adjusted for all other maternal characteristics in the table and for maternal smoking.

†Reference category.

were associated with increased risks of poor scholastic achievement in both crude and adjusted analyses.

Compared with girls, boys were more likely to have poor school performance (Table 2). We also found increased risks among subjects who had a low (0–3) Apgar score at 5 minutes and among those with low birth weight, short birth length, early delivery, and small head circumference for gestational age. When adjusted for maternal characteristics, the overall pattern was unchanged.

We then explored in detail associations between maternal smoking during pregnancy and school performance in the offspring (Table 3). In univariate analyses, the risk of poor performance in children of moderate (1–9 cigarettes/d) and heavy (10+ cigarettes/d) smokers were more than 2 and 3 times higher, respectively, than in children of nonsmokers. To investigate

whether these associations were confounded by social characteristics, we adjusted for maternal characteristics; although the observed associations became attenuated, children of moderate and heavy smokers still faced a 60% and a 90% increase in risk, respectively. Next, we investigated whether associations between smoking and risk of poor school performance were mediated by the smoking-related effect on pregnancy outcomes such as fetal growth restriction and preterm birth; when adjusted for birth characteristics, risks were similar to the crude risk estimates. In the full model, when adjustments were made for both maternal and birth characteristics, moderate and heavy smoking remained associated with a 60% and 90% increase in risk of poor school performance, respectively.

Because the magnitude of residual confounding may differ among social groups, we also performed analyses

TABLE 2. Birth Characteristics and the Risk of Poor School Performance in the Offspring (Grade-Point Summary Score <160)

	Total No.	Low Grades		Crude OR (95% CI)	Adjusted* OR (95% CI)
		No.	%		
Sex					
Boys	205,579	36,107	18	1.58 (1.56–1.61)	1.72 (1.68–1.76)
Girls	195,786	23,192	12	1.00	1.00
Apgar score					
0–3	437	96	22	1.60 (1.28–1.99)	1.63 (1.21–2.18)
4–6	2372	452	19	1.35 (1.22–1.49)	1.45 (1.27–1.65)
7–10 [†]	394,748	58,103	15	1.00	1.00
Data missing	3808	648	17		
Birth weight for gestational age (SDS)					
Less than –2	9654	2032	21	1.49 (1.42–1.57)	1.34 (1.25–1.43)
–2 to +2 [†]	378,624	55,343	15	1.00	1.00
Greater than 2	10,014	1430	14	0.99 (0.94–1.05)	1.05 (0.98–1.13)
Data missing	3073	494	16		
Birth length for gestational age (SDS)					
Less than –2	10,786	2231	21	1.46 (1.40–1.54)	1.25 (1.18–1.33)
–2 to +2 [†]	376,714	55,022	15	1.00	1.00
Greater than 2	9922	1292	13	0.89 (0.84–0.94)	0.97 (0.90–1.05)
Data missing	3943	754	19		
Head circumference for gestational age (SDS)					
Less than –2	12,395	2403	19	1.37 (1.31–1.43)	1.30 (1.23–1.38)
–2 to +2 [†]	371,525	54,315	15	1.00	1.00
Greater than 2	10,138	1312	13	0.88 (0.83–0.93)	0.96 (0.89–1.03)
Data missing	7307	1269	17		
Gestational age (wks)					
<32	1498	333	22	1.66 (1.47–1.87)	1.50 (1.27–1.77)
32–26	14,315	2524	18	1.26 (1.21–1.32)	1.13 (1.07–1.20)
37–39	131,567	20,070	15	1.09 (1.06–1.11)	1.05 (1.03–1.08)
40–41 [†]	202,095	28,539	14	1.00	1.00
42+	51,202	7680	15	1.07 (1.04–1.10)	1.10 (1.07–1.14)
Data missing	688	153	22		

*Adjusted for all maternal characteristics (in Table 1) and for maternal smoking.
[†]Reference category.
 SDS indicates standard deviation scores.

TABLE 3. Maternal Smoking and the Risk of Poor School Performance

	Total No.	Low Grades		Crude OR (95% CI)	Adjusted for Maternal Characteristics* OR (95% CI)	Adjusted for Birth Characteristics [†] OR (95% CI)	Fully Adjusted [‡] OR (95% CI)
		No.	%				
Mother's smoking (no. of cigarettes per day)							
0 (Nonsmoking) [§]	263,540	28,075	11	1.00	1.00	1.00	1.00
1–9	69,265	15,094	22	2.27 (2.22–2.33)	1.59 (1.55–1.63)	2.26 (2.21–2.32)	1.58 (1.53–1.62)
10+	42,874	12,003	28	3.11 (3.03–3.19)	1.92 (1.86–1.98)	3.09 (3.01–3.17)	1.89 (1.83–1.96)
Missing	25,686	4127	16				

*Adjusted for all maternal characteristics (listed in Table 1).

[†]Adjusted for all birth characteristics (listed in Table 2).[‡]Adjusted for maternal and birth characteristics.[§]Reference category.

TABLE 4. Maternal Smoking and the Risk of Poor School Performance Stratified by Maternal Level of Education

Mother's Education	Mother's Smoking (No. Cigarettes Per Day)	Crude OR (95% CI)	Adjusted* OR (95% CI)
9-yr compulsory	0 [†]	1.00	1.00
	1-9	1.69 (1.61-1.78)	1.62 (1.55-1.71)
	10+	1.99 (1.89-2.09)	1.92 (1.82-2.02)
Secondary school 2 yr	0 [†]	1.00	1.00
	1-9	1.83 (1.77-1.89)	1.79 (1.73-1.85)
	10+	2.44 (2.36-2.53)	2.36 (2.27-2.45)
Secondary school 3 yr	0 [†]	1.00	1.00
	1-9	2.02 (1.88-2.17)	1.95 (1.82-2.10)
	10+	2.40 (2.21-2.61)	2.32 (2.13-2.52)
Higher education <3 yr	0 [†]	1.00	1.00
	1-9	1.91 (1.76-2.07)	1.87 (1.73-2.03)
	10+	2.43 (2.19-2.69)	2.33 (2.10-2.59)
Higher education ≥3 yr	0 [†]	1.00	1.00
	1-9	1.81 (1.64-2.00)	1.75 (1.58-1.93)
	10+	2.51 (2.20-2.87)	2.35 (2.06-2.68)

*Adjusted for mother's age and parity.
[†]Reference category.

stratified for maternal levels of education and socioeconomic index in fine strata. There was a strong association between tobacco smoking and poor scholastic achievement in offspring regardless of mother's educational attainment (Table 4) or maternal socioeconomic index (data not shown).

We also compared the risk of poor school performance in first- and second-born siblings in relation to maternal smoking habits in each pregnancy (Table 5). In comparison with nonsmoking status in both pregnancies, there was a clear

pattern of elevated risks of poor school performance for both siblings associated with smoking in one or both pregnancies. Among children born to mothers who were nonsmokers in the first pregnancy, maternal smoking in second pregnancy was associated with a dose-dependent increase in risk among both first- and second-born children. Conversely, if the mother had quit smoking in the second pregnancy, the younger sibling was also at increased risk of poor school performance.

TABLE 5. Maternal Smoking in First and Second Pregnancy and the Risk of Poor School Performance in Siblings*

Mother's Smoking (No. of Cigarettes Per Day)		First Birth			Second Birth	
First Pregnancy	Second Pregnancy	No.	Crude OR (95% CI)	Fully Adjusted [§] OR (95% CI)	Crude OR (95% CI)	Fully Adjusted [§] OR (95% CI)
0	0 [‡]	29,269	1.00	1.00	1.00	1.00
0	1-9	1017	2.09 (1.75-2.49)	1.45 (1.17-1.81)	2.25 (1.92-2.65)	1.54 (1.26-1.88)
0	10+	216	3.24 (2.33-4.50)	1.70 (1.12-2.60)	2.44 (1.74-3.41)	1.19 (0.77-1.84)
1-9	0	2275	1.59 (1.39-1.81)	1.24 (1.05-1.46)	1.77 (1.57-1.99)	1.41 (1.22-1.63)
1-9	1-9	4075	2.50 (2.28-2.75)	1.57 (1.40-1.76)	2.56 (2.35-2.79)	1.73 (1.56-1.91)
1-9	10+	1226	3.91 (3.41-4.49)	2.13 (1.79-2.54)	3.61 (3.17-4.13)	1.96 (1.66-2.31)
10+	0	659	2.48 (2.01-3.05)	1.59 (1.22-2.05)	2.74 (2.27-3.31)	1.83 (1.46-2.30)
10+	1-9	1322	3.67 (3.21-4.19)	2.25 (1.90-2.66)	3.42 (3.01-3.90)	2.05 (1.74-2.40)
10+	10+	1986	3.61 (3.22-4.04)	1.79 (1.55-2.07)	4.14 (3.73-4.59)	2.11 (1.85-2.41)
Data missing	Data missing	8890				

*Based on 50,935 women with first and second consecutive births between 1983 and 1987.

[†]Adjusted for all birth characteristics, including offspring sex, and all other maternal characteristics.

[‡]Reference category.

DISCUSSION

In the initial analyses, we found evidence of strong associations between maternal smoking during pregnancy and substandard academic achievement at age 15. Although adjustments for maternal socioeconomic factors substantially reduced the smoking-related risk of poor school performance, the risk remained almost twice as high in children whose mother smoked 10 or more cigarettes per day in early pregnancy compared with children of nonsmoking mothers. These results broadly corroborate findings from several,^{3,8-14} but not all,^{16,25,26} earlier studies that have examined cognitive function in the offspring in relation to maternal smoking. Adjustment for birth characteristics did not influence smoking-related risk estimates, suggesting that the observed associations were not mediated by smoking-related risks of fetal growth restriction or preterm birth.

Because maternal smoking may be correlated with a less advantageous home environment, unmeasured factors related to social standing could have influenced results in the earlier studies that indicated an association with poor cognitive function.^{16,17} For that reason, we extended our analyses in 2 steps. First, in a stratified approach, we examined the impact of smoking in different socioeconomic and educational groups separately, and found that associations were of similar magnitude in all strata. Second, we compared the risk of poor school performance in first- and second-born siblings in relation to maternal smoking habits in each pregnancy. If maternal smoking during pregnancy is causally associated with offspring school performance, risk of poor school performance would be increased in the sibling exposed to maternal smoking in utero compared with the unexposed sibling. However, risk estimates were consistently elevated in both siblings in which the mother had smoked during at least one of the pregnancies compared with nonexposed sibling pairs. For example, in children of mothers who smoked in the first pregnancy, but not in the second pregnancy, the risks of poor school performance in both siblings increased with amount smoked in first pregnancy. Although we were unable to determine the prevalence of maternal smoking between pregnancies, indirect assessment based on smoking status in first and second pregnancy gave no consistent support for an important association between postnatal exposure to passive smoking and scholastic achievement; first-borns not exposed to maternal smoking in utero, but whose second-born sibling was exposed, were also at an increased risk of underachievement.

The strengths of the present study include its size and the population-based design. The availability of data from a high-quality Medical Birth Register provided information on smoking in consecutive pregnancies, and we were also able to adjust not only for socioeconomic factors, but also for birth characteristics that could lie in the causal pathway between smoking during childbearing and cognitive development in the offspring. Information on smoking was based on self-report. A Swedish study found that only 6% of self-reported nonsmokers had serum cotinine values corresponding to active smoking.²⁷ Moreover, the validity of self-reported smoking has not changed over time,²⁸ and this is probably also true for pregnant women in Sweden.²⁹ A weakness, shared with

almost all previous studies in this area, was the absence of information on maternal alcohol use during pregnancy and exposure of the child to passive smoking. Also, no data were available on breast-feeding, an exposure that has been positively linked to cognitive development.^{30,31} Although scholastic achievement is generally closely associated with intelligence,³² academic results are also likely to be influenced by motivation and ability to concentrate. Thus, studies based on school performance cannot determine whether any association with maternal smoking reflects detrimental effects on intelligence, increased risks of attention deficits,⁴ or behavioral problems.^{2,3}

Taken together, the results of the present study suggest that associations between maternal smoking and poor cognitive function in the offspring that were observed in initial analyses in this study, and reported in previous studies,^{3,10-14} may not be causal; instead, they may reflect an influence of unmeasured characteristics of the home environment that differ between smokers and nonsmokers in all social strata. These characteristics could include differences in parenting skills such as time spent with and attention given to the child.³³

Our findings indicate that in the context of smoking, adjustment for traditional measures of social class is insufficient when evaluating the association with outcomes for which subtle environmental factors are likely to play an important role.

Although our results indicate that previously observed associations between tobacco use during pregnancy and risk of poor school performance in the offspring might not be causal, established adverse effects of maternal smoking on the fetus already provide a strong and compelling rationale to further strengthen tobacco control efforts. Thus, of particular concern are recent signs of an increasing smoking prevalence among young women in many regions and a continuing high prevalence of tobacco use during pregnancy in most Western countries.¹

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