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# Maternal smoking during pregnancy and child behaviour problems: the Generation R Study

Sabine J Roza; Frank C Verhulst; Vincent WV Jaddoe; Eric AP Steegers; Johan P Mackenbach; Albert Hofman; Henning Tiemeier 

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### Abstract

**Background** Several studies showed that maternal smoking in pregnancy is related to behavioural and emotional disorders in the offspring. It is unclear whether this is a causal association, or can be explained by other smoking-related vulnerability factors for child behavioural problems.

**Methods** Within a population-based birth cohort, both mothers and fathers reported on their smoking habits at several time-points during pregnancy. Behavioural problems were measured with the Child Behavior Checklist in 4680 children at the age of 18 months.

**Results** With adjustment for age and gender only, children of mothers who continued smoking during pregnancy had higher risk of Total Problems [odds ratio (OR) 1.59, 95% confidence interval (CI): 1.21–2.08] and Externalizing problems (OR 1.45, 95% CI: 1.15–1.84), compared with children of mothers who never smoked. Smoking by father when mother did not smoke, was also related

to a higher risk of behavioural problems. The statistical association of parental smoking with behavioural problems was strongly confounded by parental characteristics, chiefly socioeconomic status and parental psychopathology; adjustment for these factors accounted entirely for the effect of both maternal and paternal smoking on child behavioural problems.

**Conclusions** Maternal smoking during pregnancy, as well as paternal smoking, occurs in the context of other factors that place the child at increased developmental risk, but may not be causally related to the child's behaviour. It is essential to include sufficient information on parental psychiatric symptoms in studies exploring the association between pre-natal cigarette smoke exposure and behavioural disorders.

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**Keywords:** [Smoking](#), [maternal exposure](#), [pregnancy](#), [infant behaviour](#), [confounding factors](#)

**Topic:** [pregnancy](#) , [smoking](#) , [emotion](#) , [child](#) , [child behavior](#) , [father](#) , [habits](#) , [mothers](#) , [parent](#) , [psychopathology](#) , [smoke](#) , [socioeconomic factors](#) , [behavior](#) , [gender](#) , [psychiatric symptoms](#) , [behavioral problem](#) , [smoking in pregnancy](#) , [offspring](#)

**Issue Section:** [Intergenerational Influences on Health](#)

## Introduction

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Maternal smoking during pregnancy leads to intrauterine growth restriction, perinatal morbidity and mortality.<sup>1,2</sup> The neurodevelopmental consequences of pre-natal nicotine exposure are, despite a large body of research, less clear. Both direct and indirect effects of products of cigarette smoke on the developing fetal brain have been proposed.<sup>1,3,4</sup> An alternative explanation for the association of pre-natal maternal smoking with neurodevelopment in the offspring centres around the epiphenomenon of smoking, such as parental psychopathology, low socioeconomic status, co-abuse of other substances and poor pre-natal care.<sup>5</sup>

Several methodological problems limit the interpretation of the association between [maternal smoking](#) during pregnancy and offspring behavioural disorders. First, many researchers relied on retrospective assessment of pre-natal smoking, which may induce recall bias and hampers the identification of vulnerability periods during

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to inconclusive findings. Some studies reported significant attenuation, some reported complete erosion, whereas others reported no effect of confounding variables on the association between smoking during pregnancy and offspring behaviour.

One approach to investigate whether maternal smoking during pregnancy has a direct biological effect on behavioural problems or rather is generated by confounding factors is to compare the strength of the association with smoking of fathers and child behaviour. If maternal smoking is causally related to behavioural problems, the association with offspring behaviour should be much stronger for smoking of mothers than for smoking of fathers.<sup>8</sup> To assess whether the association of paternal smoking and behaviour is driven by passive smoking inhalation, it is also important to separate the effect of smoking inside the house from smoking outdoors.

In this study, we examine the hypothesis that parental smoking during pregnancy is related to behavioural problems. We address the following questions: (i) Is there an effect of maternal smoking during pregnancy on the child behavioural problems at the age of 18 months that cannot be explained by confounding variables? and (ii) What are the effects of father's smoking on child behaviour?

## Materials and methods

### Setting

This study was conducted within the Generation R Study, a population-based cohort in Rotterdam, The Netherlands.<sup>9</sup> Enrolment was aimed in early pregnancy. All children were born between April 2002 and January 2006 and form a pre-natally enrolled birth cohort that is currently followed until young adulthood. The study has been approved by the Medical Ethics Committee of the Erasmus Medical Center, Rotterdam. Written informed consent was obtained from all adult participants.

### Study population

In total, 7654 pre-natally included live born children and their mothers were approached for post-natal consent. Children without information on maternal

eligible for the present study. Mothers of 877 children did not give full consent for post-natal participation. Another 1715 mothers did not complete the 18-month questionnaire. Information on child behavioural problems at age 18 months was available in 4680 toddlers (64.4% of 7272). Some mothers participated with two ( $n = 341$ ) or three children ( $n = 5$ ). After random exclusion of these siblings, 4329 children were included in the analyses.

## Maternal smoking during pregnancy

Information about maternal smoking was obtained by questionnaires in the first, second and third trimester. Maternal smoking was categorized into 'never smoked', 'quit smoking before pregnancy', 'quit smoking in first trimester' and 'continued smoking'. In smokers, the number of cigarettes smoked daily was categorized, according to the highest amount reported. Both mothers and fathers were asked on paternal smoking behaviour. We used maternal information on paternal smoking when fathers did not complete this question ( $n = 1104$ ). Furthermore, mothers were asked whether they were exposed to environmental smoke at home in the second and third trimester. We categorized parental active and passive smoking as 'no active or passive smoking', 'father smoked outside, mother did not smoke', 'father smoked indoors, mother did not smoke' and 'mother smoked'.

## Child behavioural and emotional problems

The Child Behavior Checklist for toddlers (CBCL/1½–5) was used to obtain standardized parent reports of children's problem behaviours. The Total Problems score is the sum score of the 99 problem items. The broadband scale Internalizing is the sum score of items in four syndrome scales: Emotionally Reactive, Anxious/Depressed, Somatic Complaints and Withdrawn. Externalizing is the sum score of Attention Problems and Aggressive Behaviour. Each item is scored 0 = not true, 1 = somewhat or sometimes true and 2 = very true or often true, based on the preceding 2 months. Good reliability and validity have been reported for the CBCL.<sup>10</sup>

We used the borderline cut-off score (83rd percentile of a Dutch norm group<sup>11</sup>) to classify children as having behavioural problems in the borderline/clinical range.

Gestational age at birth, birth weight and gender of the infant were obtained from midwife and hospital registries at birth. We classified marital status of the pregnant woman into married/cohabiting vs single. Parents reported on their highest completed education. The child was of non-Dutch origin if one of the parents was born abroad. If both parents were born abroad, the country of birth of the mother decided on the ethnic background. We classified national origin into four categories: (i) Dutch or other Western, (ii) Turkish or Moroccan, (iii) Surinamese or Antillean or (iv) other non-Western. Family income was categorized into <1200 euros, 1200–2000 euros or >2000 euros net a month. To assess maternal and paternal psychopathology in mid-pregnancy, we used the Brief Symptom Inventory, which is a well-validated self-report questionnaire with 53 items covering nine scales of psychiatric symptoms: somatization, obsessive-compulsivity, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation and psychoticism.<sup>12,13</sup> The score on the Global Severity Index (GSI) was standardized. In mid-pregnancy, both parents reported on their delinquent past.

## Statistical analyses

Differences in baseline characteristics between children with and without behavioural problems were compared with the chi-squared statistic, independent *t*-tests and Mann–Whitney U-tests. We used the chi-squared and the Kruskal–Wallis test for comparison of parental characteristics between the different maternal smoking categories. Successive logistic regression models with introduction of a new set of variables are presented to show whether the association between maternal smoking and behavioural problems holds-up when potential confounders are controlled. Interaction terms of maternal smoking with all significant confounding variables were tested and included at  $\alpha = 0.15$ . In addition, we analysed the dose–response relationships of active and passive smoking with child behavioural problems. Measures of association are presented with their 95% confidence intervals (CI). Statistical analyses were carried out with the Statistical Package of Social Sciences version 11.0 for Windows (SPSS Inc, Chicago, IL, USA).

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## Response analyses

On average 115 g (95% CI 95–140,  $t = 8.0$ ,  $P < 0.001$ ) lower birth weight, had shorter gestation [median 39.7 (95% range 34.7–42.3) weeks vs 40.1 (35.6–42.4) weeks,  $P < 0.001$ ] and were less often of Dutch or other Western origin [45% vs 75%,  $\chi^2 = 638(3)$ ,  $P < 0.001$ ] than children with behavioural data. Their mothers were 3.0 (95% CI 2.8–3.3,  $t = 23.6$ ,  $P < 0.001$ ) years younger, lower educated [20.1% primary level vs 5.6% primary level,  $\chi^2 = 744(2)$ ,  $P < 0.001$ ], more often continued smoking during pregnancy [21% vs 13%,  $\chi^2 = 82(3)$ ,  $P < 0.001$ ], and had higher scores on psychopathology [median 0.23 (95% range 0–1.87) vs 0.13 (0–1.19),  $P < 0.001$ ].

## Results

Characteristics of the study subjects are presented in **Table 1**. Children with and without behavioural problems at the age of 18 months differed widely on sociodemographic characteristics. Children within the borderline/clinical range of Total Problems were more often pre-term, had on average lower birth weight, and were more often of non-Western origin than children in the normal range of total problems. Parents of children with behavioural problems were younger and lower educated. A correlation matrix of determinants, outcome and co-variates are available online as [Supplementary data](#).

**Table 1**

Subject characteristics in children with and without behavioural problems at the age of 18 months

	No behavioural problems N = 3886	Borderline or clinical range of Total Problems N = 407	P-value
Male (%)	49.1	53.2	0.07
Gestational age at birth (weeks)	40.1 (35.9–42.4)	40.0 (34.7–42.4)	0.08
Preterm birth <37 weeks (%)	4.4	8.4	0.002
Birth weight (g)	3454 (551)	3330 (584)	<0.001

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	problems <i>N</i> = 3886	Total Problems <i>N</i> = 407	value
Low birth weight <2500 g (%)	4.6	6.9	0.08
<b>National origin</b>			
Dutch/other Western (%)	77.0	46.6	
Turkish/Moroccan (%)	8.8	23.0	
Surinamese/Antillean (%)	7.0	15.4	<0.001
Other non-Western (%)	7.2	14.9	
<b>Maternal education</b>			
Primary (%)	4.7	17.0	
Secondary (%)	37.9	48.7	<0.001
Higher (%)	57.4	34.3	
<b>Paternal education</b>			
Primary (%)	4.6	11.6	
Secondary (%)	35.9	50.8	<0.001
Higher (%)	59.5	37.6	
Maternal age at intake (years)	31.2 (4.5)	29.0 (5.7)	<0.001
Paternal age at intake (years)	33.6 (5.2)	32.5 (6.2)	0.003

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	<b>problems N = 3886</b>	<b>Total Problems N = 407</b>	<b>value</b>
GSI score mother in mid-gestation	0.13 (0–1.13)	0.32 (0.02–1.90)	<0.001
GSI score father in mid-gestation	0.06 (0–0.62)	0.12 (0–0.97)	<0.001

Values are means  $\pm$  SDs for continuous, normally distributed variables, medians (95% range) for continuous non-normally distributed variables and percentages for categorical variables. *P*-values are derived from independent *t*-tests for continuous normally distributed variables, Mann–Whitney U-tests for continuous non-normally distributed variables or chi-squared tests for categorical variables.

**Table 2** compares parental characteristics in the different smoking categories. The overall rates of maternal and paternal smoking during pregnancy were 21.7% of mothers-to-be and 44.6% of fathers-to-be. Mothers who continued smoking during pregnancy had the lowest socioeconomic position, the highest psychopathology scores, were more often single and had more often a delinquent past than non-smokers.

**Table 2**

## Parental characteristics associated with maternal smoking

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	<b>smoked N = 2610</b>	<b>smoking before pregnancy N = 779</b>	<b>smoking in first trimester N = 364</b>	<b>smoking N = 576</b>	<b>statistic (df)</b>	<b>value</b>
Primary (%)	4.6	4.4	3.1	10.5		
Secondary (%)	32.7	37.2	42.5	56.5	124 (6)	<0.001
Higher (%)	62.8	58.4	54.4	33.1		
<b>National origin</b>						
Dutch/other Western (%)	71.8	81.3	81.4	70.1		
Turkish/Moroccan (%)	11.2	7.0	4.6	13.2	65.2 (9)	<0.001
Surinamese/Antillean (%)	7.8	5.1	8.7	10.9		
Other non-Western (%)	9.3	6.6	5.2	5.8		
GSI score mother in mid-gestation	0.13 (0–1.16)	0.13 (0–1.13)	0.15 (0–1.14)	0.23 (0–1.71)	98 (3)	<0.001
GSI score father in mid-gestation	0.06 (0–0.63)	0.06 (0–0.61)	0.06 (0–0.77)	0.08 (0–0.71)	13.6 (3)	0.003
<b>Paternal smoking</b>						
No (%)	67.7	55.9	34.8	18.2		
Outdoor (%)	22.7	32.2	44.9	19.9	990 (6)	<0.001

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	<b>smoked N = 2610</b>	<b>smoking before pregnancy N = 779</b>	<b>smoking in first trimester N = 364</b>	<b>smoking N = 576</b>	<b>statistic (df)</b>	<b>value</b>
Indoors (%)	9.6	11.9	20.3	62.0		
<b>Family net month income (euros)</b>						
<1200	10.8	10.1	12.5	23.7		
1200–2000	14.7	15.1	14.9	23.5	110 (6)	<0.001
>2000	74.4	74.8	72.6	52.8		
Single mother (%)	6.9	8.1	13.1	21.4	119 (3)	<0.001
Delinquent past mother (%)	1.3	2.4	5.0	9.5	117 (3)	<0.001
Delinquent past father (%)	8.0	9.5	16.8	14.7	45 (3)	<0.001

Values are percentages for categorical variables and medians (95% range) for continuous, non-normally distributed psychopathology scores.

Test statistic for categorical variables  $\chi^2$ , and for non-normally distributed continuous variables Kruskal-Wallis.

**Table 3** compares parental characteristics in different categories of paternal smoking. Fathers who smoked inside the house were significantly lower educated, had higher psychopathology scores, were more often of non-Dutch origin, had a lower family income and had more often a history of delinquency than fathers who smoked outside and fathers who did not smoke at all.

**Table 3**

Characteristics associated with father's smoking  
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	<b>smoking N = 2266</b>	<b>outside the house N = 1028</b>	<b>inside the house N = 712</b>	<b>statistic (df)</b>	<b>value</b>
<b>Paternal education</b>					
Primary (%)	3.8	4.9	9.8		
Secondary (%)	30.0	38.8	58.6	196 (4)	<0.001
Higher (%)	66.2	56.3	31.6		
<b>National origin</b>					
Dutch/other Western (%)	76.1	77.4	67.1		
Turkish/Moroccan (%)	8.4	8.3	15.3	53 (6)	<0.001
Surinamese/Antillean (%)	6.9	7.4	11.0		
Other non-Western (%)	8.6	6.9	6.6		
GSI score father in mid-gestation	0.06 (0–0.58)	0.06 (0–0.71)	0.08 (0–0.90)	36 (2)	<0.001
<b>Family net month income (euros)</b>					
<1200	8.4	10.7	23.4		
1200–2000	13.3	15.6	23.1	167 (4)	<0.001
Skip to Main Content >2000	73.3	73.7	53.5		
Delinquent past father (%)	6.8	12.7	17.4	75 (2)	<0.001

Test statistic for categorical variables  $\chi^2$ , and for non-normally distributed continuous variables Kruskal-Wallis.

Next, we examined whether we could identify factors that explain the association between maternal smoking and child behavioural problems ([Table 4](#)). Model 1 shows that children of mothers who continued smoking during pregnancy had a higher risk [odds ratio (OR) 1.6, 95% CI 1.2–2.1] of a borderline/clinical score on Total Problems compared with children of mothers who never smoked. Model 2 introduces national origin. The higher risk of behavioural problems in children of mothers who continued smoking reduced to 1.5 (95% CI 1.2–2.0). Model 3 shows that parental educational attainment and family income reduced the effect of maternal smoking on behavioural problems to an OR of 1.2 (0.9–1.6), which was no longer significant. Finally, we introduced parental psychopathology in Model 4, and showed that these variables in combination accounted entirely for the effect of maternal smoking during pregnancy on child behaviour. Direct inclusion of parental psychopathology into Model 1 reduced the effect of maternal smoking on behavioural problems to an OR of 1.3 (1.0–1.7), but did not account entirely for the effect of maternal smoking. Marital status and parental history of delinquency, although related to maternal smoking, did not further change the effect estimates. Similarly, other potential confounders like maternal alcohol use and breastfeeding did not change the effect estimates of Model 4. Birth weight and gestational age at birth did not mediate the effect of maternal smoking habits on problem behaviour (data not shown).

**Table 4**

## Successive models of the effects of maternal smoking on total behavioural problems

	OR (95% CI)	P- value	OR (95% CI)	P- value	OR (95% CI)	P- value	OR (95% CI)	P- va
Never smoked	Reference		Reference		Reference		Reference	
Quit before pregnancy	0.75 (0.56– 1.03)	0.07	0.83 (0.60– 1.15)	0.26	0.82 (0.59– 1.15)	0.26	0.81 (0.58– 1.13)	0.1
Quit in first trimester	0.86 (0.57– 1.28)	0.45	1.01 (0.67– 1.52)	0.97	0.91 (0.60– 1.38)	0.65	0.89 (0.59– 1.36)	0.6
Continued smoking	1.60 (1.22– 2.10)	0.001	1.54 (1.16– 2.04)	0.003	1.22 (0.90– 1.63)	0.25	1.08 (0.80– 1.47)	0.6
<b>National origin</b>								
Dutch/other Western	–	Reference		Reference		Reference		
Turkish/Moroccan	–	4.11 (3.11– 5.34)		<0.001		2.04 (1.45– 2.87)	<0.001	1.79 (1.26– 2.53)
Surinamese/Antillean	–	3.50 (2.55– 4.82)		<0.001		2.14 (1.51– 3.03)	<0.001	2.10 (1.47– 2.89)
Other non-Western	–	3.41 (2.47– 4.70)		<0.001		2.08 (1.46– 2.97)	<0.001	2.03 (1.42– 2.90)
<b>Maternal education</b>								
Skip to Main Content	Primary	–	–	1.81 (1.20– 2.72)		0.004	1.89 (1.25– 2.86)	0.0

	<b>OR (95% CI)</b>	<b>P- value</b>	<b>OR (95% CI)</b>	<b>P- value</b>	<b>OR (95% CI)</b>	<b>P- value</b>	<b>OR (95% CI)</b>	<b>P- va</b>
Secondary	–		–		1.16 (0.88– 1.53)	0.30	1.12 (0.85– 1.48)	0.4
Higher	–		–		Reference	Reference	Reference	Reference
<b>Paternal education</b>								
Primary	–		–		1.55 (0.92– 2.61)	0.10	1.42 (0.84– 2.41)	0.1
Secondary	–		–		1.52 (1.11– 2.07)	0.01	1.45 (1.05– 1.98)	0.0
Higher	–		–		Reference	Reference	Reference	Reference
<b>Family income (euros)</b>								
<1200	–		–		2.50 (1.78– 3.52)	<0.001	1.96 (1.38– 2.79)	<0
1200–2000	–		–		1.39 (1.00– 1.85)	0.05	1.22 (0.87– 1.71)	0.1
>2000	–		–		Reference	Reference	Reference	Reference
Maternal GSI (per SD)	–		–		–	–	1.31 (1.21– 1.42)	<0

	OR (95% CI)	P- value	OR (95% CI)	P- value	OR (95% CI)	P- value	OR (95% CI)	P- va
Paternal GSI (per SD)	-	-	-	-	-	-	1.13 (1.03– 1.23)	0.1

Model 1 = adjusted for age and gender, Model 2 = as Model 1, additionally adjusted for national origin, Model 3 = as Model 2, additionally adjusted for parental education and family income, Model 4 = as Model 3, additionally adjusted for parental psychiatric symptoms.

Similarly, we examined the relationship of intensity of smoking during pregnancy with a high score on the CBCL Total Problems scale (**Table 5**). In the model which was only adjusted for age and gender, children of mothers who smoked more than nine cigarettes a day had an OR of 1.6 (95% CI 1.1–2.4) for having behavioural problems at the age of 18 months compared with mothers who did not smoke (Model 1). Parental socioeconomic status-related variables and parental psychopathology scores accounted for the higher risk of behavioural problems with all levels of smoking (Models 3 and 4).

**Table 5**

Number of cigarettes per day smoked during pregnancy and offspring's total behavioural problems

<b>Maternal smoking habits</b>	<b>n</b>	<b>Model 1</b>	<b>Model 2</b>	<b>Model 3</b>	<b>Model 4</b>
		<b>OR (95% CI)</b>	<b>OR (95% CI)</b>	<b>OR (95% CI)</b>	<b>OR (95% CI)</b>
None	3365	Reference	Reference	Reference	Reference
<5 cigarettes a day	468	1.28 (0.94– 1.74)	1.26 (0.91– 1.74)	1.10 (0.79– 1.53)	1.00 (0.71– 1.40)
5–9 cigarettes a day	256	1.46 (0.98– 2.16)	1.49 (0.99– 2.24)	1.15 (0.76– 1.76)	1.09 (0.71– 1.67)

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Maternal smoking habits	n	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
>9 cigarettes a day	222	1.61 (1.07–2.43)	1.65 (1.07–2.54)	1.28 (0.82–1.99)	1.19 (0.76–1.87)
P for trend		0.003	0.003	0.21	0.45

Model 1 = adjusted for age and gender. Model 2 = as model 1, additionally adjusted for national origin. Model 3 = as model 2, additionally adjusted for parental education and family income. Model 4 = as model 3, additionally adjusted for parental psychiatric symptoms.

Finally, we present the influence of smoking by father during pregnancy on child behavioural outcome in **Table 6**. Passive smoking of the pregnant woman, due to smoking indoors by father, was related to a higher risk of behavioural problems. The effect of passive smoking was similar to the effect of active smoking (OR of Total Problems with active smoking of the mother as a reference: 0.97 (95% CI 0.66–1.42),  $P = 0.97$ ). When father smoked outside, there was no increased risk of behavioural problems. The OR of Total Problems for children of fathers who smoked indoors was 66% higher (OR 1.66, 95% CI 1.14–2.42,  $P = 0.009$ ) than for children of fathers who smoked outside during pregnancy. Again, parental characteristics explained the effects of parental smoking during pregnancy on behavioural outcome (Model 2 of **Table 6**). Exclusion of fathers with only maternal information on paternal smoking habits did not change the results.

**Table 6**

Associations between parental smoking during mid- and late-pregnancy and child behavioural problems

n	Total problems		Internalizing		Externalizing	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P

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**CBCL broadband scales, associated for age and gender**

	<i>n</i>	OR (95% CI)	<i>P</i>	OR (95% CI)	<i>P</i>	OR (95% CI)	<i>P</i>
No active or passive smoking	2013	Reference		Reference		Reference	
Father smoked outside, mother did not smoke	925	1.17 (0.87– 1.56)	0.30	1.05 (0.76– 1.44)	0.76	1.26 (1.00– 1.60)	0.05
Father smoked indoors, mother did not smoke	383	1.93 (1.37– 2.73)	<0.001	1.74 (1.19– 2.53)	0.004	1.64 (1.21– 2.21)	0.001
Mother smoked	579	2.00 (1.49– 2.87)	<0.001	1.59 (1.14– 2.22)	0.006	1.73 (1.34– 2.23)	<0.001

**Model 2****CBCL broadband scales, fully adjusted**

	<i>n</i>	Reference		Reference		Reference	
No active or passive smoking	2013	Reference		Reference		Reference	
Father smoked outside, mother did not smoke	925	1.19 (0.88– 1.61)	0.27	1.10 (0.79– 1.54)	0.58	1.27 (1.00– 1.62)	0.05
Father smoked indoors, mother did not smoke	383	1.18 (0.81– 1.71)	0.39	1.03 (0.68– 1.57)	0.88	1.25 (0.91– 1.72)	0.17
Mother smoked	579	1.26 (0.91– 1.75)	0.17	1.02 (0.70– 1.47)	0.94	1.28 (0.97– 1.69)	0.08

CBCL Broadband scales were dichotomized using the borderline cut-off score (83rd percentile) of a Dutch norm group.

**Sk** Model 1 is only adjusted for age and gender of the child. Model 2 is additionally adjusted for parental educational level, family income, national origin and parental psychopathology.

Odds ratios of active maternal smoking differ from OR in [Table 3](#), due to a changed reference category.

The present study showed that children of mothers who continued smoking during pregnancy had a higher risk of behavioural problems, compared with children of non-smoking mothers. However, the observed association between maternal smoking during pregnancy and children's behaviour was accounted for entirely by national origin, parental socioeconomic status and parental psychiatric symptoms. In line with this, the dose-response relationship of maternal smoking was explained by parental socioeconomic status and psychopathology as well. Finally, paternal smoking inside the house was associated in a very similar way with behavioural problems as active maternal smoking, which further supports the view that the effect of mother's smoking during pregnancy is not directly causal.

Several reviews suggested small associations between maternal smoking during pregnancy and behavioural problems in the offspring.<sup>5-7,14</sup> However, these reviews also concluded that results are difficult to interpret because of the numerous confounding variables.<sup>5,14</sup> In particular, Linnet *et al.*<sup>6</sup> reported that 'information on parental psychopathology is essential to fully exploring the association between ADHD and exposure to maternal lifestyle factors'. Other main potential confounders in studies of cigarette smoke exposure are, according to these reviews, parental socioeconomic status, home environment, other environmental or personal exposures, child-rearing practices and parental intelligence.<sup>14</sup>

Earlier studies in large ( $n > 1000$ ) population-based samples that prospectively assessed smoking habits of the pregnant women described effects of maternal smoking during pregnancy on externalizing behaviour<sup>15</sup> and hyperactivity<sup>16</sup> in childhood and violent offending in adulthood.<sup>17,18</sup> These studies adjusted the association for socioeconomic status, which, despite reduced risk ratios, did not account for the associations. Very few researchers,<sup>19</sup> described complete attenuation in the association between pre-natal smoke exposure and active behaviour after adjustment for socioeconomic status. Brennan *et al.*<sup>18</sup> and Linnet *et al.*<sup>20</sup> adjusted for psychiatric hospitalization as a proxy of psychopathology, which did not explain the effect of maternal smoking on offspring behaviour, whereas others assessed only one or two specific psychiatric disorders.<sup>7,15,21-25</sup> Although most studies found no complete attenuation of the effect of smoking in pregnancy on behaviour, two studies in large twin samples showed that effect estimates of pre-natal smoking on conduct disorders

the analyses.<sup>22,23,25</sup> Our study shows, by providing both maternal and paternal information on psychiatric symptoms throughout a range of different disorders, that measurement of parental psychopathology is important to interpret the association between pre-natal smoke exposure and behavioural disorders.

Our findings are in line with studies that described confounding in the relationship between maternal smoking in pregnancy and cognitive performance in childhood<sup>26</sup> and adolescence.<sup>27</sup> These studies concluded that the effects of pre-natal cigarette smoke exposure on cognitive function were entirely explained by characteristics of the home environment and maternal cognitive abilities.

Discrepancies in the confounding effects of social class in the studies so far may be the result of varying patterns of tobacco consumption among countries, cultures and time.<sup>28</sup> It is known that health-related behaviours like smoking changed from typical of men in advantaged classes to a higher prevalence in disadvantaged classes. Since women lag 10–20 years behind men, these trends in social inequalities in smoking habits are probably still ongoing.<sup>29</sup> The rates of maternal smoking during pregnancy in our study (21.7%) were similar to recent reports in Finland (16%),<sup>30</sup> Norway (17%),<sup>31</sup> Denmark (29–36%),<sup>30</sup> United Kingdom (21%),<sup>23</sup> Canada (25.1%)<sup>25</sup> and the United States (13–31%).<sup>26,32</sup>

We found that maternal and paternal smoking had very similar effects on child behaviour; effect estimates hardly differed. It is unlikely that this observation is due to the effect of passive smoking, since the effect of environmental tobacco smoke exposure on negative birth outcomes has been reported to be only 25–50% of the effect of active smoking.<sup>33,34</sup> Our finding further strengthens the hypothesis that confounding factors generate the effect of maternal smoking. Fathers who smoke outside the house may take the health of their pregnant partner into account, and thereby create a more favourable environment for their unborn child than fathers who smoked in the same room as their pregnant wives. Indeed, we show that fathers who smoked in the house had different socioeconomic and psychopathological characteristics than those who smoked outside.

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The strength of our study was the assessment of maternal smoking habits during pregnancy at several time-points during pregnancy, which enables identification of

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vulnerability periods more precise. Several limitations need to be discussed as well.

First, selective attrition may have influenced our findings. Children and mothers without information on behavioural outcome differed on both maternal smoking and several important confounding variables. Multiple imputation methods to complete data on the outcome could not be used, since related information on, e.g., temperament at younger ages was not available for children with missing data on the outcome. Therefore, the possibility of biased results due to selective attrition cannot be ruled out. The fact that only 9% of the children in our sample had deviant scores on the CBCL, whereas the cut-off point in a Dutch norm sample was at the 83rd percentile, indicates that our sample is of low risk for behavioural problems and does not represent the general population. The use of self-reports of maternal smoking during pregnancy is a second potential limitation. Another source of reporter bias is the use of parent reports to assess behavioural problems. Parental perception of problems might lead to misclassification, which, in theory, could be related to their smoking habits. Our adjustment for maternal symptoms of psychopathology may capture part of a possible information bias, but only studies using several observers of behaviour can clarify this issue. Related to this, the increased rates of behavioural problems in non-Western children within our sample may reflect observer bias. However, many studies in Western European countries have described increased risks of behavioural problems in immigrant children. As reviewed recently, it is difficult to interpret differences between ethnic groups since the overall impact of migration on mental health in children is complicated by many factors.<sup>35</sup> Furthermore, we assessed child behaviour at the lower age boundary of the CBCL. Further research is needed to evaluate the consequences of parental smoking for behavioural development in later childhood and adolescence. Finally, we may have over-adjusted our associations by controlling for socioeconomic status that may, in part, act as a preceding factor in the association between smoking and behavioural problems.

Our findings provide new information on the phenomenon of maternal smoking during pregnancy in relation to behavioural problems. Parental smoking habits are mainly markers for a set of vulnerabilities for child behavioural and emotional problems. We found no indication that smoking is causally related to behavioural disorders. Notwithstanding our results, it may well be that pre-natal cigarette smoke exposure is related to behavioural problems in the most vulnerable children. Furthermore, there is wide consensus that maternal smoking in pregnancy has

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mortality in the child. These negative effects of pre-natal smoking exposure, as well as the high prevalence of parental smoking, underscore the importance of developing programs aimed at smoking prevention and cessation in pregnant women and their partners. These programs need to be accompanied by assessment of and intervention strategies to vulnerabilities that are highly related to smoking habits, such as parental psychopathology.

## Supplementary data

Supplementary data are available at *IJE* online.

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**Conflict of Interest:** None declared.

## KEY MESSAGES

- The association between maternal smoking during pregnancy and children's behaviour was accounted for entirely by national origin, parental socioeconomic status and parental psychiatric symptoms.
- The effect of father's smoking inside the house was of similar strength as the effect of maternal smoking during pregnancy.

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