

Association between maternal smoking and low birth weight in Switzerland: the EDEN study

Arnaud Chiolerio, Pascal Bovet, Fred Paccaud

Institute of Social and Preventive Medicine, University of Lausanne, Switzerland

Summary

Purpose: To study the association between maternal smoking during pregnancy and low birth weight (LBW), small-for-gestational-age birth weight (SGA) and preterm birth, and to quantify the population-attributable fractions for these outcomes in Switzerland.

Methods: Data were gathered for all births in the Canton of Vaud (Switzerland) over a twelve-month period in 1993–1994. LBW was defined as birth weight <2500 g, SGA as a birth weight <10th percentile for gestational age, and preterm birth as a birth occurring at a gestational age <37 weeks. Maternal smoking before and during pregnancy was recorded.

Results: Of a total of 6284 singleton births, 303 (4.8%) were LBW, 731 (11.7%) were SGA, and 364 (5.8%) were preterm. 19.1% of the mothers reported smoking during pregnancy (“smokers”). Mean birth weight, adjusted for maternal age, parity, parents’ occupation and neonates’ sex and na-

tional, was lower by 190 g (95% confidence interval: 150–220) in babies of smokers than those of non-smokers. Comparing smokers to non-smokers, the adjusted odds ratios were 2.7 (2.1–3.5) for LBW, 2.1 (1.7–2.5) for SGA and 1.4 (1.1–1.9) for preterm birth. Past smoking was not associated with the outcomes. Maternal smoking during pregnancy accounted for 22% (15–29%) of all LBW babies in the population, 14% (10–18%) of SGA and 7% (1–12%) of preterm births.

Conclusion: Maternal smoking during pregnancy was closely associated with LBW, SGA and preterm birth. A large proportion of these perinatal outcomes could have been prevented in Switzerland if maternal smoking had been avoided.

Key words: low birth weight; preterm; small for gestational age; maternal smoking; population attributable fraction

Introduction

Low birth weight (LBW), small-for-gestational-age birth weight (SGA), premature birth or a combination of these outcomes are closely related to neonatal and long-term morbidity [1, 2]. Preterm birth accounts for a large proportion of early neonatal deaths [3, 4]. It is also increasingly recognised that SGA increases the risk of developing chronic diseases in adulthood, such as hypertension, type-2 diabetes and coronary heart disease [5, 6].

Cigarette smoking during pregnancy is a strong dose-dependent risk factor for LBW [7–9]. Maternal smoking also increases the risk of preterm birth [4, 7], although it appears to affect foetal growth more than gestational duration [3].

To our knowledge, the relationship between maternal smoking and LBW, SGA and preterm birth has not been studied yet at population level in Switzerland. This issue has important clinical and public health implications in view of the high prevalence of smoking among women of child-bearing age in Switzerland [10] and the severe adverse effects of maternal smoking on the health of newborns.

We therefore studied the relationship between maternal smoking and LBW, SGA and preterm birth in a survey of all births in the Canton of Vaud in the period 1993–1994. We estimated the proportion of these outcomes which could have been prevented if maternal smoking had been avoided.

Conflict of interest: none. The EDEN study was supported by the Service des Hospices Cantonaux, Lausanne (Grant No. 4002).

Methods

This study uses data from a survey of all births in the Canton of Vaud (Switzerland) conducted in the period 1993–1994, aimed at recruiting a population-based cohort of newborns at high risk of chronic conditions (the EDEN study, Etude du Développement des Nouveau-nés). The methods and subjects have been described previously [11]. Briefly, data were gathered for all live births to mothers residing in the Canton of Vaud between 1 October 1993 and 30 September 1994. Data were collected in all of the canton's maternity hospitals plus one outside the canton widely attended by residents of the Canton of Vaud. Out of a total of 19 districts in the canton, two peripheral districts (Nyon and Avenches) were excluded since a large proportion of their residents receive obstetric care outside the canton. In 1993 the population corresponding to the 17 districts considered was 534 849. Births at home were not included (0.5% of all live births in Vaud in 1993).

Sex and weight of the children and parity and age of the mothers were extracted from birth certificates. At the time of the mothers'/newborns' hospitalisation midwives completed a structured questionnaire on the mother's smoking habits, both parents' occupation and nationality, and the obstetrician's estimation of gestational age at the time of delivery. This estimation was based on the first day of the last menstrual period and/or early ultrasound examination which was commonly performed in Switzerland at that time. Most women had early prenatal care. Midwives asked mothers about their smoking habits before pregnancy and during the first, second and third trimesters of pregnancy. Maternal smoking during pregnancy (smoker) was defined as smoking at any time during any of the 3 trimesters. The mean number of cigarettes smoked per day during pregnancy was calculated as the average of the numbers reported for each trimester. Among smokers, women who quit smoking after the first or the second trimester were defined as quitters. No woman began smoking during pregnancy. Mothers who stopped smoking before pregnancy were classified as ex-smokers.

Three outcomes were considered: (1) low birth weight (LBW) defined as a birth weight <2500 g [7]; (2) small-for-gestational-age (SGA), defined as a birth weight below the sex-specific 10th percentile of weight for gesta-

tional age [12]; and (3) preterm birth defined as a birth occurring at a gestational age of <37 weeks [3]. Four job categories were defined on the basis of the more highly qualified occupation between mother and father: (1) unskilled worker; (2) skilled worker; (3) senior executive, manager; (4) other. This was considered as a socioeconomic status indicator. Neonates were considered to be Swiss if at least one of the parents had Swiss nationality.

Logistic regression was used to identify independent predictors of dichotomous outcomes (LBW, SGA and preterm birth). Smoking habits were assessed on the basis of either a dichotomised variable (smokers vs. the combination of ex-smokers and non-smokers) or smoking frequency categories. Multivariate analyses were adjusted for maternal age, parity, occupation and child's sex and nationality. Interactions between maternal age and smoking were studied [13]. Crude mean birth weight was reported for each smoking category. Differences in birth weight between smoking categories adjusted for maternal age, parity, occupation of the parents and sex and nationality of the neonates were reported.

We calculated the proportions and 95% confidence intervals (95% CI) of, respectively, cases of LBW, SGA and preterm birth attributable to smoking among pregnant smokers [14]. These "attributable fractions among exposed" or "aetiological fractions" are computed as $(RR-1)/RR$, where RR is the risk ratio approximated to the odds ratio (OR) obtained from multiple logistic regression. We also calculated the proportions of cases of, respectively, LBW, SGA and preterm birth attributable to smoking among all pregnant women. These "population attributable fractions" (PAF) are traditionally computed as $P(RR-1)/[1+P(RR-1)]$, where P is the proportion of pregnant smokers [14, 15]. For RR we used the adjusted odds ratio estimated from multivariate logistic regression and confidence intervals were based on asymptotic approximation [15]. PAF is the proportion of cases in the entire population which would be prevented if maternal smoking were avoided [16]. Attributable fractions assume that smoking is related causally to the outcomes. Analyses were performed with Stata 8.0.

Results

Between 1 October 1993 and 30 September 1994, 6497 newborns were delivered in the study area (20 stillbirths and 6477 liveborn infants, from 6379 pregnancies). In this study we used data on singleton births ($n = 6284$) (table 1). The mean maternal age was 29.5 years (SD: ± 4.5 ; median: 29; inter-quartile range (IQR): 26–32).

24% of mothers had smoked before pregnancy. 5% of mothers stopped smoking before pregnancy ("ex-smokers"). Thus 19.1% of mothers smoked during pregnancy ("smokers"), smoking a mean of 10.3 cigarettes per day (SD: ± 7.2 ; median: 10; IQR: 5–15).

Mean birth weight was 3300 g (SD: ± 500 ; median: 3310; IQR: 3020–3610). LBW was found in 303 neonates (4.8%). 731 neonates were SGA (11.4%). The mean gestational age was 39.0 completed weeks (SD: ± 1.7 ; median: 39; IQR: 38–40)

and 364 neonates were preterm (5.8%). 166 neonates were both LBW and preterm (2.7%), and 35 (0.6%) were both SGA and preterm.

The proportions of LBW, SGA and preterm birth in relation to selected maternal or neonatal characteristics are shown in table 2. LBW and preterm birth were more frequent in infants of older mothers. Nulliparous women had LBW, SGA or preterm babies more frequently. An unskilled occupation tended to be associated with all the outcomes, especially for SGA. Female gender of the baby was associated with LBW. Gestational age was the strongest risk factor for LBW.

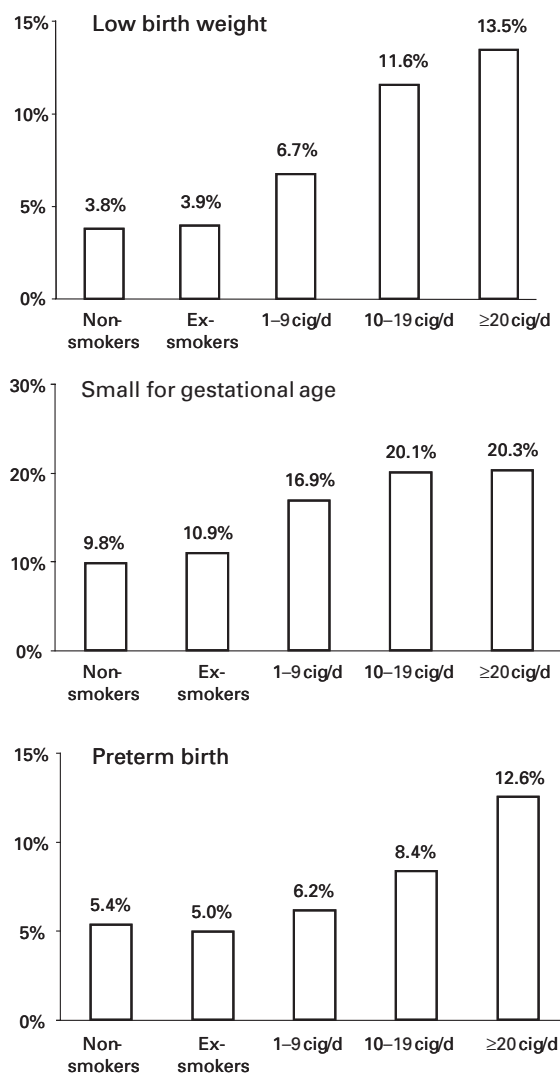
The proportions of LBW, SGA and preterm birth were lower in babies from non-smokers than from those of smokers (table 3). There was a dose-response relationship between the number of cigarettes smoked and all the outcomes, particularly

Table 1

Characteristics of mothers and neonates (n = 6284).

Mother	Age (years)	n	%
	<25	818	13.0
	25–29	2426	38.6
	30–34	2175	34.6
	≥35	865	13.8
Parity			
	First baby	2974	47.3
	Second or more	3310	52.7
More qualified occupation of one parent			
	Unskilled worker	1248	20.8
	Skilled worker	3099	51.8
	Senior executive, manager	1055	17.6
	Other	584	9.8
Smoking habits			
	Non-smoker	4656	75.9
	Ex-smoker	305	5.0
	Smoker	1170	19.1
	1–9 cigarettes/day	505	8.8
	10–19 cigarettes/day	398	6.6
	≥20 cigarettes/day	208	3.4
Neonate			
Sex			
	Boy	3254	51.8
	Girl	3030	48.2
Nationality			
	Swiss	4260	68.1
	Foreign	1996	31.9
Birth weight (g)			
	<2500	303	4.8
	≥2500	5981	95.2
Gestational age (week)			
	<37 (preterm)	364	5.8
	37–38	1581	25.3
	39–40	3595	57.5
	≥41	713	11.4
Small for gestational age (SGA)			
	Yes	731	11.7
	No	5522	88.3

LBW (figure 1). Mean birth weight was 3340 g (3320–3350) in infants of non-smokers, compared to 3140 g (3110–3170) in those of smokers. This corresponded to a difference in birth weight, adjusted for maternal age, parity, parents' occupation and sex and nationality of the neonates, of 190 g (150–220). Mean birth weight was 3200 g (3150–3250), 3100 g (3050–3150) and 3060 g (2990–3130) in infants of women smoking 1–9, 10–19, and ≥20 cigarettes per day respectively. Compared with non-smokers, this corresponded to an adjusted difference in birth weight of 120 g (70–160), 240 g (190–290) and 290 g (220–360) respectively. Babies of ex-smokers (3340 g; 3280–3390) had similar weight to those of non-smokers. Among smokers, 58 quit smoking during pregnancy (“quitters”), i.e. 39 after the first trimester and 19 after the second. Birth weight

**Figure 1**

Proportions of infants with low birth weight, small weight for gestational age or born prematurely across categories of maternal smoking.

of babies of quitters tended to be slightly higher (3180 g; 3020–3340) than that of those whose mothers smoked throughout pregnancy (3140 g; 3110–3170). Removing quitters from the smokers did not significantly change our results.

Smoking during pregnancy was associated independently with each of the outcomes considered (table 3). The odds for the outcomes considered increased across rising categories of cigarette consumption (table 4). Smoking 1–9 cigarettes per day was significantly associated with LBW and SGA, but not with preterm birth. Smoking ≥10 cigarettes per day was associated with the three outcomes, particularly LBW. Past smoking was not associated with the outcomes. No significant interaction was found between maternal age and smoking.

Smoking accounted for about half of LBW and SGA and for more than a quarter of preterm births among women who smoked during pregnancy (table 3). Among all pregnant women (smokers, ex-smokers and non-smokers), the proportions of cases ascribable to smoking (population attributable fraction) were respectively 22% (15–29%) for LBW, 14% (10–18%) for SGA and 7% (1–12%) for preterm birth.

Table 2

Proportions (%) of infants with low birth weight, small weight for gestational age and born prematurely across categories of selected variables.

		Low birth weight	Small for gestational age	Preterm birth
Mother	Age (years)			
	<25	4.3	12.7	4.4
	25–29	4.7	12.0	4.5
	30–34	4.9	11.6	4.0
	≥35	5.4	9.9	6.6
	Parity			
	First baby	5.9	14.8	5.3
	Second or more	3.9	8.9	4.0
	More qualified occupation of one parent			
	Unskilled worker	5.1	13.4	4.7
	Skilled worker	4.7	11.4	4.5
	Senior executive, manager	4.2	9.3	4.8
	Other	5.0	11.9	3.8
Neonate	Sex			
	Boy	4.0	11.8	4.8
	Girl	5.7	11.6	4.4
	Nationality			
	Swiss	4.8	11.7	4.5
	Foreign	4.6	11.8	4.6
	Gestational age (weeks)			
	≥41	0.6	10.4	–
	39–40	1.1	12.5	–
	37–38	5.9	11.0	–
<37 (preterm)	45.6	9.6	–	

Table 3

Proportions of infants with low birth weight, small weight for gestational age or born prematurely attributable to maternal smoking during pregnancy.

	Proportion among		OR (CI*)	Attributable fraction among smokers (CI*)	Population attributable fraction (CI*)
	non- or ex-smokers (n = 4961)	smokers (n = 1170)			
Low birth weight	3.9%	10.7%	2.7 ^a (2.1–3.5)	63% (51–71%)	22% (15–29%)
Small for gestational age	9.9%	18.8%	2.1 ^a (1.7–2.5)	52% (42–60%)	14% (10–18%)
Preterm birth	5.3%	8.1%	1.4 ^a (1.1–2.9)	30% (9–46%)	7% (1–12%)

OR: odds ratio (smokers vs. non- or ex-smokers); 95% confidence interval* are indicated in parentheses.

^a adjusted for maternal age, parity, sex, occupation, and nationality.

Table 4

Association (odds ratio and 95% confidence interval*) between categories of maternal smoking and low birth weight, small for gestational age or preterm birth.

	Low birth weight OR (CI*)	Small for gestational age OR (CI*)	Preterm birth OR (CI*)
Non-smoker	1	1	1
Ex-smoker	0.9 (0.5–1.7)	1.1 (0.7–1.6)	0.9 (0.5–1.5)
1–9 cigarettes/day	1.7 (1.2–2.6)	1.9 (1.5–2.5)	1.0 (0.7–1.6)
10–19 cigarettes/day	3.5 (2.4–5.0)	2.2 (1.7–2.9)	1.5 (1.0–2.3)
≥20 cigarettes/day	4.0 (2.5–6.3)	2.4 (1.7–3.5)	2.4 (1.5–3.9)

All odds ratios are adjusted for maternal age, parity, sex, occupation, and nationality.

Discussion

Our study confirms the detrimental effects on birth weight of smoking during pregnancy: maternal smoking was associated with a greatly increased risk of LBW, SGA and, to a lesser extent, preterm birth. The magnitude of these hazards coupled with a high prevalence of smoking among pregnant women underlie the large proportion of infants with a low birth weight or born prematurely, with the related disease burden, which could have been avoided if smoking during pregnancy had been avoided.

Close associations between maternal smoking and these perinatal outcomes have been repeatedly reported [3, 7, 8, 17, 18]. In a comprehensive review of the risk factors for LBW, birth weight was 149 g lower in children of smoking mothers [7], which is consistent with the 190 g found in our study. In this review, maternal smoking increased the risk of SGA by 2.4 (vs. 2.1 in our study) and preterm birth by 1.4 (vs. 1.4 in our study) [7].

Smoking after the fourth month appears to be particularly crucial in lowering birth weight [7]. In our study, infants' birth weight tended to be slightly higher in women who quit smoking during pregnancy than in those who did not. The small number of quitters did not allow us to analyse this issue in more detail. It may partly relate to our inability to distinguish between women who quit before pregnancy and those who did so during the first trimester.

Our estimates suggest that eliminating smoking during pregnancy (all other risk factors being unchanged) would have avoided more than one fifth of all LBW, one seventh of all SGA and one out of 13 of all preterm births in the population (table 3). This would correspond to 67 (95% CI: 45-86) infants with LBW, 103 (73-131) with SGA and 25 (4-45) preterm births avoided in one year among the half-million population considered. In Switzerland, according to the Swiss Federal Office of Statistics, an average of 4400 babies with LBW were born in 1993/94. Assuming the same risk ratios and smoking prevalence in Switzerland as in the Canton of Vaud, eliminating smoking in pregnant women in Switzerland would have avoided some 1000 LBW babies for that period. These population-attributable fractions/numbers depend directly on the prevalence of smoking in pregnant women, a prevalence not assessed recently in Switzerland, but which in women of child-bearing age (15-44 years) was 28% in 2002 [10]. In the present study, data were gathered in 1993-94 and 24% of women had smoked before pregnancy. Hence the number of babies with LBW attributable to smoking is probably just as high now as ten years ago. This estimate does not account for factors that may have changed in the meantime, e.g. maternal age at delivery has increased and, in addition, a larger proportion of very-low birth weight/premature are currently born alive.

The risk of the three outcomes considered increased with the number of cigarettes smoked daily. However, for LBW and SGA, the association was not largely different for heavy smokers as compared to moderate smokers, suggesting a plateau. Actually, in previous studies, a difference in risk between heavy and light smokers was consistently reported [19], but the relationship was not necessarily linear when relating either LBW or preterm delivery to more than two smoking categories [19]. In our study the apparent attenuation of the relationship to rising smoking categories may relate to a social desirability bias whereby some heavy-smoker pregnant women may underreport their smoking and be classified as moderate smokers.

Our study has limitations. We did not have data on maternal weight and maternal drinking. These two factors could potentially confound the relation of maternal smoking to birth weight since they are associated with both birth weight and maternal smoking [3, 20-22]. However, the impact of these potential biases is likely to be limited in our study. First, the independent effect of low maternal weight on birth weight is limited, since low maternal weight is partly a consequence of smoking. In addition, pathologically low maternal weight (undernutrition) is rarely encountered in Switzerland [10]. Similarly, the prevalence of heavy drinking is low among women in Switzerland [10], and probably more so in pregnant women. Our estimate of the PAF may be slightly overestimated, particularly for SGA, since we used the odds ratio as an approximation of the relative risk and the relative risk tends to be closer to the independent value of one compared to the odds ratio.

Our estimation of socioeconomic status was limited to the parents' occupation since we did not have information on parents' income or education and some residual confounding can therefore not be ruled out [23]. On the other hand, several factors support the validity of our results: the population-based design of our study, the large sample size, and the similar magnitude of our effect estimates to other studies.

These findings further stress the need for appropriate policy and programmes aimed at reducing tobacco use among pregnant women, including the systematic and effective integration of smoking cessation counselling and treatment in clinical practice [24].

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Correspondence:

Arnaud Chiolero, M.D.

Institute of Social and Preventive Medicine,

17, rue du Bugnon

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