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Weight growth in infants born to mothers who smoked during pregnancy

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Abstract

Objective—To determine whether maternal smoking during pregnancy causes impairment in growth after birth.

Design—Longitudinal study.

Setting—Six medical university centres of six towns of north, central, and south Italy.

Subjects—12 987 babies (10 238 born from non-smoking mothers, 2276 from mothers smoking one to nine cigarettes a day, and 473 from mothers smoking ≥ 10 cigarettes a day) entered the study.

Main outcome measures—Difference in weight gain between children born to smoking mothers and those born to non-smoking mothers. Weight was measured at birth and at 3 and 6 months of age. Maternal smoking habit was derived from interview on third or fourth day after delivery.

Results—Compared with children born to mothers who did not smoke during pregnancy, the birth weights of children born to mothers who smoked up to nine cigarettes a day were 88 g (girls) and 107 g (boys) lower; in children born to mothers who smoked ≥ 10 cigarettes a day weights were 168 g and 247 g lower. At six months of age for the first group the mean weight for girls was 9 g (95% confidence interval -47 g to 65 g) higher and for boys 64 g (-118 g to -10 g) lower than that of children born to mothers who did not smoke. The corresponding figures for the second group were 28 g (-141 g to 85 g) lower for girls and 24 g (-136 g to 88 g) lower for boys.

Conclusions—The deficits of weight at birth in children born to mothers who smoked during pregnancy are overcome by 6 months of age. These deficits are probably not permanent when smoking habit during pregnancy is not associated with other unfavourable variables (such as lower socio-economic class).

Introduction

A causal relation between smoking in pregnancy and birth weight is generally accepted. Mothers who smoke during pregnancy generally deliver infants weighing from 100 g to 300 g less than children born to non-smoking mothers.^{1,2} A dose-effect relation between number of cigarettes smoked by a pregnant woman and her infant's weight has been shown, whereas there are

no differences in weight between babies born to women who never smoked during their lives and those who quit smoking only during pregnancy.^{1,3,5} Limited data on the follow up of children born to mothers who smoke suggest that the deficits at birth may remain in childhood and possibly even into adulthood.^{3,6,7} Almost all these data, however, were collected on small samples in the early 1970s in the United States and the United Kingdom, where smoking habit was often associated with poor social class and lower educational level. Furthermore this long term effect has not been found by other authors.^{8,9} The issue of maternal smoking during pregnancy and child development thus remains controversial.

We evaluated weight gain in the first six months of life of babies born to mothers who smoked during pregnancy.

Subjects and methods

SUBJECTS

Data reported here were obtained from a large nationwide multicentre obstetric-paediatric survey carried out in Italy between 1973 and 1981 supported by the Consiglio Nazionale delle Ricerche (CNR).¹⁰⁻¹² The survey consisted of a cross sectional part at birth and a longitudinal part up to the third birthday. Babies were born in six university medical centres of six towns of north, central, and south Italy. Some of these centres were referring centres for pregnancies at risk, and high risk infants were therefore systematically oversampled. The longitudinal survey collected data on about 60% of children whose mothers turned up for at least one visit among the eight planned. Information on smoking and sociodemographic characteristics of the mothers was obtained by interview on the third or fourth day after delivery.

In this study only singleton babies without congenital malformations for whom information on maternal smoking habit and weight growth was available were considered. Babies born to mothers who quit smoking during pregnancy (2464) were excluded from this study. Birth weight and weight growth in these babies were the same as those of babies born from non-smoking mothers. In total, 12 972 babies (6193 girls and 6779 boys) who were followed up at 3 and 6 months and 15 (11 girls and four boys) who had only birth weight (two) or birth weight and weight at 6 months

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(one) or birth weight and weight at 3 months (12) entered the study.

VARIABLES CONSIDERED

Socioeconomic index—The socioeconomic classification comprised six groups. The classes allow for both parents' educational level and occupation as well as for two indices of housing quality (density and availability of toilet)¹³; the first group represents the best condition of living, the sixth the worst.

Parity—Two categories were considered: no previous delivery and one or more previous deliveries.

Maternal age comprised two categories: <35 years and ≥35 years.

Gestational age was computed in completed weeks from the first day of the last menstrual period as <37 weeks and ≥37 weeks.

Mother's smoking habit comprised three categories: non-smokers; one to nine cigarettes a day (light smokers), and ≥10 cigarettes a day (heavy smokers).

Weight was registered and recorded to the nearest 10 g at birth and to the nearest 100 g at 3 and 6 months, as routinely done.

These criteria were used by all centres to classify the variables. The variability of distribution of socioeconomic class and smoking habit in the different centres reflects the local situation in the different areas in Italy¹³; the relation between socioeconomic class and mother's smoking habit was similar in all centres, so all subjects were evaluated as one group.

The data set of the cross sectional study concerning the relation between smoking during pregnancy and weight at birth¹² showed that 34% of mothers were smokers before pregnancy and 3% smoked more than 20 cigarettes a day; as a comparison, data reported by the Italian Institute for Statistics (ISTAT) in a nationwide study for all women in 1980 showed a lower percentage of smokers (19%) and the same proportion of heavy smokers.¹⁴ The difference in our sample may be explained by the larger proportion of women living in urban areas and the younger age of subjects enrolled in our study.

In our sample smoking before pregnancy was more common among younger mothers and in mothers belonging to the upper social classes; interestingly, 48% of women who smoked quit smoking during pregnancy and another 43% reduced the number of cigarettes smoked per day. This trend was more pronounced in women with a higher level of education

(higher socioeconomic index) or with a non-smoking partner.

Overall, babies born to mothers who smoked had a reduced weight at birth, a higher proportion of subjects with birth weight lower than 2500 g, or head circumference below the 10th centile. No differences for rate of prematurity or perinatal mortality were noticed between babies born to smoking or non-smoking mothers.⁵

ANALYSIS

All the analyses were carried out separately for boys and girls. Firstly, univariate and bivariate analyses was carried out to describe the relation between mother's smoking habit, baby's weight, and the other covariates.

To consider all the different aspects together, a multivariate analysis of the variance was carried out. Three measures of baby's weight (at birth, 3 months, and 6 months) were considered as the response variable. In the final model (in both sexes) variables considered were mother's smoking habit, parity, and gestational age.

This statistical model gives a description of both differences noticed at birth and at 6 months and different growth rate up to 6 months in babies born to smoking mothers or non-smoking mothers with all the variables considered at the same time. Dose-effect trend was evaluated separately for light smokers and for heavy smokers. Multivariate analysis of the variance (MANOVA) was computed by the generalised linear interactive modelling procedure of the sas package (version 6.04). Results were tested with Wilk's λ.

Results

Table I shows the relation between socioeconomic index and mother's smoking habit during pregnancy. Smoking habit was more common in the upper classes, whereas the percentage of heavy smokers was independent of the socioeconomic class. Most subjects belonged to intermediate classes (groups 3 and 4). Table II shows the comparison at birth and at 3 and 6 months of age of the mean weight in each group of children born to non-smoking mothers and children born to mothers smoking up to nine or ≥10 cigarettes a day. No differences were seen between mean and median weights, and thus mean weights only are reported. The mean birth weight of children of non-smoking mothers was 3220 g for girls and 3373 g for boys. In children born to light smokers these weights were reduced by 88 g and 107 g, respectively; the reduction was higher in children born to heavy smokers (168 g for girls and 247 g for boys). As shown in table II, however, differences in weight observed at birth had decreased by 3 or 6 months of age. As a result of the weight gain the mean weight difference in the group of children born to light smokers, which at birth was -2.7% for girls and -3.2% for boys, became +0.1% and -0.8% at six months for girls and boys,

TABLE I—Smoking habit during pregnancy according to social class. Figures are numbers (percentages)

Socioeconomic class	Non-smokers	Light smokers (≤9 cigarettes/day)	Heavy smokers (≥10 cigarettes/day)	Total No
1 (highest)	1802 (76.3)	477 (20.2)	83 (3.5)	2362
2	1331 (77.0)	338 (19.5)	60 (3.5)	1729
3	3145 (78.8)	703 (17.6)	144 (3.6)	3996
4	2735 (82.6)	487 (14.4)	107 (3.2)	3389
5	255 (85.0)	37 (12.3)	8 (2.7)	300
6 (lowest)	119 (86.9)	13 (9.5)	5 (3.6)	137

TABLE II—Mean weight at birth and at 3 and 6 months of age in children born to mothers with different smoking habit in pregnancy, and weight differences in respect of babies born to non-smoking mothers

Mother's smoking habit	At birth			At 3 months			At 6 months		
	No	Weight	95% Confidence interval for difference	No	Weight	95% Confidence interval for difference	No	Weight	95% Confidence interval for difference
Girls:									
Non-smokers	4904	3220		4904	5584		4895	7462	
1-9 Cigarettes/day	1072	3132	(-121 to -55)	1071	5550	(-77 to 9)	1072	7471	(-47 to 65)
≥10 Cigarettes/day	228	3052	(-234 to -102)	228	5519	(-152 to 22)	227	7434	(-141 to 85)
Boys:									
Non smokers	5334	3373		5332	6026		5330	8038	
1-9 Cigarettes/day	1204	3266	(-139 to -75)	1204	5958	(-113 to -23)	1204	7974	(-118 to -10)
≥10 Cigarettes/day	245	3126	(-312 to -181)	245	5907	(-212 to -26)	245	8014	(-136 to 88)

TABLE III—Mean weight (95% confidence interval) at birth and at 3 and 6 months of age in children born to mothers with different smoking habit in pregnancy and weight differences in respect of babies born from non-smoking mothers subdivided in groups according to gestational age and parity

Detail	Gestational age < 37 weeks			Gestational age ≥ 37 weeks		
	Non-smokers	Light smokers	Heavy smokers	Non-smokers	Light smokers	Heavy smokers
Girls:						
Mother's parity = 0						
No born	202	54	11	2482	624	108
Weight of infant (g):						
At birth	2557	-42 (-220 to 136)	-271 (-631 to 89)	3244	-88 (-124 to -52)	-118 (-197 to -38)
At 3 months	5078	35 (-175 to 245)	-333 (-763 to 97)	5611	-22 (76 to 32)	-89 (-207 to 29)
At 6 months	7090	34 (-227 to 295)	-135 (-664 to 394)	7490	13 (-54 to 80)	-20 (-168 to 129)
Mother's parity ≥ 1						
No born	222	28	12	1936	350	94
Weight of infant (g):						
At birth	2558	17 (-213 to 247)	-53 (-391 to 285)	3330	-104 (-156 to -52)	-207 (-300 to -114)
At 3 months	5032	111 (-198 to 420)	226 (-241 to 693)	5654	-78 (-151 to -5)	-16 (-148 to 116)
At 6 months	7073	-9 (-358 to 340)	277 (-248 to 802)	7514	-10 (-104 to 84)	-61 (-230 to 108)
Boys:						
Mother's parity = 0						
No born	242	61	14	2700	710	120
Weight of infant (g):						
At birth	2736	-41 (-195 to 113)	-185 (-470 to 100)	3382	-88 (-125 to -51)	-261 (-343 to -179)
At 3 months	5569	-59 (-297 to 179)	-33 (-486 to 420)	6044	-60 (-115 to -5)	-135 (-259 to -11)
At 6 months	7684	97 (-344 to 150)	-248 (-724 to 228)	8055	-44 (-113 to -25)	22 (-132 to 176)
Mother's parity ≥ 1						
No born	250	29	14	2061	384	95
Weight of infant (g):						
At birth	2777	-245 (-482 to -8)	-81 (-408 to 246)	3508	-136 (-187 to -85)	-228 (-325 to -131)
At 3 months	5584	-436 (-765 to 107)	-334 (-793 to 125)	6120	-55 (-131 to 21)	-71 (-216 to 74)
At 6 months	7691	-360 (-718 to 2)	-377 (-885 to 131)	8114	-47 (-139 to 45)	-8 (-184 to 168)

respectively. Likewise in the group of children born to heavy smokers the difference was reduced from -5% in girls and -7.3% in boys at birth to -0.4% and -0.3% at 6 months.

To investigate confounding effects on weight growth in the first six months of life we considered for each sex the following variables: age of the mother, parity, and gestational age. Sixteen subgroups were identified accordingly. In this data set social class was not associated with a difference in weight between 0 and 6 months in children, as already reported,¹¹ and thus it was not considered as a confounding variable. Table III shows for each subgroup the number and mean weights at 0, 3, and 6 months of children born to non-smoking mothers and weight differences with confidence intervals in children with mothers smoking up to 9 or ≥ 10 cigarettes a day. In almost all the subgroups the deficits of weight at birth in children of smoking mothers were overcome. Only in the subgroups of boys with gestational age < 37 weeks (very few subjects) was weight recovery not evident.

The influence of mothers' smoking habit on children's growth was investigated with a multivariate model of the variance. The final model considered weight as the dependent variable and mother's smoking habit, parity, and gestational age as independent variables. Analysis was done in three steps to give the following results. Firstly, mean weight at birth in children with smoking mothers or non-smoking mothers was significantly different ($P < 0.0001$ by Wilk's λ). Secondly, mean weights at 6 months between children with smoking mothers or non-smoking mothers were not significantly different. Thirdly, the difference in speed of growth from 0 to 6 months between children with smoking mothers and non-smoking mothers was significant ($P < 0.0001$ by

Wilk's λ)—that is, babies born to smoking mothers have a greater rate of growth in the first six months. These findings were the same in both sexes. These results were confirmed in each step by the contrasts between smoking and non-smoking mothers and between non-smoking and heavy smoking mothers. Table IV gives the estimated differences (95% confidence intervals) of mean weights of children with non-smoking mothers in respect of children with smoking mothers and of children with mothers smoking ≥ 10 cigarettes a day (subdivided by sex and age).

Discussion

Data reported by Sexton and Hebel² and Fox *et al*⁶ suggest that deficits of weight at birth in children born to mothers who smoke during pregnancy may remain throughout life. The number of children entered in their studies, however, was relatively small and the comparison was actually between smoking mothers who quit (188 subjects) or did not quit smoking (526 subjects) during pregnancy. Children from smoking mothers had a weight reduction of 92 g at birth and of 450 g at age three years, suggesting that the deficits associated with maternal smoking may not be overcome by 3 years of age.⁶ Difference in weight at 3 years, however, was significant only when other variables such as birth weight, household variables, or length of gestation, had not been adjusted for, and thus weight at 3 years could be more related to these variables than to smoking in pregnancy.² In other studies in Finland and England children of smokers were found to be shorter and with poorer academic ability.^{3,4} In these studies smoking habit was associated with poorer socioeconomic factors.

In contrast with these results Barr *et al* found that in a small sample of primarily white, married, and well educated mothers in the United States maternal smoking during pregnancy was not significantly related to infant size (weight, height, and head circumference) at 8 months, although nicotine use was highly related to the birth size.⁸

The social context of our study was quite different from those mentioned. In the 1970s in Italy the highest prevalence of smoking was in women with high school diploma or university degree.^{12,14} This association was observed in our sample too (table I). In keeping with

TABLE IV—Estimated weight differences (95% confidence interval) of babies with non-smoking mother by MANOVA statistical model

Mother's smoking habit	Weight difference		
	At birth	At 3 months	At 6 months
Girls born to:			
Non-smokers v smokers	-257** (-319 to -181)	-76 (-188 to 9)	-50 (-136 to 121)
Non-smokers v heavy smokers	-172** (-222 to -103)	-55 (-141 to 30)	-55 (-129 to 93)
Boys born to:			
Non-smokers v smokers	-335** (-408 to -269)	-153** (-285 to -78)	-62 (-218 to 37)
Non-smokers v heavy smokers	-231** (-293 to -173)	-97* (-204 to -24)	-17 (-135 to 86)

** = $P < 0.01$.

* = $0.01 < P < 0.05$.

Key messages

- Smoking habit during pregnancy is associated with lower birth weight
- The issue of weight growth in babies born to smoking mothers remains controversial
- Data obtained in this study confirm the association of smoking during pregnancy with lower birth weight
- The reduction of weight at birth, however, may be completely overcome by 6 months of age

published data^{1,2} in our sample birth weights of girls and boys born to light or heavy smokers were, respectively, 88 g, 107 g, 168 g, and 247 g lower than those of infants born to non-smoking mothers.

The deficit of weight at six months of age was reduced to +9 g for girls and -64 g for boys in children born to light smokers and to -28 g and -24 g in children born to heavy smokers. These data indicate that the deficits of weight at birth in children born to smoking mothers are overcome by 6 months of age. This trend was consistent in almost all subgroups evaluated.

The same findings have been obtained by multiple analysis of variance model. The analysis with parity and gestation considered as covariates showed that birth weight is related to mother's smoking habit; rate of growth from 0 to 6 months is higher in babies born to smoking mothers; weight differences between children born to smoking or non-smoking mothers are no longer measurable at 6 months. Weight recovery was faster in girls. Mother's age and social class were not associated with the weight of the baby.

Our data suggest that the well known effects of smoking during pregnancy on birth weight are not

permanent and that smoking in pregnancy does not affect the growth in childhood when smoking habit during pregnancy is not associated with other unfavourable variables. Future investigations on this issue should evaluate carefully the role of other factors, such as exposure to environmental smoke after birth¹⁵ and socioeconomic class.

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Pressor reactions to psychological stress and prediction of future blood pressure: data from the Whitehall II study

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Abstract

Objective—To examine whether reactions of blood pressure to psychological stress predict future blood pressure.

Design—Blood pressure was recorded at a medical screening examination after which pressor reactions to a psychological stress task were determined. Follow up measurement of blood pressure was undertaken, on average, 4.9 years later.

Setting—20 civil service departments in London.

Subjects—1003 male civil servants aged between 35 and 55 years at entry to the study.

Main outcome measure—Blood pressure at follow up screening.

Results—Reactions of systolic blood pressure to stress correlated positively with systolic blood pressure at follow up screening ($r=0.22$, $P<0.01$). The dominant correlate of follow up blood pressure was blood pressure at initial screening ($r=0.60$; $P<0.01$ between initial and follow up systolic blood pressure; $r=0.59$, $P<0.01$ between initial and follow up diastolic blood pressure). Stepwise multiple regression analysis indicated that reactions to the stressor provided minimal prediction of follow up blood pressure over and above that afforded by

blood pressure at initial screening. In the case of follow up systolic blood pressure, systolic reactions to stress accounted for only 1% of follow up variance; systolic blood pressure at initial screening accounted for 34%. With regard to diastolic blood pressure at follow up, the independent contribution from diastolic reactions to stress was less than 1%.

Conclusion—Pressor reactions to psychological stress provide minimal independent prediction of blood pressure at follow up. Measurement of reactivity is not a useful clinical index of the course of future blood pressure.

Introduction

What has come to be called the "reactivity hypothesis" considers that cardiovascular reactions to episodic psychological stress are involved in the aetiology of essential hypertension.¹⁻³ Large magnitude increases in blood pressure, heart rate, or cardiac output provoked by stress may lead, over time, to sustained increases in resting blood pressure. Some authorities remain sceptical⁴ and the precise character of the risk conferred by cardiovascular hyperreactivity