The effect of nutritional intake on outcome of pregnancy in smokers and non-smokers

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The relationship between nutrient intake and pregnancy outcome (adjusted birth weight and gestational age) was investigated in randomly selected non-smokers (*n* 97) and in heavy smokers (15+ cigarettes/d) (*n* 72) booking for ante-natal care at a hospital in South London. Weighed dietary intakes (7 d) were obtained at 28 and 36 weeks gestation. Birth weight was adjusted for gestational age, maternal height, parity and sex of infant.

Compared with non-smokers, intakes of micronutrients and fibre were lower in smokers at both 28 and 36 weeks, and smokers reduced their intakes more in late pregnancy. The babies of smokers had a lower adjusted birth weight but there was no difference in length of gestation between smokers and non-smokers. After controlling for smoking, social class and alcohol consumption, nutrient intakes at 28 weeks were found to have no effect on adjusted birth weight. However, intakes of protein, zinc, riboflavin and thiamin at 36 weeks, and the change in intakes of these nutrients (plus iron) between 28 and 36 weeks, had independent positive effects on birth weight. Some of the effect of smoking on birth weight appeared to be mediated through differences in nutrient intakes. Smoking explained 14·3% of the variance in birth weight in this population and a further 2·4–7·2% was explained by change in nutrient intakes between 28 and 36 weeks. It is recommended that women in pregnancy do not reduce their dietary intakes in late pregnancy.

Diet: Pregnancy: Smoking: Gestational age: Birth weight

There has been considerable interest over the past 25 years in the effects of nutrition in pregnancy on fetal growth. Results of supplementation studies in several Third World populations, and in poor communities in the USA (Ebbs *et al.* 1941; Lechtig *et al.* 1975*b*; Stein *et al.* 1978; Mora *et al.* 1979; Prentice *et al.* 1983; Whitehead *et al.* 1983) have been contradictory, largely because of different or inconsistent methodology and different initial planes of nutrition. The issue remains important, however, as poor women continue to produce small babies in all parts of the world, and to have a high perinatal mortality risk (Lechtig *et al.* 1975*a*; Rush & Cassano, 1983).

Smoking is known to reduce birth weight (Meyer *et al.* 1976; Rantakallio, 1978) and to increase preterm delivery (Meyer, 1977). Findings from the St George's Birthweight Study (of which the present study is a part) have indicated that smoking in this population is the most important environmental influence on birth weight, and that social, economic and psychological factors have little independent effect. Alcohol was found to reduce birth weight only in smokers (Brooke *et al.* 1989; Peacock *et al.* 1990). Several studies have suggested that part of the effect of smoking on birth weight may be mediated by nutritional factors through reduced overall energy intake or weight gain, or both (Rush, 1974; Davies *et al.* 1976; Garn, 1979), but dietary information to date has been insufficient to test this hypothesis. We have reported that smokers had poorer quality of diet than non-smokers in pregnancy, although their energy intakes were not significantly reduced, and that this effect was independent of the effects of social class (Haste *et al.* 1990). Other studies, using less rigorous methods (e.g. 24 h recall methods of data collection) have been conflicting, reporting that intakes of smokers were higher (Haworth *et al.* 1980; Picone *et al.* 1982), lower (Papoz, 1982), or similar (Smithells *et al.* 1977, using weighed intakes) to those of non-smokers in pregnancy. Further impetus to the hypothesis that the effects of smoking may be mediated through nutritional factors has been provided by studies of biochemical nutritional status which have indicated that smokers have lower circulating levels of folate (Witter *et al.* 1982; Nakazawa *et al.* 1983), vitamin C (Calder *et al.* 1963; Pelletier, 1970, 1975; Schorah *et al.* 1978) and carotene (Witter *et al.* 1982), and by studies indicating that birth weight is associated with lower circulating zinc (Meadows *et al.* 1981; Patrick *et al.* 1982; Simmer & Thompson, 1984; Wells *et al.* 1987), carotene and amino acids (Crosby *et al.* 1977).

In the present study we have investigated the effects of nutrient intakes in pregnancy on two measures of pregnancy outcome – birth weight adjusted for gestational age, and gestational age at delivery – in an unselected group of heavy smokers (15+ cigarettes/d) and a group of randomly selected non-smokers from the ante-natal clinics at St George's Hospital in London who competed a 7 d weighed dietary intake in mid- and late pregnancy.

METHODS

The study was carried out at St George's hospital, Tooting, London, as part of the larger St George's Birthweight Study (Brooke *et al.* 1989). All Caucasian women presenting at the ante-natal clinics from August 1982 to August 1984 were given a structured questionnaire by trained interviewers to obtain details of smoking habit. All women who reported smoking 15+ cigarettes/d in the previous week were selected for the smoking group. Non-smokers were selected using random number tables from women who reported that they had never smoked. Information on income, social class, marital status, education and housing tenure was obtained by the interviewers. Subjects were asked to do a 7 d weighed dietary intake at 28 weeks and at 36 weeks gestation. Details of the methods of weighed dietary intake have been reported elsewhere (Haste *et al.* 1990). Data used in the analysis were mean daily intakes of 7 d recorded intakes. Data were analysed using *McCance and Widdowson's The Composition of Foods* (Paul & Southgate, 1978). Nomenclature of nutrients is that used in *McCance and Widdowson's The Composition of Foods*. Of those asked to participate in the study 139 were smokers and 149 were non-smokers. Twenty-six non-smokers and thirty-nine smokers refused to take part, either initially or subsequently, twelve women aborted or moved away, and five records were considered incomplete or inadequate. Complete dietary data at 28 weeks were obtained for ninety-four smokers and 112 non-smokers. Two of the non-smokers had started smoking by 28 weeks and so were excluded from the analysis. All smokers were still smoking at 28 and 36 weeks. Of the participants seventy-two smokers and ninety-seven non-smokers completed a further week's data collection at 36 weeks, and these subjects form the population for this analysis.

Obstetric data including maternal height and parity were obtained from the obstetric case notes. Gestational age at delivery was calculated from the agreed delivery data recorded by the attending obstetrician using last menstrual period and early ultrasound examination data. Birth weight was measured by the midwife within 30 min of delivery using a Marsden spring balance. Birth weight is known to vary with gestational age, maternal height, age and parity, and sex of the infant. In order that comparisons can be made between individuals in whom these characteristics differ, i.e. to allow for these confounding factors, we calculated an adjusted birth weight as follows: the expected birth weight-for-gestational age was calculated using a large data set from Sheffield (*n* 1500, stratified by gestational age) as an external standard. Using the ratio of observed:expected values, birth weight was adjusted for gestational age. Further adjustments were made for maternal parity and height, and sex of infant, using linear regression equations from the St George's study population. No adjustment for maternal age was required. These techniques have been described in detail elsewhere (Brooke *et al.* 1989; Bland *et al.* 1990). Birth weight presented has been adjusted to a reference birth weight for a male infant of 40 weeks gestation of a mother of parity 1+ and height 1·60 m.

For the purpose of analysis, variables which did not have an approximately Normal distribution were logarithmically transformed. We have already reported that maternal height and social class have an effect on dietary intake, therefore in the analysis of the effect of smoking on dietary intake we used three-way analysis of variance (SPSS-X (1983), ANOVA procedure, regression method) to test the significance of the effect of smoking on dietary intake, while allowing for the effects of social class and maternal height simultaneously. Student's *t* tests were used to test for the significance of the difference between group means of adjusted birth weight and gestational age. Multiple regression was used to test for the significance of the effects of various factors on birth weight, using a method in which the effect of each factor is calculated taking into account the effects of all other factors in the equation simultaneously. R^2 values from this analysis are presented, with their significance values where specified.

RESULTS

Non-smokers were taller than smokers (163·7 (SD 5·4) *v.* 160·6 (SD 6·0), $P < 0.001$) so the effect of maternal height was allowed for in the analysis where appropriate.

Nutrient intakes of smokers were lower than those of non-smokers at both 28 and 36 weeks after allowance had been made for the effects of maternal height and social class, particularly for micronutrients (minerals and vitamins) and fibre (Table 1). Energy intakes were not significantly lower. Both smokers and non-smokers significantly decreased their energy intakes from 28 to 36 weeks, and smokers also reduced their intakes of other macro- and micronutrients.

Birth weight, presented as adjusted birth weight (birth weight adjusted for gestational age, maternal height and parity, and sex of infant) was significantly lower in smokers than non-smokers (Table 2). There was no difference in mean gestational age at delivery between smokers and non-smokers.

The effects of dietary intake on adjusted birth weight were assessed in a multiple-regression analysis including smoking and alcohol consumption. We have previously reported that nutrient intake varies significantly with social class (Haste *et al.* 1990) thus, social class was also included in the present analysis. There was no significant independent effect of intake of any nutrient at 28 weeks on adjusted birth weight but intake of protein, zinc, thiamin and riboflavin at 36 weeks (model 1) had a positive independent effect on adjusted birth weight (Table 3). Also examined was the effect of change in nutrient intake between 28 and 36 weeks (model 2). Change in intakes of protein, minerals (iron and zinc) and vitamins (riboflavin, thiamin and vitamin B_6) also had a significant, positive effect on adjusted birth weight. There was no significant effect of change in energy intake.

Smoking explained 14·5% ($P < 0.0001$) of the variance in adjusted birth weight, and the combined effects of smoking, alcohol and social class explained 18·9% before nutrient intakes were entered into the regression analysis. Addition of 36-week nutrient intakes (protein, Zn, riboflavin and thiamin) separately to the regression models significantly increased the percentage of the variance explained (R^2) by from 2·1% (protein; ($P < 0.05$) to 3·1% (riboflavin; $P < 0.05$), but decreased the R^2 of smoking by approximately equivalent amounts. Addition of change in nutrient intake the model increased the R^2 by

Table 1. *Nutrient intakes in smokers (S) and non-smokers (NS) at 28 and 36 weeks gestation*

(Geometric mean values with their standard errors)

	28 weeks					36 weeks					Statistical significance of difference 28 week *v.* 36 week intake‡ *P* <	
	S		NS		Statistical significance of difference†: *P* <	S		NS		Statistical significance of difference†: *P* <		
Nutrient	Mean	SE	Mean	SE		Mean	SE	Mean	SE		S	NS
Energy (MJ)*	8·0	0·2	8·4	0·2	0·8	7·4	0·3	7·8	0·3	0·8	0·01	0·05
Protein (g)	69	2	75	2	0·1	65	2	73	2	0·2	0·05	0·07
Fat (g)	88	3	91	2	0·9	81	3	88	3	0·9	0·05	0·08
Carbohydrate (g)	230	8	238	6	0·8	217	8	230	7	0·9	0·07	0·2
Fibre (g)*	13·6	0·6	19·5	0·8	0·001	13·2	0·6	18·3	1·0	0·01	0·4	0·3
Calcium (mg)	910	34	1030	33	0·2	840	37	990	32	0·2	0·05	0·07
Iron (mg)*	9·3	0·3	11·7	0·5	0·01	8·5	0·4	11·2	0·5	0·05	0·05	0·8
Zinc (mg)*	8·4	0·3	9·7	0·4	0·05	7·7	0·3	9·5	0·4	0·07	0·05	0·5
Carotene (μg)*	826	80	1110	75	0·1	805	70	1100	75	0·1	0·6	0·9
Thiamin (mg)	1·10	0·04	1·32	0·03	0·01	1·08	0·05	1·31	0·04	0·05	0·6	0·7
Riboflavin (mg)*	1·7	0·1	2·0	0·1	0·07	1·6	0·1	2·1	0·1	0·05	0·4	0·2
Vitamin C (mg)*	44	3	72	5	0·001	41	3	69	5	0·001	0·3	0·8
Vitamin E (mg)*	3·6	0·2	4·8	0·2	0·01	3·4	0·2	4·5	0·2	0·06	0·5	0·1
Vitamin B_6 (μg)*	1·03	0·04	1·24	0·04	0·01	0·98	0·05	1·17	0·05	0·08	0·2	0·2
Total folate (μg)*	139	6	179	6	0·01	126	5	172	8	0·01	0·01	0·6

* Logarithmically transformed for analysis.
† Significance of the effect of smoking using 3-way analysis of variance allowing for the effects of maternal height and social class.
‡ Paired *t* test.

Table 2. *Adjusted birth weight and gestational age at delivery from mothers who were smokers or non-smokers*

(Mean values with their standard errors)

	Smokers (*n* 72)		Non-smokers (*n* 97)		Statistical significance of difference*: *P* <
	Mean	SE	Mean	SE	
Adjusted birth wt† (g)	3384	49	3740	42	0·001
Gestational age (weeks)	39·9	0·2	39·9	0·1	0·9

* Student's *t* test.
† Adjusted for maternal height, parity, gestational age and sex of infant.

between 2·4% (Fe) and 7·2% (riboflavin) but the R^2 for smoking in these models generally did not decrease. Entering all these nutrients into the model increased the overall R^2 to 28·6% ($P < 0·01$).

The regression coefficients for change in intakes of those nutrients that were found to have a significant effect on adjusted birth weight are given in Table 4, with the mean change in intakes of those nutrients for the population. This shows an estimated mean reduction of 82 g in adjusted birth weight for women who reduced their protein intakes, and of 87 g for women who reduced their riboflavin intakes. Similar differences were seen for other nutrients.

Table 3. *Percentage of the variance* (R^2) *in adjusted birth weight explained by smoking, nutrient intake at 36 weeks (model 1), and change in nutrient intake in late pregnancy (model 2)**

	Model 1				Model 2			
		Nutrient				Change in nutrient		
Nutrient	Smoking R^2	R^2	Statistical significance: $P <$	Total† R^2	Smoking R^2	R^2	Statistical significance: $P <$	Total† R^2
None entered‡	14·3	—	—	18·9	14·3	—	—	18·9
Energy	14·0	1·0	0·2	20·0	14·4	0·6	0·3	19·5
Protein	12·8	2·1	0·05	21·5	14·5	4·1	0·01	23·5
Fat	14·1	0·5	0·4	19·3	14·3	0	—	19·0
Carbohydrate	14·5	1·2	0·2	20·0	14·3	0	—	19·1
Fibre	11·7	0·9	0·2	19·8	14·3	0·8	0·3	19·6
Calcium	13·5	0·5	0·4	19·3	14·3	1·2	0·2	20·0
Iron	11·3	1·3	0·1	20·2	12·7	2·4	0·05	21·2
Zinc	11·7	2·4	0·05	21·3	13·7	6·1	0·001	25·0
Carotene	12·4	1·9	0·06	20·7	14·3	0·6	0·3	19·5
Thiamin	11·8	3·2	0·05	22·0	14·3	3·0	0·05	21·8
Riboflavin	11·2	3·1	0·05	22·0	12·5	7·2	0·001	26·2
Vitamin C	11·0	0·6	0·3	19·5	14·4	0	—	19·1
Vitamin E	12·7	0·5	0·4	19·3	13·8	0·8	0·3	19·7
Vitamin B_6	12·2	1·6	0·08	20·5	14·4	3·0	0·05	21·8
Total folate	11·1	1·1	0·2	20·0	14·0	0·8	0·2	19·7
Combined nutrients§	10·2	3·9	0·1	22·8	12·5	9·7	0·01	28·6

* Multiple regression analysis, with maternal social class and alcohol consumption also in each model.
† R^2 for whole model.
‡ Model contains smoking, maternal social class and alcohol consumption.
§ Protein, Zn, thiamin, riboflavin, Fe and vitamin B_6 entered simultaneously.

Table 4. *The effect of change in intake of selected nutrients on mean adjusted birth weight* (g) *of women who increased or decreased their intakes*

Change in nutrient	Regression coefficient*	Percentage who reduced intake	Mean change in nutrient intake		Estimated mean change (g) in adjusted birth wt†	
			Decrease	Increase‡	Decrease	Increase
Protein (g)	7	61	11·7	10·2	82	71
Iron (mg)	24	56	2·3	2·2	55	53
Zinc (mg)	49	54	1·9	1·5	93	73
Thiamin (mg)	220	51	0·3	0·6	66	132
Riboflavin (mg)	213	51	0·41	0·49	87	104
Vitamin B_6 (μg)	258	58	0·23	0·20	59	52

* Regression coefficient for the effect of unit change in nutrient intake on adjusted birth weight (g) after allowing for the effects of smoking, social class and alcohol consumption.
† Estimated change in adjusted birth weight for mean changes in nutrient intake.
‡ Includes women who neither increased nor decreased their intakes.

The change in dietary intakes of women who delivered small-for-gestational-age (SGA) babies (birth weight < 10th centile for gestational age) was compared with intakes of women who delivered appropriate-for-gestational-age (AGA) babies (> 10th centile for gestational age). Of the mothers of SGA babies (*n* 21) 95% had reduced their protein intakes compared with 51% of the mothers of AGA babies (χ^2 10·3, $P < 0{\cdot}01$). Change in intakes of other nutrients were not significantly different between these groups.

There was no effect of nutrient intakes at either 28 weeks or 36 weeks, nor of the change in intake, on gestational age at delivery.

DISCUSSION

Smokers had poorer dietary intakes in mid- and late pregnancy than non-smokers and they also reduced their intake of nutrients in late pregnancy more than did non-smokers. There was no evidence of an effect of dietary intake at 28 weeks on adjusted birth weight; however, there was evidence of an effect of dietary intake in late pregnancy. The lack of effect of nutrient intake at 28 weeks suggests that it is intake in later pregnancy that is more important to growth. This is not surprising since the greatest part of fetal growth occurs in the last 3 months of pregnancy. Populations which have been subjected to deprivation for part of pregnancy (e.g. war-time famine populations) have experienced the greatest effect on growth when the deprivation has been in the last trimester (Bergner & Susser, 1970). A major feature of those periods of deprivation was severe restriction of energy, although one can reasonably assume that vitamins and minerals were also restricted. Supplementation studies which have enhanced protein intakes in an attempt to increase birth weight have had mixed success (Elwood *et al.* 1981; Campbell Brown, 1983). Many have resulted in poorer fetal outcomes, particularly those which gave high-protein supplements (Ebbs *et al.* 1941; Adams *et al.* 1978; Rush *et al.* 1980), so despite our finding of a positive relationship between fetal growth and protein intake we would not feel it wise to recommend increased intake. However, it does seem that reducing protein intake may have growth-retarding effects. The finding that 95% of the women who had growth-retarded babies had reduced their protein intakes in late pregnancy strengthens this observation.

Smoking explained a higher percentage of the variance in adjusted birth weight than was found (5%) in the larger, unselected population of the St George's Birthweight Study (Brooke *et al.* 1989). This is because the present sample was stratified by smoking habit with almost equal numbers of non-smokers as heavy smokers, therefore the effect of smoking would be greater than the effect in the larger study where 9% of the population were heavy smokers. The effect of nutrient intake, however, and particularly change in nutrient intake, was independent of the effects of smoking and there is no reason to suppose that an unselected sample which included moderate smokers would not show similar effects. Combined changes in nutrient intakes explained 9·7% of the variance in birth weight, an effect that was highly significant and almost comparable with that of smoking (R^2 12·5%) in this regression model.

The findings suggest that some of the effect of smoking on birth weight may be mediated by lower nutrient intakes in late pregnancy since the proportion of the variance in adjusted birthweight that was explained by smoking was reduced by an amount equivalent to that attributable to intake of protein, Zn, thiamin or riboflavin. However, a large effect of smoking remained, and the effects of changes in nutrient intake did not act as mediators of the smoking effect. Both smokers and non-smokers should be advised not to decrease their nutrient intakes in late pregnancy, and particularly not to reduce the quality of their diets in terms of vitamins, minerals and protein.

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