ORIGINAL ARTICLE

Maternal nutritional risk factors for small for gestational age babies in a developed country: a case-control study

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Aims: To assess the effect of maternal diet during pregnancy on the risk of delivering a baby who is small for gestational age (SGA).
Methods: Case-control study of 844 cases (SGA) and 870 controls (appropriate size for gestational age (AGA)). Only term (37+ completed weeks of gestation) infants were included. Retrospective food frequency questionnaires were completed at birth on the diet at the time of conception and in the last month of pregnancy.
Results: At the time of conception, mothers of AGA infants ate significantly more servings of carbohydrate rich food and fruit, and were more likely to have taken folate and vitamin supplements than mothers of SGA infants. There was some evidence that mothers of AGA infants also ate more servings of dairy products, meat, and fish ($0.05 < p < 0.1$). However, after adjustment for maternal ethnicity, smoking, height, weight, hypertension, and occupation, fish intake ($p = 0.04$), carbohydrate-rich foods ($p = 0.04$), and folate supplementation ($p = 0.02$) were associated with a reduced risk of SGA. In the last month of pregnancy, only iron supplementation was associated with a reduced risk of SGA ($p = 0.05$) after adjustment for potential confounders.
Conclusions: This study suggests that small variations in maternal diets within the normal range during pregnancy in developed countries are associated with differences in birth weight.

Low birth weight is a consequence of being born too small or too early. Babies born small for gestational age (SGA) are at increased risk of death and developmental and behavioural problems in childhood.[1] Furthermore, these infants are at increased risk of non-insulin dependent diabetes mellitus and cardiovascular disease in adult life.[2] The causes of SGA are not well established.[3] Clearly genetic abnormalities and intrauterine infections or toxicity are factors in some cases. However, for most SGA infants the cause is thought to be reduced substrate delivery to the fetus, because of either abnormalities of the fetus or placenta or poor nutrition of the mother.

The effect of severe malnutrition on birth weight depends on the stage of gestation. In the Netherlands in 1944–1945, famine during the first trimester was associated with increased placental weight but no change in birth weight, whereas famine later in pregnancy was associated with a reduction in both placental and birth weight.[4] However, even in developed countries, a small increase in birth weight has been seen with balanced protein energy supplementation in pregnancy.[5]

Lower birth weight is associated with lower socioeconomic status.[6] How much of this is explained by maternal nutrition is unknown, as maternal nutrition and socioeconomic status are associated with many other factors, such as maternal smoking.

The aim of this study was to assess the effect of maternal diet and supplements of vitamins, folate, and iron in early and late pregnancy on the risk of delivering SGA babies.

METHODS

This case-control study has been described in detail previously.[7] In brief, between 16 October 1995 and 12 August 1996 babies born and resident in the Waitemata Health or Auckland Healthcare regions were eligible for inclusion, and from 12 August 1996 to 30 November 1997 babies born in the Auckland Healthcare region were eligible to participate. Preterm infants (< 37 completed weeks of gestation), multiple births, and those with congenital abnormalities were excluded. All SGA infants and a random sample of infants of appropriate size for gestational age (AGA) were selected. SGA was defined as equal to or below the sex specific 10th centile for gestational age in the New Zealand population.[8] AGA babies weighed more than the 10th centile. Gestation was estimated using the date of the last menstrual period if it was available and was within two weeks of the best clinical estimate of gestational age at birth; otherwise the best clinical estimate was used.

Data were collected by (*a*) interviewer administered questionnaire shortly after delivery, (*b*) self administered food frequency questionnaire (FFQ), and (*c*) obstetric databases.

A FFQ was used to assess diet. This was based on the Life in New Zealand survey.[9] The mothers were asked to recall their diet at the time of conception (''about the time you became pregnant'') and in the last month of pregnancy. Food frequencies for individual questions were converted into servings a day or week and then summed to give a total daily (or weekly) intake for seven food groups. These food groups were fresh fruit (including bananas, apples, pears, citrus fruits, stone fruits, berries, melon, and avocados), vegetables (green and root vegetables, peas, corn, lentils), carbohydrate rich food (potatoes, rice, noodles, pasta, bread, breakfast cereals), high carbohydrate snacks and soft drinks (including biscuits, potato crisps, cakes, soft drinks), meat (including meat products), fish (including shellfish), and dairy products (milk, cheese, and yoghurt). If all the answers to the questions making up a food group were missing, the intake

Abbreviations: AGA, appropriate size for gestational age; FFQ, food frequency questionnaire; SGA, small for gestational age was specified as missing. If only some of the answers were missing, they were designated as ''not at all''—that is, given a zero intake score—and the total intake calculated. Vitamin, folate, and iron supplements were recorded as taken at least once a week.

Mann-Witney U tests were used to investigate differences in daily intake of the food groups between mothers of SGA and AGA infants. χ^2 tests were used to investigate the association between having an SGA infant and the use of supplements. Logistic regression models were used to investigate whether maternal food intake had an effect on whether or not the infant was SGA after controlling for socioeconomic status, ethnicity, maternal height, maternal weight before pregnancy, maternal hypertension, and maternal smoking. In the logistic regressions, the daily intake was categorised.

The occupation of the mother and her partner was self reported. Socioeconomic status was defined using the subject's occupation, or that of her partner if higher using the Elly Irving classification of occupation.[10] Social classes I and II were categorised as high, III and IV as middle, and V, VI, and others as low. Ethnic group was the self reported ethnicity collected by the obstetric hospitals from the mothers during their pregnancy. The options available were Maori, European, Pacific Islanders, Indian, Chinese, other.

The study was approved by the North Health research ethics committee.

Diet recall study

Ninety one women were recruited early in pregnancy and completed a FFQ about their dietary intake around the time of conception. At the time of the birth of the child, they were asked to complete the same questionnaire recalling the same time period. For each food group, the median number of servings was compared, as was the distribution of the responses.

RESULTS

A total of 2182 infants were eligible for this study, and the parents of 1714 (78.6%) completed the interviewer administered questionnaire (844 SGA and 870 AGA). Of these 1714, 1691 (98.7%) allowed access to their obstetric records and the records were found. Table 1 shows the characteristics of the mothers in the study population. Overall, 67% and 66% of subjects completed the FFQ for the time relating to the time of conception and for the last month of pregnancy respectively.

Around the time of conception, mothers of AGA infants ate significantly more servings of carbohydrate rich foods, fruit, and dairy products (univariate analyses, table 2), and were more likely to take folate (odds ratio (OR) 1.61; 95% confidence interval (CI) 1.22 to 2.08) and vitamin (OR 1.35; 95%CI 1.02 to 1.78) supplements than mothers of SGA infants. There was some evidence that mothers of AGA infants also ate more servings of meat and fish ($0.05 < p < 0.1$) (table 2). However, after adjustment for ethnicity, smoking, height, weight, hypertension, and socioeconomic status, fish intake ($p = 0.04$), carbohydrate rich foods ($p = 0.04$), and folate supplementation (table 3, $p = 0.02$) were associated with a reduced risk of SGA.

In the last month of pregnancy at the univariate level mothers of AGA infants consumed significantly more servings of carbohydrate rich foods, high carbohydrate snacks and soft drinks, fruit, dairy products, and vitamin

Table 2 Median number of servings for mothers of small for gestational age (SGA) and appropriate size for gestational age (AGA) infants at the time of conception and last month of pregnancy

	SGA	AGA	p Value*
At the time of conception			
Fruit per day	1.4	1.5	0.03
Vegetables per day	1.4	1.6	0.11
Meat per week	4.0	4.5	0.09
Fish per week	0.5	1.0	0.08
Dairy products per day	2.2	2.5	0.056
Carbohydrate rich foods per day	2.8	3.1	0.004
High carbohydrate snacks and soft drinks per day	1.4	1.4	0.10
Last month of pregnancy			
Fruit per day	1.9	2.1	0.007
Vegetables per day	1.6	1.6	0.30
Meat per week	4.2	4.2	0.64
Fish per week	0.5	0.5	0.48
Dairy products per day	2.8	3.0	0.05
Carbohydrate rich foods per day	3.0	3.3	0.002
High carbohydrate snacks and soft drinks per day	1.5	1.8	0.046

*Mann-Whitney U test.

Table 1 Characteristics of the mothers of 844 small for gestational age (SGA) and 870 appropriate size for gestational age (AGA) infants

	SGA		AGA		
	n	(%)	n	(%)	OR (95% CI)
Socioeconomic group					$\chi^2=25.2$, $p<0.001$
High	348	(41.2)	464	(53.4)	1.00
Middle	319	(37.8)	266	(30.5)	1.60 (1.29 to 1.98)
Low	177	(19.0)	140	(15.1)	1.69 (1.30 to 2.19)
Ethnicity					$\chi^2=89.9$, $p<0.001$
European	385	(45.7)	486	(56.0)	1.00
Maori	106	(12.6)	72	(8.3)	1.86 (1.34 to 2.58)
Pacific	106	(12.6)	185	(21.3)	0.72 (0.55 to 0.95)
Indian	107	(12.7)	31	(3.6)	4.36 (2.86 to 6.64)
Chinese, other Asian, others	139	(16.5)	94	(10.8)	1.87 (1.38 to 2.53)
Smoking					$\chi^2=43.3$, $p<0.001$
No	547	(66.4)	683	(80.5)	1.00
Yes	277	(33.6)	165	(19.5)	2.11 (1.69 to 2.64)
	Mean	**(SD)**	**Mean**	**(SD)**	**t Value, p value**
Age (years)	29.1	(5.7)	30.3	(5.5)	4.75, <0.001
Height (m)	1.62	(0.07)	1.65	(0.07)	10.08, <0.001
Weight (kg)	59.8	(13.7)	66.5	(14.5)	9.85, <0.001

Table 3 Number and multivariate odds ratios for small for gestational age (SGA) for servings for each food group at the time of conception

Food group	SGA	AGA	Multivariate OR (95% CI)	
Fruit	n = 542	n=600		p=0.12, df=4, χ^2=7.27
0–0.75	132	104	1.49 (1.00 to 2.24)	
>0.75–1.25	107	144	0.99 (0.67 to 1.47)	
>1.25–2.0	115	117	1.44 (0.96 to 2.17)	
>2.0–3.0	84	96	1.23 (0.80 to 1.90)	
>3	104	139	1	
Vegetables	n=539	n=598		p=0.32, df=4, χ^2=4.71
0–0.75	138	137	1.25 (0.79 to 1.97)	
>0.75–1.25	93	81	1.58 (0.97 to 2.58)	
>1.25–2.0	87	104	1.12 (0.70 to 1.80)	
>2.0–3.0	126	190	1.40 (0.91 to 2.14)	
>3	99	86	1	
Meat	n=533	n=598		p =0.79, df=4, χ^2=1.71
0–2	60	42	1.36 (0.80 to 2.29)	
>2–4	180	193	1.07 (0.76 to 1.51)	
>4–5	85	114	0.97 (0.64 to 1.45)	
>5–6	71	81	1.01 (0.65 to 1.56)	
>6	137	168	1	
Fish	n=529	n=592		p =0.04, df=2, χ^2=6.68
None	110	84	1.69 (1.07–2.69)	
Up to one	312	382	1.09 (0.75 to 1.58)	
More than one	107	126	1	
Dairy products	n=533	n=597		p =0.21, df=4, χ^2=5.83
0–1.25	108	92	1.13 (0.75 to 1.72)	
>1.25–2.0	115	121	1.09 (0.73 to 1.62)	
>2.0–3.0	114	152	0.81 (0.55 to 1.19)	
>3.0–4.0	70	103	0.74 (0.48 to 1.14)	
>4.0	117	125	1	
Carbohydrate rich foods	n=538	n=598		p =0.04, df=4, χ^2=10.37
0–1.5	154	127	1.31 (0.88 to 1.97)	
>1.5–2.25	114	109	1.22 (0.80 to 1.86)	
>2.25–2.75	105	147	0.81 (0.54 to 1.23)	
>2.75–3.5	70	108	0.77 (0.49 to 1.21)	
>3.5	96	107	1	
High carbohydrate snacks and soft drinks	n=538	n=597		p=0.35, df=3, χ^2=3.31
0–<1	189	197	1.27 (0.85 to 1.91)	
1–<2	172	171	1.37 (0.91 to 2.06)	
2–<3	101	132	1.06 (0.68 to 1.65)	
⩾3	72	97	1	
Vitamins	n=529	n=593		p =0.09, df=1, χ^2=2.81
Yes	124	173	0.78 (0.58 to 1.04)	
No	405	420	1	
Folate supplement	n=503	n=573		p=0.02, df=1, χ^2=5.58
Yes	139	220	0.70 (0.52 to 0.94)	
No	349	345	1	
Iron supplement	n=497	n=562		p=0.81, df=1, χ^2=0.06
Yes	98	90	1.05 (0.73 to 1.50)	
No	399	472	1	

Food groups are analysed according to servings a day, except for meat and fish which are analysed according to servings a week.

supplementation (OR 1.35:95%CI 1.01 to 1.85) than mothers of SGA infants (table 2). However, after adjustment for potential confounders only iron supplementation was associated with a reduced risk of SGA (table 4, p = 0.05).

Diet recall study

Eighty women completed questionnaires during early pregnancy (mean (SD) gestation 8.2 (1.9) weeks) and after the birth of the child (mean (SD) age 1.4 (1.3) weeks).

The median number of servings for each food group did not differ markedly between the two recorded times; however, there was a tendency for mothers to recall slightly lower quantities of dairy products, meat, and carbohydrate rich foods (table 5).

DISCUSSION

Limitations in this study must be recognised. We have previously shown that non-respondents were more likely to be mothers of SGA infants than mothers of AGA babies (22.3% *v* 16.6%) and that non responders are more likely to be smokers.[7] Furthermore, among the subjects who were interviewed, non-Europeans were less likely to complete the FFQs. Secondly, FFQs have considerable measurement error, as do most dietary assessment tools.[11] Studies of nutritional effects using FFQs tend to be notoriously underpowered even when conventional methods of adjusting for measurement error are used. However, FFQ was chosen as we were particularly interested in the diet around the time of conception, and it would not have been feasible to identify sufficient women in early pregnancy to use the seven day semiquantitative food diary or weighed food records. Furthermore, diet at the time of conception was recalled about nine months later. However, we have shown that this does not introduce a systematic error, although it does increase measurement error. The strengths of this study are the large sample size and large number of SGA babies.

After adjustment for potential confounders, mothers of AGA infants ate more servings of fish (p = 0.04) and carbohydrate rich foods (p = 0.04) and more used supplements of folic acid (p = 0.02) in early pregnancy.

Table 4 Number and multivariate odds ratios for small for gestational age (SGA) for servings for each food group in the last month of pregnancy

Food group	SGA	AGA	Multivariate OR (95% CI)	
Fruit	n = 540	n = 598		p = 0.19, df = 4, χ^2 = 6.11
0–0.75	95	62	1.53 (0.99 to 2.35)	
>0.75–1.25	82	83	1.08 (0.72 to 1.63)	
>1.25–2.0	111	136	0.93 (0.61 to 1.40)	
>2.0–3.0	89	123	1.04 (0.69 to 1.57)	
>3	163	194	1	
Vegetables	n = 539	n = 598		p = 0.12, df = 4, χ^2 = 7.25
0–0.75	146	126	1.20 (0.76 to 1.92)	
>0.75–1.25	76	84	0.94 (0.57 to 1.56)	
>1.25–2.0	91	132	0.69 (0.43 to 1.10)	
>2.0–3.0	159	183	0.98 (0.64 to 1.51)	
>3.0	67	73	1	
Meat	n = 534	n = 597		p = 0.66, df = 4, χ^2 = 2.44
0–2	56	57	0.70 (0.43 to 1.16)	
>2–4	177	202	0.84 (0.59 to 1.19)	
>4–5	102	123	0.85 (0.57 to 1.26)	
>5–6	66	72	0.97 (0.62 to 1.53)	
>6	133	143	1	
Fish	n = 529	n = 593		p = 0.39, df = 2, χ^2 = 1.90
None	138	137	1.29 (0.83 to 1.99)	
Up to one	284	344	1.07 (0.73 to 1.57)	
More than one	144	112	1	
Dairy products	n = 536	n = 596		p = 0.38, df = 4, χ^2 = 4.22
0–1.25	77	64	1.21 (0.78 to 1.87)	
>1.25–2.0	81	85	1.08 (0.72 to 1.63)	
>2.0–3.0	130	144	0.98 (0.69 to 1.40)	
>3.0–4.0	158	124	0.76 (0.52 to 1.19)	
>4.0	102	175	1	
Carbohydrate rich foods	n = 539	n = 598		p = 0.17, df = 4, χ^2 = 6.48
0–1.5	123	101	1.52 (0.99 to 2.33)	
>1.5–2.25	96	100	1.36 (0.87 to 2.13)	
>2.25–2.75	114	125	1.08 (0.71 to 1.65)	
>2.75–3.5	118	170	1.00 (0.67 to 1.51)	
>3.5	89	102	1	
High carbohydrate snacks and soft drinks	n = 538	n = 597		p = 0.22, df = 3, χ^2 = 4.40
0–<1	173	155	1.26 (0.86 to 1.85)	
1–<2	165	184	1.18 (0.81 to 1.71)	
2–<3	100	137	0.88 (0.58 to 1.32)	
⩾3	100	121	1	
Vitamins	n = 526	n = 591		p = 0.1, df = 1, χ^2 = 2.78
Yes	97	139	0.76 (0.55–1.05)	
No	429	452	1	
Folate supplement	n = 473	n = 546		p = 0.2, df = 1, χ^2 = 1.65
Yes	33	38	0.70 (0.41 to 1.20)	
No	440	508	1	
Iron supplement	n = 507	n = 579		p = 0.05, df = 1, χ^2 = 3.71
Yes	185	220	0.76 (0.57 to 1.01)	
No	322	359	1	

Food groups are analysed according to servings a day, except for meat and fish which are analysed according to servings a week.

The strongest association was found with folic acid supplementation. Folic acid is thought to be important for fetal growth.[12] Our finding is consistent with some randomised controlled studies which have shown that folic acid supplementation increases birth weight,[13] although a Cochrane review found a non- significant reduction in low birth weight in controlled trials of folate supplementation.[14] In developed countries, there is a well established association between folate status of pregnant women and the birth weight of their infant.[15] Folic acid intake from the diet is thought to be marginal in many pregnant women in developed countries.[16]

Table 5 Diet recall study: difference in servings at the time of conception recorded in early pregnancy compared with that recalled at the time of the birth of child

	Median	Lower quartile, upper quartile
Fruit a day	0.0	−0.57, 0.57
Vegetables a day	0.0	−0.82, 0.25
Meat a week	0.5	−1.0, 1.5
Fish a week	0.0	−0.5, 0.0
Dairy products a day	0.40	−0.09, 1.04
Carbohydrate rich foods a day	0.25	−0.14, 0.96
High carbohydrate snacks and soft drinks a day	0.07	−0.28, 0.78

The finding that fish intake in early pregnancy was associated with a lower risk of SGA was in keeping with observations from Scandinavia that women who eat a lot of fish tend to have heavier babies.[17 18] It is postulated that the high intake of omega-3 oils affects prostaglandin synthesis, leading to prolonged pregnancies as well as babies that are heavier for gestational age. An interventional study found that a fish oil supplementation reduced the recurrence risk of preterm birth, but had no effect on intrauterine growth retardation.[19] Fish is expensive in New Zealand, and the amount of fish eaten in our cohort was generally small. Our findings suggest that in New Zealand even a modest fish intake in pregnancy is associated with a reduced risk of having a growth restricted baby.

The number of servings of carbohydrate rich foods in early pregnancy was associated with a reduced risk of SGA ($p = 0.04$). The evidence linking variations in carbohydrate intake of supposedly well nourished women with size of their babies at birth is contradictory. Our results contrast with the prospective observational study of Godfrey *et al*.[20] That study found that mothers with a high carbohydrate intake in early pregnancy had lighter babies. Matthews *et al*,[21] in another prospective study set like that of Godfrey *et al* in the south of England, failed to find any relation between size at birth and the intake of any macronutrient. The authors looked at macronutrients and micronutrients derived from a semi-quantitative seven day food diary and from extensive FFQs respectively. Given the retrospective nature of this part of our study, we felt it prudent to describe the foods eaten, rather than extrapolate to their constituent parts. Thus our measure of carbohydrate intake will not be directly comparable to that of Godfrey *et al*. In rural India where maternal undernutrition is common, no association was seen with maternal energy intake and size at birth.[15]

In contrast with the findings at the time of conception, there were few associations with SGA when the diet in the last month of pregnancy was considered. Only oral iron supplementation was significantly associated with a reduced risk of SGA after adjustment for potential confounders ($p = 0.05$). This finding contrasts with the conclusion of a review that iron supplementation of anaemic or non-anaemic pregnant women does not increase birth weight.[22] It is also consistent with previous studies in developed countries that have assessed diet in late pregnancy, which have concluded that maternal nutrition does not have an important effect on birth weight. Godfrey *et al*[20] also found that there was no univariate association between nutrient intake in late pregnancy and either birth weight or placental weight.

In summary, after allowing for factors known to be associated with SGA in this cohort, we have shown that eating more fish and carbohydrate rich foods and taking folate supplements around the time of conception is associated with a reduced risk of having an SGA baby. Iron supplements in late pregnancy are also associated with a reduced risk. This study suggests that small variations in maternal diet in early pregnancy could have important effects on birth weight and even on later health outcomes.

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