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Maternal dietary patterns in pregnancy and the association with small-for-gestational-age infants

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Maternal nutritional status before and during pregnancy is important for the growth and development of the fetus. The effects of pre-pregnancy nutrition (estimated by maternal size) are well documented. There is little information in today's Western society on the effect of maternal nutrition during pregnancy on the fetus. The aim of the study was to describe dietary patterns of a cohort of mothers during pregnancy (using principal components analysis with a varimax rotation) and assess the effect of these dietary patterns on the risk of delivering a small-for-gestational-age (SGA) baby. The study was a case–control study investigating factors related to SGA. The population was 1714 subjects in Auckland, New Zealand, born between October 1995 and November 1997, about half of whom were born SGA ($\leq$10th percentile for sex and gestation). Maternal dietary information was collected using FFQ after delivery for the first and last months of pregnancy. Three dietary patterns (traditional, junk and fusion) were defined. Factors associated with these dietary patterns when examined in multivariable analyses included marital status, maternal weight, maternal age and ethnicity. In multivariable analysis, mothers who had higher 'traditional' diet scores in early pregnancy were less likely to deliver a SGA infant (OR = 0·86; 95 % CI 0·75, 0·99). Maternal diet, particularly in early pregnancy, is important for the development of the fetus. Socio-demographic factors tend to be significantly related to dietary patterns, suggesting that extra resources may be necessary for disadvantaged mothers to ensure good nutrition in pregnancy.

Maternal nutrition: Nutritional epidemiology: Small for gestational age: Dietary patterns: Pregnancy

Adequate nutritional status before pregnancy is essential for optimal development and growth of the fetus. In terms of pre-pregnancy nutritional status, most commonly measured by maternal stature, it has been shown that maternal size (weight) before pregnancy has one of the most significant effects on birth weight[1]. Data from the Auckland Birthweight Collaborative study have previously confirmed such a relationship in the population studied here[2].

Also of notable importance is nutritional intake during pregnancy, for which there is relatively little literature particularly in human subjects. Most information in this field comes from trials of supplementation in developing countries rather than in 'Western' society where nutrition is considered more adequate or from animal studies where manipulation of the diet can be undertaken and the effect on birth outcome studied.

Data from the Dutch famine of 1944–5 during the war[3–6] demonstrated that exposure to famine during the third trimester, the time of greatest growth of the fetus, reduced birth weight by about 10 %. Exposure to famine in early or mid pregnancy did not appear to have an effect on birth weight[4,7]. However, such studies are relatively extreme and these environments are rare in Western society today. Most work has been carried out in animals with restriction of diet in early and late pregnancy showing large effects in terms of outcomes at birth[8–11] and development of disease in later life. However, how these animal data translate to nutrition during pregnancy in human subjects still remains unclear.

Current recommendations for nutritional requirements for pregnancy are limited, as they are based on supplementary intake in addition to the estimated requirements for non-pregnant women. It is recognised that the nutritional health of the mother before pregnancy may be as important as her nutrition throughout pregnancy. An important example of this is dietary folate, a lack of which is recognised as leading to increased risk of developing neural tube defects[12–15].

The effects of maternal diet in pregnancy and disease of the resulting offspring in adult life would appear to be dependent on the combination of maternal diet and the dietary exposure of the infant child and adult[16,17].

Abbreviation: SGA, small-for-gestational-age.
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Identification of dietary patterns has become a useful tool in epidemiological studies that seek to explore the relationship between dietary exposures and health outcome. The use of an FFQ in the present study to determine dietary habits enables a longer term view of dietary intakes as opposed to using a 24 h dietary recall or food diary method. This approach to dietary analyses is population specific; thus, making it suitable for use in cohort studies that aim to describe relationships between dietary exposures and health outcomes over periods of time. It also has the advantage of reducing a large number of individual variables to a more manageable number of summary variables. An analysis of specific nutrients or foods to risk of disease is limited because of the inter-correlations between nutrients and/or food groups. Dietary patterns as defined by principal components analysis avoid this problem and describe overall diet more generally and can also be used to estimate the risk of disease and have the advantage of being amenable to the formation of subsequent public health recommendations.

The primary aim of the present study was to identify risk factors for small-for-gestational-age (SGA), in term infants, particularly those factors that may be modifiable[2]. A previous analysis from the present study relating food groups in the maternal diet identified fish, carbohydrate and folate supplementation in early pregnancy as reducing the risk of SGA[18].

This report analyses diet using food items from FFQ to identify dietary patterns. It assesses the relationship of dietary patterns with socio-demographic and obstetric factors and the effect of dietary patterns on having an SGA infant.

Methods

The Auckland Birthweight Collaborative study was designed to identify risk factors for SGA infants. The methodology has been described in detail previously[2]. In brief, it was a case–control study carried out in the Auckland and Waitemata District Health Boards in Auckland, New Zealand. Babies born at term (completed gestation of 37 or more weeks) between 16 October 1995 and 12 August 1996 from both regions were eligible and between 13 August 1996 and 30 November 1997 in the Auckland District Health Board only. All infants born SGA as defined by national population birth weight percentile[19] (≤ 10th percentile) were selected and a random sample of appropriate-for-gestational-age infants were selected as controls.

Information was collected by (1) a maternal interview that collected data on socio-demographic variables, obstetric history and detailed information about the index pregnancy, (2) data extracted from the electronic obstetric notes, (3) macroscopic and microscopic examination of the placenta and (4) two maternally self-completed FFQ.

The FFQ were completed shortly after the birth of the infant. They were semi-quantitative FFQ, identical and derived from the Life in New Zealand study questionnaires[20]. One FFQ asked the mothers about their frequency of consumption of individual foods in the first month of pregnancy and the other questionnaire about the last month before delivery of their baby. Questions were asked about individual foods in the broad categories: fresh fruits; vegetables; rice/noodles; chicken, meat or substitutes; dairy foods; puddings; cereals, cakes and biscuits; spreads, sauces and garnishes; snacks and takeaways; drinks. The questions on each food were asked in the following manner 'At about the time you became pregnant how often did you eat a serving of...' for the first month of pregnancy and 'During the last 4 weeks how often did you have a serving of...' for the last month of pregnancy. The choices were (1) not at all, (2) less than once a week, (3) once a week, (4) a few times a week, (5) once a day and (6) a few times a day. The questionnaire collected information on seventy-one food items.

Statistical methods

The analysis to determine characteristics of dietary patterns was carried out using all seventy-one food items from the early pregnancy questionnaire. This analysis was carried out using a principal components analysis with a varimax rotation using PROC FACTOR in Statistical Analysis Systems version 9.1 (SAS Institute, Cary, NC, USA). Using a varimax rotation ensured that the distributions of the scores would be centred around 0, with a standard deviation of 1. This allows easy interpretation of the results, as the point estimates from regression analyses will be equivalent to a change of the magnitude of the equivalent number of standard deviations.

A scree plot was used to determine the number of factors, along with the percentage of variance explained by each factor. The distribution of the loadings across dietary patterns was examined to ensure that there was no great overlap between factors. Factor loadings were considered to have a strong association when these had a magnitude of 0·3 or greater, and the foods within a factor with loadings of these values are considered to be descriptive of the 'pattern' of diet associated with this factor.

The weightings were then used to create scores for each woman for each of the three diets for both early and late pregnancy. In order to ensure the same interpretability of the results, we standardised the late pregnancy distributions so that the dietary scores would also have a mean of 0 and standard deviation of 1. Using the same weightings for early and late pregnancies enabled us first to have consistent dietary patterns across the pregnancy and second to assess the correlation between the time points to assess the change in diet from early to late pregnancy.

Associations between pattern of diet and independent predictors were assessed by linear regression. Because of the disproportionate sampling of the SGA infants at birth, analyses were weighted using PROC SURVEYREG in Statistical Analysis Systems (SAS Institute). Variables associated with each diet at the 10 % level in univariable analyses were included in a multivariable analysis.

To determine associations between dietary pattern and SGA, logistic regression was carried out with the individual diet factor scores used as independent variables. OR describe the change in risk of an SGA infant associated with a unit change (1 SD) in the diet score. Finally, the significant dietary scores were added to our previously published multivariable model of risk factors for SGA to assess whether dietary score had an additional effect to those variables already controlled for. This analysis controlled for gestational age, infant sex, maternal smoking during pregnancy, maternal height and pre-pregnancy weight, primiparity, ethnicity and maternal hypertension.

Table 1. Loading factors from factor analysis using varimax rotation for early pregnancy (a negative factor means the diet was less likely to have this food)

Food	Early pregnancy Fusion	Junk	Traditional
Percentage of variation explained	4·96 %	4·52 %	4·36 %
Avocados	0·05989	−0·00338	0·35023*
Berry fruits	0·20190	0·10609	0·34340*
Stone fruits	0·25774	0·05226	0·35746*
Apples/pears	0·39593*	0·01690	0·47179*
Citrus fruits	0·34872*	−0·02648	0·44923*
Kiwi/feijoa	0·33781*	0·02160	0·33764*
Melon	0·35940*	0·08943	0·21695
Bananas	0·34450*	0·11129	0·41833*
Dried fruits	0·01396	−0·07569	0·42527*
Tinned fruit	0·39723*	0·20196	0·19130
Tinned in water	0·35111*	0·08013	0·16012
Fruit pies	0·32507*	0·26801	0·14280
Green vegetables	0·08925	−0·19655	0·53287*
Root vegetables	0·04716	−0·01334	0·58861*
Peas/maize/lentils	0·18251	0·06739	0·40458*
Potato etc.	0·04236	0·24823	0·35930*
Fried rice/noodles	0·49956*	0·14764	−0·05139
Boiled rice/pasta	0·48352*	−0·20052	0·02018
Lean meat	0·23086	−0·01157	0·21724
Chicken with skin	0·36294*	0·07390	−0·07340
Meat with fat	0·19558	0·23684	−0·06090
Fish/shellfish	0·56350*	−0·02158	0·06023
Made-up meat dishes	0·39759*	0·12822	0·01838
Small goods	0·25106	0·27122	0·05043
Vegetarian substitute†	0·02997	0·08514	0·35895*
Soup with meat	0·66914*	0·12545	0·00295
Cream cheese	0·00072	0·00238	0·18977
Hard cheeses	−0·30063*	0·08763	0·39377*
Soft cheeses	−0·07805	0·01428	0·21978
Reduced fat cheese	−0·21617	−0·00753	0·39117*
Cream	0·06409	0·20721	0·15999
Condensed milk	0·35642*	0·04433	0·07087
Dairy food/yogurt	0·14356	0·11216	0·35464*
Milk pudding	0·27775	0·03523	0·05708
Fruit pudding	0·16049	0·13666	0·17698
Cake-type pudding	0·22111	0·28100	0·09154
Jelly	0·40233*	0·21676	−0·00817
Ice cream	0·36322*	0·45168*	0·11809
Plain biscuits	0·01820	0·33225*	0·32608*
Sweet biscuits	0·01108	0·52291*	0·14949
Scones	0·12196	0·39281*	0·19444
Croissants	0·19561	0·16656	0·15080
Cakes	0·29754	0·46053*	0·04529
Bread	−0·22284	0·27757	0·35569*
Porridge	0·32426*	0·12124	0·12738
Cereal	−0·04021	0·22766	0·23721
Sweetened cereal	0·21090	0·33057*	−0·02578
Sweet spreads	−0·19583	0·30498*	0·29615
Sauces	−0·14933	0·39517*	0·24862
Salad dressing	−0·14341	0·28411	0·32649*
Savoury spreads	−0·18416	0·23880	0·21248
Crisps	−0·00907	0·46637*	0·05501
Instants noodles	0·34801*	0·29805	−0·00487
Pies	0·15281	0·49800*	−0·12437
Crackers	0·04217	0·27793	0·26222
Muesli bar	−0·02712	0·21643	0·22880
Chocolate bar	0·00852	0·66536*	−0·08149
Lollies	0·04877	0·63642*	−0·08341
Roll up‡	0·16711	0·23064	−0·01586
Ice blocks	0·18164	0·55762*	−0·07295
Butter/margerine *v.* none	−0·02444	−0·22033	0·18842
Eggs	0·10479	0·04371	0·04799
Milk	0·42002*	0·06866	0·13417
Fruit juice/cordial	0·04509	0·22985	0·24688
Water	0·08344	−0·18521	0·37147*
Milo§	0·30575*	0·34992*	0·03566
Coffee/tea	−0·44878*	0·12730	0·20460
Decaffeinated beverages	0·01030	0·04517	0·13391
Sherry/wine	−0·33950*	−0·02927	0·23642
Beer	−0·15422	0·11858	0·08722
Spirits	−0·19884	0·03141	0·10432

* Loading factors above 0·3.
† Vegetarian substitute for meat such as tofu.
‡ Roll up – extruded fruit snack.
§ Milo – malted chocolate milk drink.

All analyses were carried out using Statistical Analysis Systems version 9.1 for windows (SAS Institute).

Subjects

Interview data were available for 1714 subjects of which 844 had been born SGA and 870 appropriate for gestational age. Nutritional questionnaires were returned for 1209 (71 %) women and 723 (83 %) European women. There were seventy-five early pregnancy questionnaires and seventy-three late pregnancy questionnaires that were incomplete and could not be analysed, leaving 1134 questionnaires for early pregnancy and 1136 questionnaires for late pregnancy diets available for analysis.

Results

Total sample

Analysis of data from early pregnancy indicated that three dietary patterns best described the dietary pattern of the women in the present study. For descriptive purposes, we have named the dietary patterns ‘junk’, ‘traditional’ and ‘fusion’. The list of foods and the loading factors are shown in Table 1. Of the seventy-one foods included in the analyses, fifty had a loading of greater than 0·3 for at least one of the three dietary patterns. For the ‘junk’ diet, foods identified as being characteristic included ice cream, sweet biscuits, scones, cakes, sweetened cereal, crisps, pies, lollies, chocolate bars, ice blocks and milo (chocolate energy drink). A traditional New Zealand diet is similar to a ‘traditional’ British diet, which is meat (lamb in particular), potatoes, carrots (and other root vegetables), peas, gravy, and meat dishes such as cottage pie. The ‘traditional’ diet included apples/pears, citrus fruit, kiwifruit/feijoas, bananas, green vegetables, root vegetables, peas/maize, dairy food/yogurt and water. The ‘fusion’ diet is one that combines elements of Asian cuisine with the addition of Western foods. The ‘fusion’ diet included fruits, fried rice/noodles, boiled rice/pasta, fish/shellfish, milk and negative loading for tea/coffee, sherry/wine and hard cheeses.

The distributions of the diet scores are shown in Fig. 1.

An analysis of the late pregnancy data showed similar dietary patterns (data not shown). Due to this reason and to avoid confusion of similar diets at two time points, we chose to apply the weightings from the early pregnancy diets to the

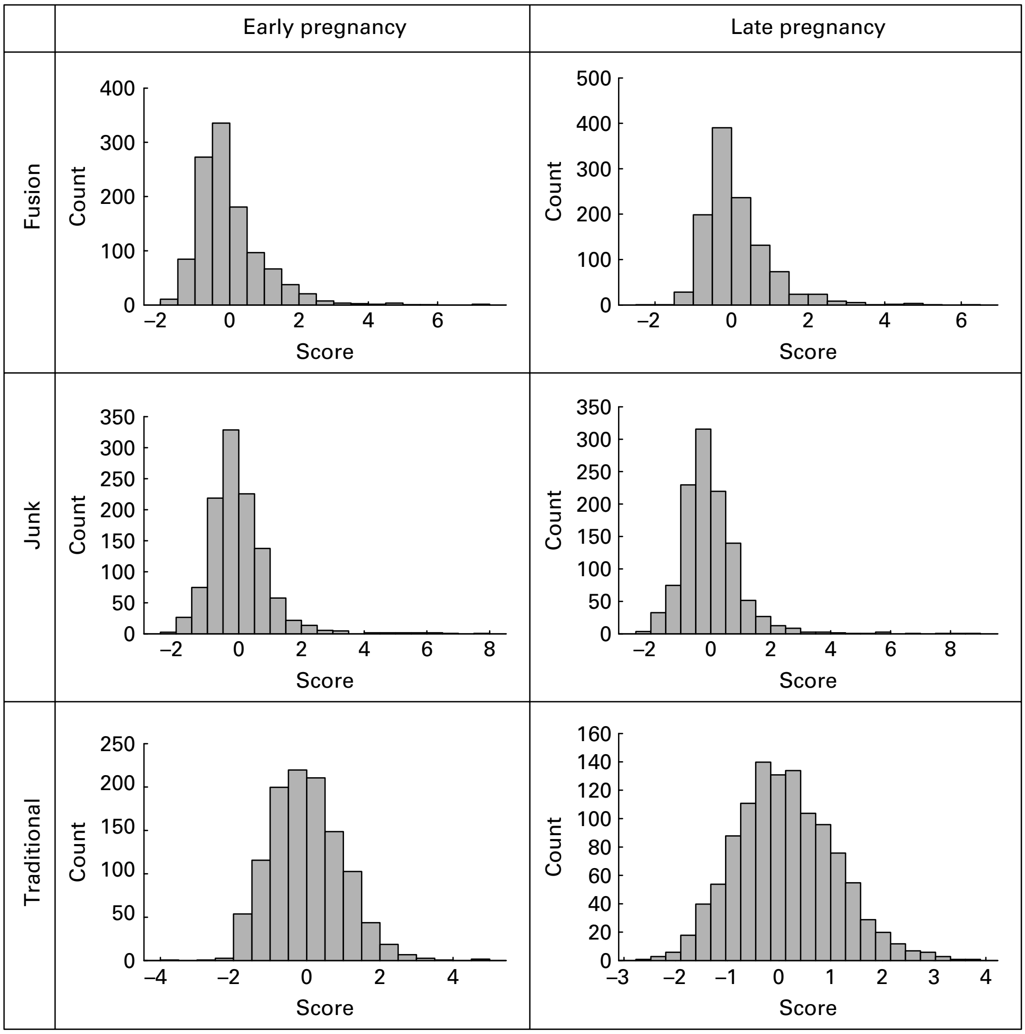

Fig. 1. Distribution of factor scores for diet in early and late pregnancy.

late pregnancy data. Analysis of non-standardised late pregnancy data revealed means of 0·13 (SD 0·88), 0·00 (SD 1·06) and 0·14 (SD 0·97). The correlation between the two time points for each dietary pattern was high. The correlation between the first and last months of pregnancy was 0·75 for the 'junk' diet, 0·74 for the traditional diet and 0·83 for the 'fusion' diet. In contrast, the correlation between the different dietary patterns, at the different time points, was poor. The relatively similar dietary score distributions in conjunction with the high correlations between early and late pregnancy suggest that there is little change in dietary pattern from the first to last month of pregnancy.

Factors associated with dietary habits

We analysed factors that were potentially related to mothers' choice of particular dietary patterns. We have only shown factors associated with early diet here, as the relationships with late diet were very similar.

For the junk diet, at the univariate level, women who were of lower or middle socio-economic status, were unmarried, smoked during pregnancy, were multiparous, had not attended antenatal classes and were heavier had an increased 'junk' diet score (Table 2). Furthermore, the score increased linearly with decreasing maternal age. In comparison to European women, the scores were higher for mothers of Maori and Pacific Island ethnicity and lower for Indian and Chinese women. When these variables were put into a multivariable model, only the relationship with ethnicity remained significant (Table 3).

For the traditional diet, women had higher scores if they were of high socio-economic status, left school after 16, were married or in a *de facto* relationship, did not smoke or use marijuana during pregnancy, were of average or taller than average height, of average weight and attended antenatal classes (Table 2). The score for this diet also increased linearly with maternal age and was higher among European women. Compared to European women, Maori, Pacific Island and Chinese women had statistically lower scores for this dietary pattern. In a multivariable analysis, those associations with marital status, maternal weight, maternal age and those of Maori and Chinese ethnicity remained statistically significant (Table 3).

For the 'fusion' diet, women of low or middle socio-economic status, of unmarried status and of average or shorter than normal height had higher scores. The score also increased with decreasing maternal age. Compared to European women, women of all other ethnicities had higher scores for this

Table 2. Univariable associations with each diet (early pregnancy), all subjects*
(OR and 95 % CI values)

	Fusion			Junk			Traditional		
	P	OR	95 % CI	*P*	OR	95 % CI	*P*	OR	95 % CI
Sex	0·98			0·85			0·75		
Male (*n* 585)		Ref			Ref			Ref	
Female (*n* 549)		0·00	−0·16, 0·16		−0·02	−0·18, 0·15		0·03	−0·13, 0·18
Socio-economic status	<0·0001			0·03			<0·0001		
High (*n* 622)		Ref			Ref			Ref	
Medium (*n* 350)		0·36	0·17, 0·56		0·26	0·04, 0·47		−0·47	−0·65, −0·30
Low (*n* 162)		1·04	0·72, 1·35		0·25	−0·05, 0·56		−0·42	−0·71, −0·12
Age left school (years)	0·0013			0·26			<0·0001		
< 16 (*n* 122)		−0·06	−0·32, 0·20		0·08	−0·10, 0·25		−0·62	−0·88, −0·37
16 (*n* 270)		−0·30	−0·47, −0·14		0·19	−0·06, 0·45		−0·14	−0·32, 0·04
> 16 (*n* 734)		Ref			Ref			Ref	
Marital status	0·03			0·02			<0·0001		
Married (*n* 821)		Ref			Ref			Ref	
De facto (*n* 188)		−0·19	−0·39, 0·01		0·27	0·04, 0·49		−0·31	−0·51, −0·11
Unmarried (*n* 125)		0·15	−0·07, 0·37		0·35	−0·05, 0·75		−0·96	−1·23, −0·69
Smoking during pregnancy	0·81			0·0072			<0·0001		
Yes (*n* 254)		−0·02	−0·20, 0·16		0·34	0·09, 0·59		−0·46	−0·68, −0·25
No (*n* 870)		Ref			Ref			Ref	
Marijuana use during pregnancy	0·04			0·24			0·0002		
Yes (*n* 75)		−0·19	−0·38, −0·01		0·34	−0·22, 0·90		−0·61	−0·94, −0·29
No (*n* 1051)		Ref			Ref			Ref	
Parity	0·18			0·0044			0·93		
Primiparous (*n* 437)		Ref			Ref			Ref	
Multiparous (*n* 697)		0·11	−0·05, 0·27		0·22	0·07, 0·38		−0·01	−0·17, 0·15
Maternal height (cm)	<0·0001			0·37			0·08		
< 158 (*n* 269)		0·46	0·25, 0·67		0·18	−0·10, 0·46		−0·27	−0·53, −0·02
158–168 (*n* 579)		0·23	0·07, 0·40		0·09	−0·08, 0·27		0·02	−0·19, 0·16
> 168 (*n* 274)		Ref			Ref			Ref	
Maternal weight (kg)	<0·0001			0·0008			0·0018		
< 54 (*n* 267)		0·07	−0·33, 0·37		−0·50	−0·78, −0·23		0·02	−0·20, 0·24
54–70 (*n* 609)		−0·38	−0·59, −0·18		−0·42	−0·65, −0·18		0·29	0·10, 0·49
> 70 (*n* 246)		Ref			Ref			Ref	
Antenatal classes	<0·0001			0·0004			0·0038		
Yes (*n* 452)		−0·57	−0·71, −0·43		−0·27	−0·43, −0·12		0·24	0·08, 0·40
No (*n* 668)		Ref			Ref			Ref	
Maternal age	<0·0001			<0·0001			<0·0001		
Per year		−0·034	−0·049, −0·020		−0·035	0·049, −0·021		0·054	0·039,0·068
Ethnicity	<0·0001			<0·0001			<0·0001		
European (*n* 699)		Ref			Ref			Ref	
Maori (*n* 91)		0·50	0·36, 0·65		0·62	0·20, 1·04		−0·87	−1·09, −0·65
Pacific (*n* 135)		1·54	1·23. 1·84		0·83	0·44, 1·22		−0·54	−0·85, −0·23
Indian (*n* 62)		0·77	0·54, 0·99		−0·33	−0·63, −0·04		0·05	−0·35, 0·25
Chinese (*n* 87)		1·95	1·59, 2·30		−0·90	−1·05, −0·76		−0·54	−0·79, −0·30
Other Asian (*n* 44)		1·53	0·94, 2·12		−0·09	−0·59, 0·40		−0·07	−0·68, 0·53
Other (*n* 15)		0·64	0·35, 0·92		0·00	−0·60, 0·59		−0·60	−1·30, 0·10

Ref, reference.
* Estimates are changes (equivalent to number of standard deviations) in diet score for each category compared to the reference group, and in the case of maternal age the change in diet score per year of age.

Table 3. Multivariable risk factors for each diet (early pregnancy)*
(OR and 95 % CI values)

	Fusion			Junk			Traditional		
	P	OR	95 % CI	*P*	OR	95 % CI	*P*	OR	95 % CI
Socio-economic status	0·0048								
High		Ref							
Medium		0·14	−0·02, 0·31						
Low		0·39	0·11, 0·68						
Marital status							0·0026		
Married								Ref	
De facto								−0·19	−0·40, 0·03
Unmarried								−0·63	−0·99, −0·27
Maternal weight (kg)							0·02		
< 54								0·01	−0·23, 0·25
54–70								0·21	0·02, 0·40
> 70								Ref	
Maternal age							0·0099		
Per year								0·023	0·006, 0·040
Ethnicity	< 0·0001			< 0·0001			0·0004		
European		Ref			Ref			Ref	
Maori		0·48	0·29, 0·67		0·25	−0·09, 0·59		−0·33	−0·60, −0·06
Pacific		1·36	1·03, 1·69		0·71	0·31, 1·12		−0·25	−0·59, 0·09
Indian		0·67	0·45, 0·90		−0·24	−0·56, 0·07		0·10	−0·42, 0·21
Chinese		1·81	1·45, 2·18		−0·94	−1·16, −0·72		−0·62	−0·90, −0·35
Other Asian		1·49	0·93, 2·05		−0·07	−0·57, 0·42		−0·13	−0·77, 0·51
Other		0·37	0·08, 0·65		−0·09	−0·76, 0·58		−0·56	−1·20, 0·07

Ref, reference.
* Estimates are changes (equivalent to number of standard deviations) in diet score for each category compared to the reference group, and in the case of maternal age the change in diet score per year of age. Only significant variables shown.

diet. In multivariable analysis, the associations with socio-economic status and ethnicity remained significant.

Associations between dietary patterns and birth weight of infant

In logistic regression models of SGA, at a univariate level, traditional diet scores in early pregnancy showed a protective effect for an SGA infant (OR = 0·79; 95 % CI 0·70, 0·89; per standard deviation change in score), while in late pregnancy, the effect was similar (OR = 0·83; 95 % CI 0·74, 0·94; Table 4). When both time periods were put in a model together, the effect of diet in early pregnancy remained significantly associated with SGA and that of late pregnancy was no longer significant (Table 4). The junk and fusion diet scores showed no significant effect on SGA.

When the early diet factor scores were added to the main model that has been published previously[2], the traditional diet score showed a reduced risk of SGA (OR = 0·89; 95 % CI 0·78, 1·03), the removal of non-significant variables from this model rendered this effect significant at the 5 % level (OR = 0·86; 95 % CI 0·75, 0·99). The final model included gestational age, infant sex, maternal smoking during pregnancy, maternal height and pre-pregnancy weight, primiparity, ethnicity and maternal hypertension. Other variables controlled for but removed from the final model as they were no longer significant were socio-economic status, age mother left school, marital status, marijuana use during pregnancy and attendance at antenatal classes. All variables remaining

Table 4. Univariable and multivariable associations between diet and small-for-gestational-age infants, all subjects
(OR and 95 % CI values)

	Univariable model		Multivariable model*		Final multivariable model†	
Diet type	OR	95 % CI	OR	95 % CI	OR	95 % CI
Diet in early pregnancy						
Fusion	1·07	0·95, 1·21	1·15	0·91, 1·14	1·02	0·85, 1·21
Junk	0·97	0·86, 1·09	0·99	0·82, 1·18	1·01	0·88, 1·17
Traditional	0·79	0·70, 0·89	0·79	0·66, 0·95	0·86	0·75, 0·99
Diet in late pregnancy						
Fusion	1·05	0·92, 1·20	0·91	0·90, 1·18		
Junk	0·97	0·87, 1·08	0·99	0·83, 1·17		
Traditional	0·83	0·74, 0·94	1·01	0·84, 1·23		

* Multivariable model includes dietary scores for early and late pregnancy.
† Mulitvariable model controls for gestation, infant sex, maternal smoking in pregnancy, maternal pre-pregnancy height and weight, parity, ethnicity and maternal hypertension.

in the model had similar significance levels and OR as in the original published model.

Discussion

We have shown that semi-quantitative FFQ used during pregnancy can be used to describe maternal dietary patterns. Additionally, having defined these dietary patterns, we were able to describe the relationship between pattern of diet that a mother is consuming and the effect of this diet in relation to giving birth to an SGA infant, namely that mothers who eat a ‘traditional’ diet during pregnancy were less likely to give birth to an SGA infant. Our analysis has also shown that a number of factors, particularly socio-demographic factors, are related to diet. We and others have previously shown that lower socio-economic status is related to birth weight and an increased risk of an SGA infant[2]. After controlling for these variables, there continued to be a lower risk of SGA, as the score for the ‘traditional’ dietary pattern increased.

Until very recently, there have been little data on dietary patterns of mothers during pregnancy. One older study in Mexican-American women described seven dietary factors[21]; similarly, a Finnish study also found seven dietary patterns[22]; however, they chose a relatively low factor loading score of 0·2, compared to 0·3 used by most other studies. Beyond the first two dietary patterns, the additional percentage of variance explained was relatively low. A recent publication from a large Danish study has described two dietary factors that they used to categorise women into three dietary patterns[23]. An analysis from the Avon Longitudinal Study of Pregnancy and Childhood in Britain has described five dietary factors[24], while data from a Southhampton study defined two dietary patterns termed ‘prudent’ and ‘Western’[25].

A more in-depth study of diet that collected data six times from pre-conception to 6 months postnatally, in a group of eighty women, in Spain, described two dietary patterns, described as ‘sweetened beverages and sugar’ and ‘vegetables and meat’[26]. It is notable that the factor loadings across time varied considerably using this methodology as shown by their coefficients of congruence, which were good between some time points but poor between others. In comparison, our use of the same dietary definition at both time points showed good correlation between the dietary scores in early and late pregnancy. This in conjunction with similar distributions of dietary scores in early and late pregnancies indicates a relative lack of change in diet during pregnancy for individuals.

The foods and dietary pattern described in our three dietary types are similar to that previously described. For consistency, we have used similar terminology to describe them. While the range of foods eaten across different countries and cultures varies and hence there will always be differences in the questionnaires used, the relative consistency of dietary factors produced in factor analyses is reassuring and confirms the usefulness of this type of analysis for semi-quantitative FFQ.

The study in Mexican-American mothers found that nutrient-dense and protein-rich foods were associated with an increase in infant birth weight, while a diet termed traditional that contained fats and oils, high-fat meats and sugar was associated with a decrease in birth weight[21]. The recent results of the Danish study by Knudsen *et al.*[23] showed that those mothers who had the highest intakes of red and processed meats, potatoes and high dairy fat with low intakes of fruits and vegetables had the lowest birth weights. Additionally, when the present study defined three groups from their two dietary types, they found a decreased risk of having an SGA infant among the healthier diets[23]. The British study found the lowest birth weights associated with processed and vegetarian diets and the highest birth weights associated with health conscious diets[27]. In general, there is concordance across all studies with better outcomes in terms of birth weight with what are perceived as healthier diets.

Anecdotally, eating of junk food is associated with increased levels of obesity; however, there is no evidence to our knowledge on human subjects as to the reasons for this (apart from energy balance). Some animal studies do give us an insight into the possible mechanisms. In a study in which rats were fed four times their normal lard intake compared to control rats, the lard fed rats ate less but had the same energy intake and there was no effect on birth weight[28]. Another study that increased maternal food consumption in sheep by 50 % increased birth weight, but suggested that the increased energy intake placed a different metabolic demand on the mother resulting in this energy being laid down as maternal fat[29].

A study on rats fed a ‘cafeteria’ diet (which consisted of an *ad libitum* choice of palatable processed food with a high fat or high sugar content including muffins, jam doughnuts, biscuits, cheese, marshmallows, potato crisps and chocolate bars in addition to rat chow) showed no significant difference in birth weight of pups compared to controls; however, those pups whose mothers were continued on a cafeteria diet until weaning had increased perineal fat pads compared to controls and also to a group that reverted back to a normal diet after birth. Adiposity was avoided when pups were reverted back to the normal diet but muscle atrophy and fibre hypoplasia remained[30,31].

A further study with a similar design showed that those rats offered a cafeteria diet along with their normal diet ate 40 % more food and had 56 % more energy than controls, with only 20 % of their total energy coming from their normal food. At the end of pregnancy, compared to controls, the junk diet rats were 13 % heavier and there was no difference in litter size but a significant reduction in birth weight among the pups of approximately 4 %[32].

The parallels of this would suggest the human mothers who tend towards eating ‘junk’ diets not only eat less healthily but also eat more of this unhealthy food. The outcome in terms of early childhood is likely to depend on whether an infant is breastfed, a factor that differs significantly in prevalence across Western countries. The longer-term outcomes would appear more perilous, however, as one would expect the diet of the child to follow that of their parents as they become older.

There are limitations to any study investigating nutritional intake. We collected the information on early and late pregnancy dietary intakes retrospectively shortly after the birth of the child. Recall bias could be an issue, particularly for the early pregnancy data; we did, however, give cues to the mother about when this timeframe was, to help recall. We have also carried out a test–retest study using these questionnaires, with the mother filling out the questionnaires in early pregnancy and then again after the birth of the child.

This found some regression towards the mean for intakes of foods[18]. This could explain some of the similarities in dietary patterns and weightings between the time points. This would suggest less variation in the retrospectively collected data than is present at the time of intake, hence making differences found to be potentially conservative. Collecting dietary intake via FFQ has its limitations but is the primary and practical way of collecting nutritional data in large epidemiological studies. The use of a FFQ in the present study to determine dietary habits enables a longer-term view of dietary intakes as opposed to using a 24-h dietary recall or food diary method. However, FFQ cannot represent the total diet and there are assumptions made about ingredients used for composite dishes. This FFQ has previously been validated in studies in younger children, which described dietary intakes and Fe status.

The methodology of using principal components analysis is becoming commonly used to reduce a large number of foods collected using FFQ to a smaller set of variables. It is ideal for analysing dietary data of the type collected here, and the results across similar populations appear to be relatively similar. There are of course weaknesses to using this method; the dietary patterns are not chosen *a priori* but are driven by the data and hence no two studies will identify identical diets, making direct comparison between studies impossible. Also, there are no strict cut-offs for the additional percentage of variance explained to decide on how many factors should be chosen or on the cut-off for loading scores to determine which foods should be considered important in each dietary pattern. The results obtained from these sorts of analyses to date and the sense of relationships of dietary patterns to socio-demographic variables and to outcomes such as birth weight enforce the appropriateness of using this type of analysis for data of this nature.

These results, if confirmed, have major implications for antenatal care and pregnancy planning. We have shown that although the effects of a ‘traditional’ diet were significant univariately for both early and late pregnancies, the major effect was that associated with early pregnancy. Although emphasis is placed on early and pre-pregnancy, for example, ensuring adequate intakes of folate to protect against neural tube defects, the present results add to the reasons for careful planning in early and pre-pregnancy. From a public health perspective, this will be difficult, as 45 % of the pregnancies in the present study were unplanned.

The response rate among the European sample was high, and we can be confident that the results for this group are representative of this group of women. A limitation of the study, however, was the lower response rate seen among other ethnic groups. Previous analysis has shown the non-respondents are also more likely to be in the lower socio-economic groups. There needs to be caution in interpreting the results in other ethnic groups.

In conclusion, maternal diet particularly in early pregnancy is important for the development of the fetus. Socio-demographic factors tend to be significantly related to dietary pattern, suggesting that extra resources may be necessary for disadvantaged mothers so that they can purchase more healthy foods, which tend to be more expensive than high-energy foods. Eating well during pregnancy is essential for the future health of the unborn child.

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