Childhood dietary patterns and body composition at age 6 years: the Children of Screening for Pregnancy Endpoints (SCOPE) study

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Abstract

Dietary patterns describe the combination of foods and beverages in a diet and the frequency of habitual consumption. Better understanding of childhood dietary patterns and antenatal influences could inform intervention strategies to prevent childhood obesity. We derived empirical dietary patterns in 1142 children (average age 6·0 (SD 0·2) years) in New Zealand, whose mothers had participated in the Screening for Pregnancy Endpoints (SCOPE) cohort study and explored associations with measures of body composition. Participants (Children of SCOPE) had their diet assessed by FFQ, and dietary patterns were extracted using factor analysis. Three distinct dietary patterns were identified: 'Healthy', 'Traditional' and 'Junk'. Associations between dietary patterns and measures of childhood body composition (waist, hip, arm circumferences, BMI, bioelectrical impedance analysis-derived body fat % and sum of skinfold thicknesses (SST)) were assessed by linear regression, with adjustment for maternal influences. Children who had higher 'Junk' dietary pattern scores had 0·24 (SD 0·08; 95 % CI 0·04, 0·13) cm greater arm and 0·44 (SD 0·05; 95 % CI 0·01, 0·10) cm greater hip circumferences and 1·13 (SD 0·07; 95 % CI 0·03, 0·12) cm greater SST and were more likely to be obese (OR 1·74; 95 % CI 1·07, 2·82); those with higher 'Healthy' pattern scores were less likely to be obese (OR 0·62; 95 % CI 0·39, 1·00). In a large mother–child cohort, a dietary pattern characterised by high-sugar and -fat foods was associated with greater adiposity and obesity risk in children aged 6 years, while a 'Healthy' dietary pattern offered some protection against obesity. Targeting unhealthy dietary patterns could inform public health strategies to reduce the prevalence of childhood obesity.

Key words: Dietary patterns: Body composition: Pregnancy: Childhood obesity

Childhood obesity impacts on both health in childhood and adult life[1]. Global estimates from the WHO indicate that 18 % of children and adolescents aged 5–19 years were overweight or obese in 2016[2]. Diet is a key determinant of childhood obesity[3]; as dietary habits established in early childhood may track into adulthood[4,5], interventions which change dietary intake early in life have the potential to improve lifelong health. Effective intervention strategies will depend on better understanding of the specific dietary elements which contribute to obesity risk.

The assessment of dietary patterns provides a practical alternative to the more conventional measurement of isolated nutrients and dietary components, the limitations of which are appreciated[6]. Dietary patterns can be derived by one of the two approaches: theoretically, in which dietary variables are grouped according to *a priori* criteria of nutritional health, for example, a dietary index, or empirically, where dietary variables are condensed into clusters of variables using statistical modelling and examined *a posteriori*[7]. This study used the empirical

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method as an assessment of total diet as it is more likely to be informative when addressing dietary risk factors for childhood obesity than diet indexes which focus on selected foods or nutrients.

Despite being widely explored in adult cohorts[8], relationships between empirical dietary patterns and childhood obesity risk have seldom been studied[9,10], especially in the context of contemporary mother–child cohorts. Ideally, associations between childhood dietary patterns and obesity are best examined in studies with information on the potentially confounding effects of maternal obesity, gestational diabetes and the mother's own dietary patterns[11,12] and have potential to inform the development of complex interventions for mother and child.

Here, we describe a study in which we have determined empirical dietary patterns of 6-year-old children from the Children of Screening for Pregnancy Endpoints (SCOPE) (CoS) study. Their mothers were participants in the Auckland New Zealand centre of the International SCOPE study[13]. The overall objective of CoS was to identify the early life modifiable determinants of obesity and insulin resistance in children at 5–6 years of age. We have examined relationships between dietary patterns and measures of childhood obesity as assessed by childhood body composition (waist, hip and arm circumferences; BMI; bioelectrical impedance analysis-derived body fat % and sum of skinfold thicknesses) with the aim of informing new targets for intervention. Associations of maternal influences on childhood dietary patterns were also examined and taken into account as potential confounders for associations between childhood diet and adiposity.

Methods

Children of Screening for Pregnancy Endpoints (SCOPE)

CoS is a follow-up study of the offspring of women who participated in the Auckland arm of the SCOPE cohort study. SCOPE is a prospective international cohort study which aimed to identify factors in early pregnancy that predicted women at high risk of developing pre-eclampsia, spontaneous preterm birth and fetal growth restriction[13]. Nulliparous women with a singleton pregnancy were recruited at 15 weeks' gestation and a second research visit carried out at 20 weeks' gestation; detailed demographic and clinical data were recorded at each visit and at delivery and for any pregnancy complications. Details of the SCOPE study have been previously described[13]. For a child to be eligible to participate in CoS, the mother agreed to be contacted about the follow-up study and the child was aged between 5 and 6·25 years. Children with major health problems that might affect growth were excluded.

From the 2032 mothers included in the Auckland SCOPE cohort, 1208 (59 %) mothers and their children were recruited. We previously reported no difference in maternal BMI between participants in CoS and the original complete Auckland cohort; however, the mothers in CoS were more likely to be older, White, have a higher educational attainment and higher socioeconomic status, were less likely to smoke in their first trimester and were less likely to have delivered before 37 weeks[14]. Of the 1208 mother–child dyads, thirty-five were excluded due to

missing or implausible body fat %. The final study population included 1173 mother–child dyads, and a total of 1142 children had information on dietary intake collected to extract dietary patterns. All women provided consent for participation of their children. Ethical approval was granted by the Auckland Ethics Committee (AKX/02/00/364).

Dietary assessment and dietary patterns

At the follow-up visit, a research nurse asked the child's main caregiver to complete a FFQ about the child's diet. This was based on a FFQ developed for the New Zealand Children's National Nutrition Survey[15] and requests information on the consumption of 118 food and beverage items. Accompanying this list was a multiple response grid which estimated frequency of consumption of the food and beverages in the preceding month, ranging from 'never or less than once per month' to 'two or more times per d'. Each food and beverage item had a standard serving size (e.g. slice of bread, apple). Where individual food items were unanswered, we imputed data using the MICE methodology. We used ten burn-ins, followed by the construction of ten imputed data sets. Data were imputed if <20 % of items were missing.

Factor analysis with varimax rotation was performed to derive dietary patterns in each of the imputed data sets. The number of factors was chosen using the scree plot of eigenvalues and the interpretability of the factor loadings. Foods with a factor loading of ≥± 0·30 were considered to have a strong association with that factor. We then averaged factor loading for the dietary patterns across the imputed data set. These factor loadings were then applied across an averaged imputed data set constructed by averaging the responses across the imputed data sets. Sensitivity analyses were carried out to assess the MICE methodology to simple imputation of making an assumption that missed items were not answered because they were not consumed.

Childhood body composition

At the follow-up visit, the child's body composition was assessed using anthropometric and bioelectrical impedance analysis measurements. Arm circumference (cm) was measured at the mid-point between the edge of the shoulder bone and bony tip of the right elbow. Waist circumference (cm) was assessed at the mid-point between the lowest rib and top of the hip. Hip circumference (cm) was taken as the distance around the maximal diameter of buttocks. For estimation of BMI (kg/m^2), weight (kg) was measured in light clothing without shoes to the nearest 0·1 kg and height (cm) assessed in a standing position with a stadiometer. Childhood obesity was defined as BMI z-score > 2 SD according to WHO's child growth standards[16]. Body fat % was determined by bioelectrical impedance analysis (ImpediMed SFB7 tetra polar bioimpedance spectroscopy). Fat-free mass was calculated using: fat-free mass = 0·65 (height^2/impedance) + 0·686 × age + 0·15[17]. Body fat % was estimated using: (weight − fat-free mass)/weight × 100. Subscapular, triceps, biceps and suprailiac skinfold thicknesses (mm) were measured using Holtain skinfold callipers and summed to give sum of skinfold thicknesses. All measurements were taken in triplicate and mean values calculated.

Covariates

In the SCOPE study, maternal demographic, clinical and lifestyle data were recorded. This included maternal age, BMI (kg/m^2) at 15 weeks' gestation, ethnicity, socio-economic status (New Zealand Socio-economic Index 1996, education (years)), alcohol use pre-pregnancy, smoking during the first trimester, multivitamin use pre-pregnancy, maternal mood (Edinburgh Postnatal Depression Scale at 15-week visit), television (number of hours watched per d in the last month, evaluated at the 15-week visit), gestational hypertension (defined as systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg on at least two occasions after the 20-week visit and before onset of labour), gestational diabetes mellitus diagnosis (any of: (1) 75 g oral glucose tolerance test (OGTT) fasting glucose ≥5·5 mmol/l and/or 2 h ≥9·0 mmol/l, or (2) polycose 1 h glucose > 11·0 mmol/l and no OGTT available, or (3) fasting glucose ≥5·5 mmol/l and no polycose or OGTT available, or (4) random glucose > 11 mmol/l and no polycose, OGTT or fasting glucose), biomarkers measured from maternal blood samples including placental growth factor. At the time of birth, data were collected on premature birth, birth weight (g), gestational age (weeks), child's age and sex and breast-feeding (exclusive breast-feeding at discharge form obstetric unit).

Statistical analysis

Descriptive data are presented as mean values and standard deviations, frequencies and percentages, or medians and interquartile ranges as appropriate. Multiple regression analysis was carried out to examine the associations between maternal influences (including maternal BMI, ethnicity, cigarette smoking in the first trimester, multivitamin use pre-pregnancy, breast-feeding, socio-economic status, education and age[12,18]) and children's dietary patterns. To investigate the relationship between childhood dietary patterns and body composition, linear regression was used. Two models were generated: model 1, where simple linear regression with no adjustment for confounding variables was performed, and model 2, multiple linear regression including adjustment for confounders. Confounders were chosen *a priori* based on known associations with obesity[14,19–29]. The maternal and early postnatal exposures used in the adjusted model were maternal BMI, ethnicity, socio-economic status, multivitamin use pre-pregnancy, alcohol intake pre-pregnancy, cigarette smoking in first trimester, time spent watching television in first trimester, depression in first trimester, gestational hypertension, gestational diabetes mellitus diagnosis, maternal plasma placental growth factor at 15 weeks' gestation, breast-feeding and infant sex. Standardised β-coefficients are presented which represent the SD in body composition measure per SD change in dietary pattern score, enabling comparison across outcomes. Data were analysed using Stata software, version 15.0 (StataCorp).

Results

Characteristics of the study population

The characteristics of the women and children are presented in Table 1. At 15 weeks' gestation, the average age of the

Table 1. Maternal and child characteristics in Screening for Pregnancy Endpoints (SCOPE) and the Children of SCOPE studies (*n* 1142)
(Mean values and standard deviations; numbers and percentages; median values and interquartile ranges)

Maternal characteristics (15 weeks' gestation)	n	%
Age (years)		
Mean	31·0	
SD	4·4	
BMI (kg/m^2)		
Median	23·9	
Interquartile range	21·8–26·6	
BMI (categorical; kg/m^2)		
<18·5	8	0·7
18·5–24·9	698	61·2
25·0–29·9	321	28·1
≥30	113	9·9
Ethnicity		
White	1001	87·6
Asian	44	3·9
Indian	36	3·2
Maori	34	2·9
Other	16	1·4
Pacific	11	0·9
Socio-economic status (NZSEI)		
High (56–90)	315	27·6
Medium (32–55)	677	59·3
Low (10–31)	150	13·1
Education (years)		
<12	65	5·7
12–13	1058	92·6
>13	19	1·6
Smoking in first trimester	107	9·4
Alcohol intake pre-pregnancy	631	54·5
Multivitamin use pre-pregnancy	377	33·3
Gestational diabetes	18	1·7
Gestational hypertension	61	5·3
Television (hours watched per d)		
<2	483	42·4
2–4	586	51·5
>4	70	6·2
Characteristics at follow-up		
Maternal BMI (categorical; kg/m^2)		
<18·5	23	2·0
18·5–24·9	622	54·5
25·0–29·9	327	28·7
≥30	169	14·8
Child's age		
Mean	6·0	
SD	0·2	
Child's sex (female)	578	50·6
Child's height (cm)		
Mean	117·9	
SD	4·9	
Child's weight (kg)		
Median	21·7	
Interquartile range	20·0–23·7	
Child's BMI (*z*-score)		
Mean	0·28	
SD	0·91	
Child overweight or obese (BMI *z*-score ≥ 1 SD)*		
Mean	176	
SD	15·4	
Child overweight (BMI *z*-score ≥1 SD, <2 SD)		
Mean	145	
SD	12·7	
Child obese (BMI *z*-score ≥ 2 SD)		
Mean	31	
SD	2·71	
Child's body fat %		
Mean	22·8	
SD	6·3	

Table 1. (*Continued*)

Maternal characteristics (15 weeks' gestation)	n	%
Child's arm circumference (cm)		
Mean	18·6	
SD	1·7	
Child's waist circumference (cm)		
Mean	55·4	
SD	4·0	
Child's hip circumference (cm)		
Mean	61·6	
SD	4·9	
Child's sum of skinfolds (mm)		
Mean	30·5	
SD	9·3	

NZSEI, New Zealand Socio-Economic Index.
* World Health Organization (2007)[16].

mothers was 31·0 (SD 4·4) years and the median BMI was 23·9 (interquartile range 21·8–26·6) kg/m^2. The majority of women were of White ethnicity (87·6 %). The average age of the children at the follow-up visit was 6·0 (SD 0·2) years. A total of 176 (15·1 %) children were overweight or obese according to WHO standards.

Dietary patterns

A total of 1142 children had complete data in the imputed data sets. Factor analysis identified three distinct dietary patterns at age 6 years; for ease of description, we have termed these as Healthy, Traditional and Junk in line with other previously published studies[30]. The factor loadings for the dietary patterns are shown in online Supplementary Table S1. The 'Healthy' diet was characterised by high loadings including a number of fruits (berries, stone fruits, feijoas/kiwifruit, pineapple) and vegetables (avocado, tomato, green leafy vegetables, celery, cucumber, green beans, pepper). The 'Traditional' diet was based on a number of meat (meat and poultry in casseroles, roasted as part of a dish) and carbohydrate (potato, taro, kumara, and pumpkin either steamed, boiled or roasted). The 'Junk' diet was characterised by high loadings on candy bars, potato crisps, lollies or sweets, sausage rolls, and bought cake or muffin (Table 2). A number of other items in the Junk dietary pattern had loadings between 0·25 and 0·30 but were not consistently above 0·3 across factor analyses of the imputed data sets.

In sensitivity analyses, a factor analysis using data imputed by replacing missing data with never resulted in very similar dietary patterns and loadings. Examination of the imputed data set showed that in general, a large proportion of missing values on individual items were imputed as never.

Associations between maternal influences and dietary patterns

The dietary patterns had differing associations with maternal influences, which were robust to adjustment (Table 3). Children who had higher 'Healthy' dietary pattern scores were more likely to have mothers who had a lower early pregnancy BMI, of Indian ethnicity (and less likely to be Maori), who had a higher level of educational attainment and who took multivitamins pre-pregnancy (all *P* < 0·05). Children who had higher

Table 2. Dietary patterns identified using factor analysis

Variable	Healthy	Traditional	Junk
Avocado	0·45*	0·03	−0·09
Green beans	0·34*	0·15	−0·07
Berries	0·49*	−0·13	−0·02
Cake/muffin/bun	0·15	0·05	0·32*
Brown rice	0·36*	0·03	−0·09
Candy bars	0·05	0·10	0·46*
Celery	0·38*	0·11	0·01
Cucumber	0·34*	−0·06	−0·03
Dried fruit	0·32*	0·06	−0·02
Feijoas/kiwifruit	0·38*	0·12	0·02
Fish fillets not in breadcrumb/batter	0·31*	0·11	−0·03
Green leafy vegetables	0·41*	0·25	−0·08
Kumera/pumpkin roasted	0·18	0·42*	0·01
Kumera/pumpkin steamed or boiled	0·19	0·37*	−0·03
Lentils/chickpeas/other beans	0·37*	0·09	−0·12
Lollies/sweets	−0·03	−0·09	0·31*
Meat as part of dish (beef/pork/lamb)	0·05	0·36*	0·02
Meat casseroles (beef, pork, lamb)	0·08	0·45*	0·04
Meat roasted (beef/pork/lamb)	0·02	0·42*	0·12
Mixed vegetables	0·18	0·40*	0·09
Nuts	0·33*	−0·01	−0·02
Other fruit	0·33*	0·11	−0·02
Pepper	0·34*	0·05	−0·05
Pineapple	0·37*	0·09	0·08
Potato/other crisps	−0·17	0·06	0·34*
Potato/taro roasted	0·09	0·34*	0·08
Potato/taro steamed or boiled	0·03	0·36*	0·01
Poultry as part of dish	0·11	0·38*	0·02
Poultry casseroles	0·15	0·44*	0·07
Poultry roasted	0·01	0·32*	0·11
Sausage rolls	0·07	0·19	0·30*
Stone fruit	0·45*	−0·06	0·01
Tomato	0·43*	0·00	−0·03
Yogurt	0·31*	0·02	−0·01

* Factor loadings ≥±0·3 for each identified dietary pattern.

'Traditional' dietary pattern scores were more likely to have mothers of Pacific Islander ethnicity, who had a lower socio-economic status were younger (all *P* < 0·05). Children who had higher 'Junk' dietary pattern scores were more likely to have mothers of Indian or Pacific Islander ethnicity that smoked in the first trimester and had a lower educational attainment (all *P* < 0·05).

Associations between children's dietary patterns and body composition

The association between children's dietary patterns and body composition at age 6 years is shown in Table 4. Children who had higher 'Healthy' pattern scores were less likely to be obese according to WHO child growth standards in models 1 and 2 (adjusted OR 0·62; 95 % CI 0·39, 1·00).

Children who had higher 'Junk' pattern scores had greater arm (adjusted *β* = 0·08; 95 % CI 0·04, 0·13) and hip (adjusted *β* = 0·05; 95 % CI 0·01, 0·10) circumferences and sum of skinfold thicknesses (adjusted *β* = 0·07; 95 % CI 0·03, 0·12). Furthermore, children who had higher 'Junk' pattern scores were more likely to be obese (OR 1·74; 95 % CI 1·07, 2·82). These associations were robust to adjustments for confounders.

Children who had higher 'Traditional' dietary pattern scores had greater arm, waist and hip circumferences, body fat % and

Table 3. Multiple regression analysis of the maternal influences associated with child's dietary patterns at 6 years (n 1142)*
(Adjusted β-coefficients and 95 % confidence intervals)

Characteristics	Healthy			Traditional			Junk		
	Adjusted β	95 % CI	P	Adjusted β	95 % CI	P	Adjusted β	95 % CI	P
Early-pregnancy BMI (kg/m²)	−0.03	−0.04, −0.02	<0.001	0.01	−0.001, 0.02	0.071	0.01	−0.003, 0.02	0.140
Ethnicity			0.002			<0.001			0.002
White	Reference			Reference			Reference		
Asian	−0.10	−0.36, 0.15		0.14	−0.10, 0.37		0.002	−0.23, 0.23	
Indian	0.32	0.04, 0.61		−0.05	−0.31, 0.21		0.28	0.03, 0.54	
Maori	−0.32	−0.61, −0.02		0.22	−0.05, 0.48		0.12	−0.14, 0.38	
Other	0.64	0.21, 1.07		0.60	0.20, 0.99		0.47	0.08, 0.85	
Pacific Islander	−0.21	−0.73, 0.30		0.79	0.32, 1.26		0.70	0.24, 1.16	
Cigarette smoking in first trimester	0.10	−0.08, 0.27	0.274	0.01	−0.15, 0.17	0.942	0.25	0.09, 0.41	0.002
Multivitamin use pre-pregnancy	0.13	0.02, 0.24	0.016	−0.09	−0.19, 0.01	0.064	−0.01	−0.10, 0.08	0.833
Breast-feeding	0.10	−0.02, 0.22	0.098	−0.02	−0.13, 0.08	0.688	0.01	−0.10, 0.11	0.920
Socio-economic status			0.311			<0.001			0.290
High	−0.02	−0.13, 0.10		−0.21	−0.31, −0.10		0.02	−0.08, 0.12	
Medium	Reference			Reference			Reference		
Low	−0.12	−0.28, 0.04		0.09	−0.05, 0.24		0.11	−0.03, 0.26	
Education (years)	0.12	0.04, 0.20	0.002	−0.04	−0.11, 0.03	0.225	−0.09	−0.16, −0.02	0.010
Age (years)	0.01	−0.01, 0.02	0.363	−0.02	−0.03, −0.01	<0.001	0.004	−0.01, 0.01	0.496

* All of the maternal characteristics have been adjusted for each other in the multivariate analysis.

BMI in the univariable analysis. These associations were not robust to adjustments for confounders.

Discussion

In this large contemporary mother and child cohort, we found one distinct empirical childhood dietary pattern to be associated with greater adiposity and obesity risk in children aged 6 years. This pattern was characterised by high intakes of foods and beverages high in sugar and/or fat including saturated fat. A healthy dietary pattern characterised by a number of fruits and vegetables was associated with a reduced risk of obesity in a small number of children. Furthermore, we were able to characterise influences of maternal antenatal exposures on childhood dietary patterns which included maternal ethnicity, age, BMI, education, socio-economic status and smoking in pregnancy.

The majority of reports of childhood dietary patterns have addressed the hypothesis that dietary behaviours in early childhood can influence the risk of obesity in later childhood. Several studies have shown a strong relationship between unhealthy dietary patterns characterised by energy dense, low-fibre and high-fat foods and their later risk of obesity[31,32]. Few studies have examined the relationship between empirical dietary patterns and childhood body composition measured simultaneously. In one of the few to have specifically addressed this association, the Lifeways Cross-Generational Cohort study in Irish children aged 5 years showed that the upper tertiles of a 'cereal and juice' dietary pattern and the middle tertile of a 'pasta and veg' dietary pattern were negatively associated with overweight and obesity[33]. Our findings together with observations that diet in early childhood is a risk for later obesity may reflect unchanging dietary patterns throughout early and mid-childhood[4], suggesting that interventions which specifically target foods and snacks high in sugar and fat in early childhood could play a role in reducing later risk of obesity. The observation that the relationship between the Junk and Healthy patterns and BMI observed in this study was only evident in children classified as obese is particularly relevant to public health measures for the prevention of childhood obesity.

The three dietary patterns identified in this study ('Traditional', 'Junk' and 'Healthy') are consistent with those described in the New Zealand birth cohort study which assessed dietary patterns in Auckland children aged 3·5 and 7 years[30]. Similarities were observed for high factor loadings for the 'traditional' diet of meat, vegetables and potatoes, the 'healthy' diet of fruit, vegetables and nuts, and the junk diet of confectionery.

We identified important associations between maternal influences and childhood dietary patterns. Better quality diets were more common in children who had mothers with higher educational attainment, and who had a lower BMI, similar to observations in the Southampton Women's Survey[12,34]. Consistent with ALSPAC data, poorer diets were more common in children who were born to mothers who had lower educational attainment[18]. Furthermore, the mothers of children with poorer diets were more likely to smoke in pregnancy, which is similar to the New Zealand birth cohort study[30]. Recently, we

Table 4. Multiple regression analysis of the dietary patterns associated with body composition at age 6 years*
(Standardised β-coefficients and odds ratios and 95 % confidence intervals)

Body composition measure	Model 1 (unadjusted)				Model 2 (adjusted)			
	n	β	95 % CI	P	n	β	95 % CI	P
Healthy pattern								
Body fat %	1142	−0·04	−0·09, 0·01	0·101	1025	−0·02	−0·07, 0·04	0·482
BMI z-score†	1142	−0·05	−0·11, 0·002	0·060	1025	−0·01	−0·07, 0·05	0·677
Arm (cm)	1142	−0·02	−0·07, 0·03	0·417	1025	0·01	−0·04, 0·06	0·728
Waist (cm)	1142	0·001	−0·05, 0·05	0·966	1025	0·02	−0·03, 0·08	0·362
Hip (cm)	1142	−0·02	−0·07, 0·03	0·370	1025	0·01	−0·04, 0·06	0·711
Sum of skinfolds (mm)‡	1133	−0·04	−0·09, 0·01	0·120	1019	−0·03	−0·08, 0·03	0·327
Overweight or obese (BMI z-score >1 SD)	1142			0·005	1025			0·125
OR		0·76				0·85		
95 % CI			0·63, 0·92				0·69, 1·05	
Obese (BMI z-score >2SD)	1142			0·003	971			0·050
OR		0·52				0·62		
95 % CI			0·33, 0·80				0·39, 1·00	
Traditional pattern								
Body fat %	1142	0·06	0·02, 0·11	0·006	1025	0·04	−0·01, 0·09	0·097
BMI z-score†	1142	0·08	0·03, 0·13	0·003	1025	0·04	−0·02, 0·09	0·176
Arm (cm)	1142	0·05	0·002, 0·09	0·042	1025	0·02	−0·03, 0·07	0·479
Waist (cm)	1142	0·07	0·02, 0·12	0·003	1025	0·05	−0·002, 0·09	0·060
Hip (cm)	1142	0·06	0·01, 0·11	0·011	1025	0·02	−0·03, 0·07	0·396
Sum of skinfolds (mm)‡	1133	0·03	−0·02, 0·08	0·220	1019	0·01	−0·04, 0·06	0·679
Overweight or obese (BMI z-score >1SD)	1142			0·006	1025			0·135
OR		1·34				1·19		
95 % CI			1·09, 1·64				0·95, 1·50	
Obese (BMI z-score >2SD)	1142			0·740	971			0·660
OR		0·93				0·89		
95 % CI			0·59, 1·45				0·53, 1·49	
Junk pattern								
Body fat %	1142	0·04	0·0002, 0·09	0·049	1025	0·02	−0·03, 0·07	0·486
BMI z-score†	1142	0·05	0·004, 0·10	0·034	1025	0·02	−0·03, 0·08	0·372
Arm (cm)	1142	0·10	0·06, 0·15	<0·001	1025	0·08	0·04, 0·13	<0·001
Waist (cm)	1142	0·05	0·01, 0·10	0·016	1025	0·03	−0·01, 0·08	0·158
Hip (cm)	1142	0·07	0·03, 0·11	0·002	1025	0·05	0·01, 0·10	0·028
Sum of skinfolds (mm)‡	1133	0·09	0·05, 0·13	<0·001	1019	0·07	0·03, 0·12	0·002
Overweight or obese (BMI z-score >1 SD)	1142			0·003	1025			0·066
OR		1·36				1·24		
95 % CI			1·11, 1·67				0·99, 1·57	
Obese (BMI z-score > 2 SD)	1142			0·006	971			0·025
OR		1·82				1·74		
95 % CI			1·19, 2·80				1·07, 2·82	

* Standardised coefficient (β), representing the standard deviation (SD) change and 95 % CI in body composition measure per SD change in dietary pattern score enabling comparison across outcomes; model 1 (simple regression): association between dietary patterns and childhood body composition at age 6 years; model 2 (multiple regression): association between dietary patterns and childhood body composition, adjusting for infant mode of feeding, infant sex, and maternal ethnicity, BMI, socio-economic status, multivitamin use pre-pregnancy, alcohol intake pre-pregnancy, cigarette smoking in first trimester, time spent watching television in first trimester, depression in first trimester, gestational hypertension, gestational diabetes mellitus diagnosis and plasma placental growth factor.
† World Health Organization (2007)[16] BMI for age z-score.
‡ Sum of triceps, biceps, subscapular and suprailiac skinfold thicknesses.

reported on the relationship between maternal BMI and childhood obesity risk in the CoS cohort. Maternal BMI was independently associated with childhood BMI z-score, sum of skinfolds and body fat % (all $P < 0.001$)[14]. The global increase in obesity, which is reflected in women who present for antenatal care has led to the concern that obesity in pregnancy may contribute to childhood obesity risk, with evidence from observational studies to support this link[35]. Exposure *in utero* to the metabolic consequences of a high maternal BMI including dyslipidaemia, inflammatory markers, hyperinsulinaemia and hyperleptinaemia appears to influence offspring obesity risk[36,37]. This highlights the need for public health interventions to promote a healthy BMI and better quality diet in reproductive aged women.

Strengths of the present study include this being an addition to a very sparse literature which has defined the dietary patterns associated with childhood obesity. Whilst the assumption is often made that foods and snacks high in sugar and fat are major contributors, there is limited evidence to support this widely held assumption in paediatric cohorts. Furthermore, our observations have been made in a large cohort, compared with previous studies of childhood obesity in mother–child cohorts. By focusing on obesity in the children, the CoS protocol prospectively included detailed measurements of childhood adiposity and a comprehensive data set to examine maternal influences on childhood diet. By characterising dietary patterns, we have been able to capture the complexity of the diet while overcoming the limitations of single nutrient assessment[6].

Whilst this study provides evidence that specific dietary patterns in children are linked to childhood obesity, there are some limitations. At follow-up, data from 1208 (59 %) of the 2032 mothers and their children from the original Auckland arm of the SCOPE cohort were available, which could lead to erroneous conclusions if the relationships between dietary patterns and childhood body composition differ between those included in follow-up and those not. Being observational in design, we are only able to examine associations and not infer causation between dietary patterns and childhood obesity development. We assessed dietary intake using an FFQ, which may be prone to bias[38]. Factor analysis was used to derive empirical dietary patterns which involves several subjective decisions including the number of factors to extract, rotation method and naming of the factors[39]. We adjusted for several potentially confounding variables in the assessment of the relationship between maternal influences and childhood dietary patterns and between childhood dietary patterns and obesity. However, the possibility of residual confounding due to unmeasured lifestyle factors cannot be excluded. The relationship between physical activity and inactivity was not assessed in the present study. WHO guidelines on childhood obesity prevention include promoting physical activity among children in the first few years of life in addition to focusing on dietary intake[40]. Evidence from cross-sectional studies examining the association between physical activity in children and adiposity suggest that higher levels of physical activity are related to reduced adiposity[41]. Associations with sedentary time are less consistent[42]. Future studies should include physical activity in assessing the relationship between childhood health behaviours and obesity risk. Finally, the majority of women in this study were of European descent and were well educated and were not a representative cohort of New Zealand women and children.

Conclusion

This mother–child cohort study with multiple measures of childhood body composition provides support for a relationship between empirical dietary patterns representing overall diet and childhood adiposity. A dietary pattern characterised by consumption of high sugar and fat including saturated fat foods was associated with greater body circumferences, sum of skinfolds and obesity risk in children aged 6 years, while a 'Healthy' dietary pattern offered some apparent protection against obesity. We also identified a number of maternal exposures that were associated with eating patterns in early childhood providing insights into important maternal influences on children's dietary intake. Our data add to the growing evidence that targeting maternal obesity and unhealthy dietary patterns associated with early childhood adiposity could inform public health strategies to reduce the prevalence of childhood obesity.

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Supplementary material

For supplementary material referred to in this article, please visit https://doi.org/10.1017/S0007114520000628

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