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Dietary patterns and changes in body composition in children between 9 and 11 years

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Abstract

Objective: Childhood obesity is rising and dietary intake is a potentially modifiable factor that plays an important role in its development. We aim to investigate the association between dietary patterns, obtained through principal components analysis and gains in fat and lean mass in childhood.
Design: Diet diaries at 10 years of age collected from children taking part in the Avon Longitudinal Study of Parents and Children. Body composition was assessed using dual-energy X-ray absorptiometry at 9 and 11.
Setting: Longitudinal birth cohort.
Subjects: 3911 children with complete data.
Results: There was an association between the Health Aware (positive loadings on high-fiber bread, and fruits and vegetables; negative loadings on chips, crisps, processed meat, and soft drinks) pattern score and decreased fat mass gain in girls. After adjusting for confounders, an increase of 1 standard deviation (sd) in this score led to an estimated 1.2% decrease in fat mass gain in valid-reporters and 2.1% in under-reporters. A similar decrease was found only in under-reporting boys. There was also an association between the Packed Lunch (high consumption of white bread, sandwich fillings, and snacks) pattern score and decreased fat mass gain (1.1% per sd) in valid-reporting but not under-reporting girls. The main association with lean mass gain was an increase with Packed Lunch pattern score in valid-reporting boys only.
Conclusions: There is a small association between dietary patterns and change in fat mass in mid-childhood. Differences between under- and valid-reporters emphasize the need to consider valid-reporters separately in such studies.

Keywords: *dietary patterns*; *principal components analysis*; *ALSPAC*; *body composition*; *valid-reporters*

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Increasing prevalence of obesity in developed countries is a major public health concern. In 2007–08, an estimated 34% of US adults had a body mass index (BMI) of at least 30 (1), a prevalence that steadily increased over the previous 3 decades (2). A similar increase has been observed in US children (3) and appears to be at an all-time high (4) with no sign of abating (5). The prevalence of obesity and overweight among children in the European Union is accelerating (6), and it is estimated that 37% of children in 2010 will have excess body fat, defined using International Obesity TaskForce (IOTF) cutoffs. Prevalence is also high in UK children, with 33% of English children aged 10–11 estimated to be overweight or obese, according to national BMI percentiles, in 2010–11 (7). Obesity in adults and children is linked to a wide range of negative health and social outcomes (8), and childhood obesity is linked to obesity in adulthood (9). Therefore, it is important to understand the causes and effects of obesity, overweight, and fat mass gain in children.

Dietary patterns are a useful method of describing diet and its effect on health outcomes (10). They have an advantage over methods that examine individual food or nutrient intakes as they assess the whole diet and recognize that foods are consumed in combination. Principal components analysis (PCA) is one method of deriving dietary patterns that uses the correlation between foods to create scores that quantify different dietary patterns present in a population. As it provides multiple continuous scores, PCA is a useful tool for investigating the

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effects of diet on the development of obesity, and allows for exploration of effects of more than one dimension of dietary variation (11). Dietary patterns are used as exposures for many health outcomes (12, 13), including obesity, particularly in studies of children in Australia (14), Korea (15), Scotland (16), and USA (17).

Cross-sectional studies that compare dietary patterns with BMI in adults give inconsistent results (18) and, therefore, there is a need for longitudinal studies of the association between dietary patterns and obesity-related outcomes in both adults and children (19). BMI is not a perfect surrogate measure for obesity, as body mass is made up of lean and fatty tissue as well as bone. Body composition measures that assess the mass of each type of tissue give a better depiction of the physical makeup and adiposity of an individual. Increased BMI may be caused by increased fat mass or increased lean mass, or both. Therefore, it is important to consider both of these as potential obesity-related outcomes. Dietary assessment is prone to invalid reporting, and individuals can be classified as under-reporters based on their energy intake (EI). The purpose of this study is to investigate the association between dietary patterns, obtained through PCA of diet diary data from children aged 10, and gains in fat and lean mass between ages 9 and 11. Rather than excluding under-reporters, we seek to investigate whether inaccurate reporting has an effect on the relationship between dietary patterns and body composition.

Subjects and methods

This study used data from the Avon Longitudinal Study of Parents and Children (ALSPAC), an ongoing population-based cohort study in the United Kingdom (20). Eligible participants were pregnant women, living in the Avon health authority area in South-West England, who were expected to deliver between April 1991 and December 1992 inclusive. Further details are available on the ALSPAC website (http://www.bristol.ac.uk/alspac). This study used data from the core ALSPAC sample, consisting of 14,541 pregnancies, and participants later invited to participate, comprising an additional 542 eligible pregnancies. This provided a baseline group of 14,535 children who were alive at 1 year of age. Ethical approval for the study was obtained from the ALSPAC Law and Ethics Committee and the Local Research Ethics Committees.

Dietary assessment

The study children were invited to complete a 3-day diet diary prior to a clinic they attended at a mean age of 10 years 8 months (standard deviation [sd] 3 months). A fieldworker conducted a 24 h diet recall, during the clinic, if children did not complete the diary beforehand. The diaries and recalls provided the weight and energy contribution of every food consumed by the child. The accuracy of reporting was assessed by comparing reported total EI with estimated energy requirement (EER) for each child (21).

The latter was calculated for each child based on his/her body weight, using separate equations for boys and girls, with an increment added for energy used in growth. The validity of reported EI was assessed by comparing the calculated EER with EI: any ratio less than 78.45% or above 121.55% was classified as under-reporting or over-reporting, respectively.

Foods were allocated to 62 groups, chosen to be as similar as possible to groupings in studies (22–24) based on food frequency questionnaires (FFQs) administered to the ALSPAC children. The input variables for dietary pattern analysis were the average weight consumed (g/d) by each child in each of these 62 food groups.

Dietary patterns were previously extracted from this data (25) by PCA, which uses the correlations between food intake variables to express them as a small number of components, which are linear combinations of the food intake variables that explain as much as possible of the variation in the sample. Three components were deemed to best explain the underlying dietary patterns in the population, and each child had a score for each component. Within the first component, the foods that contributed most to positive scores were fruits and vegetables, high-fiber bread, pasta, cheese, and fish, while the foods that contributed most to negative scores were chips (French fries), crisps (potato and corn snacks), processed meat, and fizzy (carbonated) drinks. This component was labeled *Health Aware*. The foods that contributed most to the second component were meat, roast potatoes, vegetables, batter and pastry products, low-energy-density ($<$200 kcal/100 g) sauces such as gravy, and desserts. This component received the label of *Traditional* as it seemed to describe a traditional British diet. In the third component, the foods with highest contributions were low-fiber bread, margarine, cheese, cold meats, salty flavorings such as yeast extract, and diet squash (dilutable soft drink). This component was labeled *Packed Lunch*. All component scores were standardized, by subtracting the mean and dividing by the standard deviation, before analysis.

Body composition measurement

Children received an invitation to attend two additional clinics at mean age 9 years 11 months (sd 4 months) and 11 years 9 months (sd 3 months) during which body composition was assessed using total-body dual-energy X-ray absorptiometry (DXA) scans, performed using a Lunar Prodigy dual-energy X-ray absorptiometer (General Electric), giving fat mass, lean mass, and bone mass for each child. Height was measured with a Harpenden stadiometer. Some scans were removed from analysis due to anomalies caused by movement or metal artifacts (26).

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Confounding variables

Several variables were considered as potential confounders between dietary pattern scores and differences in fat mass and lean mass between ages 9 and 11. Some were already known to be associated with the above dietary pattern scores (25). Confounders were included if they were associated with both exposure and outcome. Variables considered as confounders are described as follows: During pregnancy, the mothers completed questionnaires that ascertained their highest educational attainment and smoking history, as well as self-reported pre-pregnancy height and weight from which BMI was calculated. The mother's age at delivery was calculated based on her date of birth. Gestation was derived from delivery files or from the last menstrual period. The birthweight of the child was collected from obstetric data, measurements taken by ALSPAC fieldworkers shortly after birth, and birth notifications. The child's ethnicity was calculated based on questionnaires administered during pregnancy: children were classified as non-White if the mother reported that either parent was non-White. Girls in the study, or their care-givers, completed a series of questionnaires that asked about menarche. These were first administered at 8 years of age and then approximately annually thereafter.

All children that attended the clinic at age 11 were asked to wear an Actigraph accelerometer (Manufacturing Technology Incorporated) for a period of up to 7 days after attending the clinic (27). Data extracted from the accelerometers, expressed as the mean counts per minute (cpm) during the period of wear, provided an objective measure of the physical activity of the children at that age.

Statistical modeling

Primary analyses were stratified by gender and by the under-/over-reporting variable. The number of over-reporters was small compared with the number of under- and valid-reporters, so over-reporters were excluded from the analyses. The characteristics of children included in each model were compared with the baseline group, and the characteristics of under-reporters were compared with valid-reporters, using t tests and chi-squared tests. Statistical calculations were carried out in Stata version 11 (StataCorp: College Station, Texas).

The relationship between dietary pattern scores and changes in fat or lean mass was investigated using multiple linear regression. Three models were considered: the initial model (Model 0) adjusted only for the effect of height. The next model (Model 1) also included confounders: maternal education and smoking were included as categorical effects, as was a variable indicating whether girls experienced menarche between body composition assessments. Maternal age and BMI were added as linear effects, as was the average daily EI, as recorded by the diet diaries and recalls, and the residual of birthweight. This was obtained from a model adjusted for gestation and size of pregnancy through nonlinear regression, in which a Gompertz curve modeled the relationship between gestation and log-transformed birthweight. The final model (Model 2) was the same as Model 1 but included physical activity (cpm) as a linear effect. Several variables were log-transformed to reduce the effect of their skewness, specifically fat and lean mass, height, maternal BMI, birthweight residual, and physical activity counts. Statistical tests were based on transformed variables, which were transformed back for presentation in results.

Results

A total of 7,473 children (51.4% of the baseline group) had complete dietary data and therefore had dietary pattern scores. Of these 5,827 (78.0%) had valid data from DXA scans at both measurement occasions. After removing 202 over-reporters and 25 without reporting information, there were 5,600 children (74.9%) available for analysis. Due to missing values in the confounding variables, there were 4,595 children (61.5%) included in Model 1 and 3,911 children (52.3%) included in Model 2.

The characteristics of the children in each model are compared with the rest of the children in the ALSPAC study in Table 1. Children with complete data were more likely to be girls, White, and have older, more educated, and non-smoking mothers. There was no association between maternal BMI and data availability. These differences did not change when fewer children were available for Models 1 and 2.

Table 2 compares the characteristics and measurements of under-reporters with valid-reporters. Under-reporters had lower mean dietary pattern scores compared with valid-reporters (all $P < 0.005$), with the exception of the Health Aware pattern in boys, which did not differ. They also had lower mean EIs ($P < 0.001$). Under-reporters were, on average, heavier and taller than valid-reporters (all $P < 0.001$) at both 9 and 11 years of age. Furthermore, there was strong evidence (all $P < 0.001$) that under-reporters were on average heavier at birth, were less physically active, and had lower educated mothers with greater BMIs.

Tables 3 and 4 show the estimated coefficients of the linear regression models for the effect of dietary patterns on differences in fat and lean mass stratified by gender, for valid- and under-reporters, respectively. The estimates are presented after transforming back from log fat mass and log lean mass, hence they are multiplicative effects. To illustrate this, consider two valid-reporting boys whose scores for the Health Aware pattern differ by 1 sd. Under Model 0, the child with the higher score will have a gain in fat mass, between age 9 and age 11, that is, 0.987 times

Table 1. Summary of characteristics of children, as means (sd) or number in each category (proportion), included in Models 0, 1, and 2, and comparison with baseline group

	Baseline	Model 0	*P*	Model 1	*P*	Model 2	*P*
Gender							
Boys	7,477 (51.45%)	2,734 (48.8%)	<0.001	2,285 (49.7%)	0.005	1,892 (48.4%)	<0.001
Girls	7,056 (48.55%)	2,866 (51.2%)		2,310 (50.3%)		2,019 (51.6%)	
Ethnicity							
White	11,474 (95.0%)	4,934 (96.5%)	<0.001	4,378 (96.6%)	<0.001	3,727 (96.6%)	<0.001
Non-White	609 (5.04%)	177 (3.46%)		153 (3.38%)		130 (3.37%)	
Birthweight[a] (kg)	3.360 (0.353)	3.367 (0.334)	<0.001	3.375 (0.319)	<0.001	3.373 (0.320)	<0.001
Maternal age (y)	28.0 (4.96)	29.2 (4.47)	<0.001	29.4 (4.40)	<0.001	29.3 (4.39)	<0.001
Maternal BMI (kg/m^2)	22.93 (3.85)	22.95 (3.71)	0.355	22.93 (3.70)	0.547	22.96 (3.70)	0.289
Maternal smoking[b]							
Never smoked	6,429 (49.25%)	3,015 (57.8%)	<0.001	2,690 (58.5%)	<0.001	2,276 (58.2%)	<0.001
Smoker	6,626 (50.75%)	2,202 (42.2%)		1,905 (41.5%)		1,635 (41.8%)	
Maternal education							
Vocational/age-16 qualification	8,024 (64.6%)	2,879 (55.6%)	<0.001	2,501 (54.4%)	<0.001	2,137 (54.6%)	<0.001
Age-18 qualification	2,794 (22.5%)	1,428 (27.6%)		1,279 (27.8%)		1,077 (27.5%)	
Post-18 qualification	1,600 (12.9%)	874 (16.9%)		815 (17.7%)		697 (17.8%)	

[a] Adjusted for gestation and size of pregnancy.
[b] Before/during pregnancy.

that of the child with the lower score. In other words, an increase of 1 sd in the Health Aware score was associated with a 1.3% decrease in fat mass gain.

In the model that only adjusted for height (Model 0), there was evidence among valid-reporters (Table 3) for an association between the Health Aware pattern and decreased fat mass gain in girls: an increase of 1 sd in Health Aware score gave an estimated 2.0% (95% CI: 1.1%, 2.9%) decrease in fat mass gain. There was also evidence ($P = 0.020$ in Model 0) for an association between the Packed Lunch pattern and decreased fat mass gain in valid-reporting girls: an increase of 1 sd in Packed Lunch score gave an estimated 1.4% (95% CI: 0.5%, 2.4%) decrease in fat mass gain. With regard to boys, there was evidence for a small association between the Packed Lunch pattern and increased lean mass in valid-reporters: an increase of 1 sd in Packed Lunch score gave an estimated 0.2% (95% CI: 0.1%, 0.4%) increase in lean mass gain.

These associations were still present after adjusting for confounding and physical activity, although the effect sizes were attenuated. In valid-reporting girls, an increase of 1 sd in Health Aware score gave an estimated 1.2% (95% CI: 0.0%, 2.4%) decrease in fat mass gain, and an increase of 1 sd in Packed Lunch score gave an estimated 1.1% (95% CI: 0.0%, 2.2%) decrease. Additionally, in Model 2, there was an association between the Health Aware pattern and decreased lean mass gain in girls: an increase of 1 sd in Health Aware score gave an estimated 0.3% (95% CI: 0.0%, 0.6%) decrease in lean mass gain. In boys, an increase of 1 sd in Packed Lunch score gave an estimated 0.3% (95% CI: 0.1%, 0.5%) increase in lean mass gain in valid-reporters, but the association between the Health Aware score and fat mass gain was no longer present.

In under-reporters (Table 4), there was an association between the Health Aware pattern and decreased fat mass gain in boys as well as girls. In Model 2, an increase of 1 sd in Health Aware score gave an estimated 2.9% (95% CI: 1.0%, 4.8%) decrease in fat mass gain in boys, and an estimated 2.1% (95% CI: 0.4%, 3.8%) decrease in girls. Unlike valid-reporters, there were no associations between body composition and the Packed Lunch pattern, or between dietary patterns and lean mass.

Discussion

We have observed small associations between dietary pattern scores and changes in fat and lean mass in mid-childhood. A dietary pattern high in high-fiber bread, pasta, cheese, fish, fruits and vegetables, and low in chips, crisps, processed meat, and soft drinks (Health Aware), was linked with decreased fat mass gain in girls between the ages of 9 and 11. A pattern high in sandwiches and snacks (Packed Lunch) was also associated with decreased fat mass gain in girls and a small increase in lean mass gain in boys. These associations were observed after adjusting for height, potential confounders, EI, and physical activity.

The associations between dietary patterns and obesity-related outcomes are inconsistent in cross-sectional studies (18). Some cross-sectional studies of food intakes, rather than dietary patterns, corroborate our

Table 2. Summary of variables included in models, as means (sd) or number in each category (proportion), and tests for differences, between valid- and under-reporters

	Boys			Girls		
	Valid-reporters	Under-reporters	*P*	Valid-reporters	Under-reporters	*P*
Variables in Model 0						
Health aware component[a]	−0.016 (1.037)	−0.064 (0.987)	0.241	0.147 (0.977)	0.019 (0.865)	<0.001
Traditional component[a]	0.085 (1.041)	−0.060 (0.943)	<0.001	0.022 (0.966)	−0.085 (0.880)	0.003
Packed lunch component[a]	0.113 (1.042)	−0.136 (0.939)	<0.001	0.032 (0.962)	−0.162 (0.827)	<0.001
Fat mass aged 9 years (kg)	5.739 (3.018)	10.306 (5.851)	<0.001	8.461 (4.300)	12.061 (5.528)	<0.001
Fat mass aged 11 years (kg)	8.352 (4.582)	14.348 (7.879)	<0.001	11.527 (5.812)	15.955 (7.355)	<0.001
Lean mass aged 9 years (kg)	24.980 (2.734)	26.444 (3.057)	<0.001	23.131 (2.975)	24.485 (3.249)	<0.001
Lean mass aged 11 years (kg)	29.481 (3.818)	31.576 (2.734)	<0.001	28.744 (4.338)	30.525 (4.466)	<0.001
Height aged 9 years (cm)	139.1 (5.976)	141.5 (5.936)	<0.001	138.7 (6.502)	140.6 (6.412)	<0.001
Height aged 11 years (cm)	149.2 (6.757)	152.0 (6.946)	<0.001	150.8 (7.253)	152.8 (7.045)	<0.001
Added in Model 1						
Average energy intake (kJ/d)	2087 (288.1)	1635 (265.0)	<0.001	1901 (251.7)	1474 (226.2)	<0.001
Birthweight[b] (kg)	3.415 (0.352)	3.435 (0.338)	<0.001	3.325 (0.293)	3.335 (0.253)	<0.001
Menarche aged 9–11						
Yes				93 (6.24%)	83 (10.1%)	0.001
No				1397 (93.8%)	737 (89.9%)	
Maternal age (y)	29.5 (4.47)	29.5 (4.40)	0.968	29.3 (4.43)	29.0 (4.19)	0.097
Maternal BMI (kg/m^2)	22.61 (3.33)	23.76 (4.31)	<0.001	22.49 (3.52)	23.54 (3.80)	<0.001
Maternal smoking[c]						
Never smoked	880 (59.5%)	449 (55.7%)	0.079	901 (60.5%)	460 (56.1%)	0.041
Smoker	599 (40.5%)	357 (44.3%)		589 (39.5%)	360 (43.9%)	
Maternal education						
Vocational/age-16 qualification	778 (52.6%)	471 (58.4%)	0.025	786 (52.8%)	466 (56.8%)	0.078
Age-18 qualification	441 (29.8%)	206 (25.6%)		411 (27.6%)	221 (27.0%)	
Post-18 qualification	260 (17.6%)	129 (16.0%)		293 (19.7%)	133 (16.2%)	
Added in Model 2						
Physical activity at 11 (cpm)	680 (192)	631 (183)	<0.001	556 (153)	532 (144)	<0.001

[a] Standardized.

[b] Adjusted for gestation and size of pregnancy.

[c] Before/during pregnancy.

findings: children with low intakes of fruits and vegetables, who would therefore not score highly on our Health Aware pattern, are known to be at greater risk of overweight or obesity (28) and children with high consumption of sugary drinks, leading to more negative scores on our Health Aware pattern, are associated with increased obesity risk (29). A cross-sectional study of Greek children aged 1–5 (30) shows an association between obesity and a dietary pattern consisting of reduced consumption of fruits and vegetables and increased consumption of sweets and red meat. This is similar to the association between our Health Aware component and reduced fat mass gain. A cross-sectional study of children in Scotland aged 5–11 (16) shows an association between lower BMI in boys and a dietary pattern high in sandwiches, snack foods and soft drinks, which is somewhat similar to our Packed Lunch pattern. This study also observed an association between higher BMI and a dietary pattern high in fish, potatoes, and pasta, which is in contrast to our Health Aware pattern and observed association with reduced fat mass gain. There is a reported association between overweight and a dietary pattern characterized by high consumption of meat and fish, in Korean children of mean age 5 (15). A study of Australian children aged 12–18 (14) shows that the observed associations between dietary patterns and BMI, or waist circumference, were actually the result of confounding.

The studies described above are all cross-sectional, and it is therefore difficult to tease out any temporal relationship. Our study benefits from a longitudinal design, which allows the measurement of gains in fat mass and lean mass, and the examination of their associations with dietary patterns. In a longitudinal study of US adolescents that examines associations between dietary patterns

Table 3. Multiplicative increase/decrease in mass gain associated with 1 sd increase in component score (valid-reporters)

		Fat mass		Lean mass	
		Boys	Girls	Boys	Girls
Number of children in analysis	Model 0	1,729	1,836	1,729	1,836
	Model 1	1,479	1,490	1,479	1,490
	Model 2	1,216	1,310	1,216	1,310
Component					
Health aware	Model 0	0.987 (0.976, 0.997)	0.980 (0.971, 0.989)	1.001 (0.999, 1.002)	0.998 (0.996, 1.001)
	P	0.016	<0.001	0.449	0.140
	Model 1	0.991 (0.979, 1.003)	0.990 (0.978, 1.001)	1.000 (0.998, 1.002)	0.997 (0.994, 1.000)
	P	0.147	0.076	0.888	0.021
	Model 2	0.991 (0.978, 1.005)	0.988 (0.976, 1.000)	0.999 (0.997, 1.002)	0.997 (0.994, 1.000)
	P	0.224	0.049	0.567	0.043
Traditional	Model 0	1.004 (0.993, 1.014)	0.992 (0.983, 1.001)	1.000 (0.998, 1.002)	0.999 (0.996, 1.001)
	P	0.521	0.079	0.960	0.210
	Model 1	1.002 (0.990, 1.014)	0.993 (0.983, 1.003)	1.002 (0.998, 1.002)	0.999 (0.997, 1.002)
	P	0.717	0.177	0.908	0.581
	Model 2	1.003 (0.990, 1.016)	0.992 (0.981, 1.003)	1.000 (0.998, 1.002)	0.999 (0.997, 1.002)
	P	0.677	0.167	0.809	0.662
Packed lunch	Model 0	0.998 (0.987, 1.009)	0.986 (0.976, 0.995)	1.002 (1.001, 1.004)	1.002 (0.999, 1.004)
	P	0.675	0.002	0.009	0.192
	Model 1	0.991 (0.979, 1.003)	0.988 (0.978, 0.999)	1.002 (1.000, 1.004)	1.000 (0.998, 1.003)
	P	0.147	0.028	0.030	0.933
	Model 2	0.989 (0.976, 1.002)	0.989 (0.978, 1.000)	1.003 (1.001, 1.005)	1.000 (0.998, 1.003)
	P	0.098	0.049	0.005	0.844

Table 4. Multiplicative increase/decrease in mass gain associated with 1 sd increase in component score (under-reporters)

		Fat mass		Lean mass	
		Boys	Girls	Boys	Girls
Number of children in analysis	Model 0	1,005	1,030	1,005	1,030
	Model 1	806	820	806	820
	Model 2	676	709	676	709
Component					
Health aware	Model 0	0.968 (0.953, 0.983)	0.975 (0.962, 0.988)	0.999 (0.996, 1.001)	0.998 (0.995, 1.001)
	P	<0.001	<0.001	0.370	0.252
	Model 1	0.973 (0.955, 0.991)	0.979 (0.963, 0.994)	0.998 (0.995, 1.001)	1.001 (0.997, 1.004)
	P	0.004	0.008	0.189	0.715
	Model 2	0.971 (0.952, 0.990)	0.979 (0.962, 0.996)	0.997 (0.994, 1.001)	1.002 (0.998, 1.006)
	P	0.003	0.015	0.109	0.387
Traditional	Model 0	1.000 (0.984, 1.016)	0.988 (0.975, 1.001)	1.001 (0.998, 1.004)	1.000 (0.997, 1.003)
	P	0.997	0.080	0.583	0.818
	Model 1	1.000 (0.981, 1.019)	0.994 (0.979, 1.009)	1.002 (0.999, 1.005)	0.997 (0.994, 1.001)
	P	0.993	0.432	0.259	0.119
	Model 2	0.998 (0.978, 1.018)	0.994 (0.979, 1.010)	1.003 (0.999, 1.006)	0.998 (0.996, 1.005)
	P	0.841	0.489	0.106	0.799
Packed lunch	Model 0	0.994 (0.979, 1.011)	0.997 (0.983, 1.012)	0.990 (0.997, 1.002)	1.002 (0.999, 1.006)
	P	0.499	0.719	0.698	0.194
	Model 1	0.990 (0.972, 1.008)	0.999 (0.983, 1.016)	0.999 (0.996, 1.002)	1.001 (0.997, 1.005)
	P	0.273	0.944	0.600	0.690
	Model 2	0.987 (0.968, 1.007)	1.000 (0.983, 1.018)	0.999 (0.996, 1.002)	1.001 (0.996, 1.005)
	P	0.199	0.996	0.484	0.799

and obesity 5 years later (17), overweight/obesity was negatively associated with a vegetable-based dietary pattern in older girls, and negatively associated with a snack-based dietary pattern in older boys, which is similar to the results that we found. However, it was also negatively associated with starchy foods in younger boys, and positively associated with fruits in younger boys, which is not consistent with our findings.

A particular strength of our study is the examination of body composition, in the form of fat and lean mass, as opposed to BMI. In addition, fat mass was measured with DXA, rather than relying on predictions based on percentage fat mass based on bioelectric impedance, which may be biased (31). A series of cross-sectional studies employing DXA (32) show similarities with our findings: an association between low fat mass and a dietary pattern with high intakes of dark green and deep yellow vegetables, which load positively on our Health Aware pattern, and an association between high fat mass and fried foods, which load negatively on our Health Aware pattern. We observed that lean mass gain is not as strongly influenced by diet as fat mass gain. Therefore, the differences in BMI associated with dietary patterns are more likely to be the result of associations with fat mass rather than lean mass.

Additional strengths of this study are the relatively large sample size, adjustment for confounders, and physical activity measurement, although we cannot rule out the possibility of residual confounding. We have previously shown in this population that diet is not associated with age at menarche (33) and have no reason to suspect that it would be associated with puberty onset in boys and so chose not to adjust for age at puberty. We adjusted for physical activity using accelerometers as an objective measurement rather than self-report, which, like dietary measurements, may be susceptible to invalid reporting. Limitations include the level of dropout from baseline which introduces potential bias in the sample towards girls, White children, and children with older, more educated, non-smoking mothers. However, these factors were adjusted for in the analysis. Finally, as the associations between dietary patterns and obesity outcomes are inconsistent in the literature, and PCA is a population-specific method, it may not be easy to generalize our results to other populations.

We have shown that it is important to consider the possibility of under-reporting and the effect that it might have on associations between dietary patterns and obesity-related outcomes. We are aware of no studies of these associations that considered under-reporting. Under-reporters had, on average, lower pattern scores and a higher fat and lean mass than valid-reporters. Therefore, not adjusting for reporting could result in the attenuation of estimates of association. Stratification by reporting showed that there were associations between the Health Aware pattern and fat mass in both groups, but an association between the Packed Lunch pattern and body composition only in valid-reporters.

Some studies (30, 32) use reduced rank regression (RRR) to simultaneously derive dietary patterns and their associations with obesity outcomes. It is likely that RRR would find greater associations, in this study, than those observed with PCA as it can be tuned to construct dietary patterns that are likely to be associated with the outcome variable. However, PCA has the advantage that it looks at more than one dimension of variation in diet (11). In this study this meant that we were able to show that the traditional dietary pattern had no association with gains in fat or lean mass, and were able to observe associations between fat mass and both the Health Aware and Packed Lunch dietary patterns.

The primary conclusion of this study is that a diet high in high-fiber bread, pasta, cheese, fish, and fruits and vegetables, and low in chips, crisps, processed meat, and soft drinks, may lead to a reduction in fat mass gain during childhood. A further implication is that Packed Lunch type dietary patterns are worth investigating, as they may have a similar effect despite their correlation with low-fiber bread and snack foods. Further research is necessary to investigate whether this type of dietary pattern, and its effect, is exclusive to children and if not, at what age it disappears. We conclude that diet in childhood, assessed using dietary patterns obtained from PCA, has a small effect on fat mass gain, and this is important in the context of childhood obesity tracking into adulthood.

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Conflict of interest and funding

All authors declare no conflict of interest.

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