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ORIGINAL ARTICLE

Dietary patterns and longitudinal change in body mass in European children: a follow-up study on the IDEFICS multicenter cohort

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BACKGROUND/OBJECTIVES: Longitudinal studies investigating dietary patterns (DPs) and their association with childhood overweight/obesity are lacking in Europe. We identified DPs and investigated their association with overweight/obesity and changes in body mass index (BMI) in a cohort of European children.
SUBJECTS/METHODS: Children aged 2–10 from eight European countries were recruited in 2007–2008. Food frequency questionnaires were collected from 14 989 children. BMI and BMI *z*-scores were derived from height and weight and were used to identify overweight/obese children. After 2 years (mean), anthropometric measurements were repeated in 9427 children. Principal component analysis was used to identify DPs. Simplified DPs (SDPs) were derived from DPs. Adjusted odds ratios (ORs) for overweight/obesity with increasing DP intake were estimated using multilevel logistic regression. Associations of BMI change with DP and SDP were assessed by multilevel mixed regression. Models were adjusted for baseline BMI, age, sex, physical activity and family income.
RESULTS: Four DPs were identified that explained 25% of food intake variance: snacking, sweet and fat, vegetables and wholemeal, and protein and water. After 2 years, 849(9%) children became overweight/obese. Children in the highest vegetables and wholemeal tertile had lower risk of becoming overweight/obese (OR: 0.69, 95% confidence intervals (CIs): 0.54–0.88). Children in the highest SDP tertile of vegetables and wholemeal had similarly lower risk of becoming overweight/obese (OR: 0.64, 95% CIs: 0.51–0.82), and their BMI increased by 0.7 kg/m^2 over the study period—significantly less than the increase in the lowest tertile (0.84 kg/m^2).
CONCLUSIONS: Our findings suggest that promoting a diet rich in vegetables and wholemeal cereals may counteract overweight/obesity in children.

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Keywords: dietary patterns; simplified dietary patterns; children; body mass index; overweight; cohort study

INTRODUCTION

Childhood overweight and obesity increased at an alarming rate in Europe and elsewhere up to about 2000, but now it appears to have levelled off.[1] However, childhood overweight and obesity remain unacceptably high in several countries[2–4] and are more prevalent among the poorer and less well educated.[1] Research into the causes and prevention of overweight/obesity therefore remains a priority.[1] Dietary behaviors in particular should be investigated as they are modifiable and likely to be responsible for excessive body weight.[5,6] Children's health and growth are affected by what they eat and by interactions between dietary components. However, the effects of individual foods and nutrients on health are difficult to estimate as they can be small; moreover, no individual dietary component is wholly responsible for excess weight.[7] It is the overall quality of the diet that seems to have most effect on weight gain.[8–10]

Principal component analysis (PCA) is one of the most commonly used tools to reduce dimensionality in the analysis of dietary data by producing linear combinations of foods called dietary patterns (DPs) that summarize predominant models of food consumption[11] and provide a more useful picture of diet, in relation to health, compared with individual foods.[12,13] Simplified DPs (SDPs) can be constructed as the sum of food variables that load high on the original DPs. SDPs have been suggested as a way of constructing less data-dependent pattern variables, that are more reproducible in other populations, and provide risk estimates that are comparable among studies.[14]

The aims of the present paper were to investigate, in a multicenter European cohort of children, whether common patterns of diet are present, to describe them and investigate associations of these patterns with subsequent risk of overweight and obesity. We hypothesized that healthy DPs (characterized by

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with low-energy density and high-nutrient density) and Western DPs (rich in refined sugar and fat) would be widespread in Europe, and that such patterns would be associated with overweight and obesity.

MATERIALS AND METHODS

Study design and cohort

Identification and Prevention of Dietary and Lifestyle Induced Health Effects in Children and Infants (IDEFICS) is a multicenter study designed to investigate and prevent diet- and lifestyle-related health problems (particularly overweight and obesity) in European children between the ages of 2 and 9 years. Detailed information on IDEFICS is available elsewhere.[15] The data for this publication were released by the steering committee of the IDEFICS Consortium (http://www.idefics.eu). All authors had access to the full IDEFICS data set.

At baseline, 16 220 children were recruited from schools in Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain and Sweden after obtaining written informed consent from the parents. Anthropometric measurements were obtained and 15 197 children completed dietary and lifestyle questionnaires. After excluding 208 children with incomplete questionnaires (>50% missing replies), 14 989 children (7622 boys and 7367 girls) were included in the DP and SDP analyses.

A total of 9427 participants (4659 girls and 4768 boys; 63% of baseline cohort) were recontacted after 2 years (mean) and a second set of anthropometric measurements were obtained.

Table 1. Food groups assessed by the study questionnaire (CEHQ) with consumption frequency in the baseline cohort ($n = 14\,989$)

Food group	*Consumption frequency (times per week)*		
	Mean	*s.d.*	*IQR*
Vegetables, cooked[a]	4.0	3.3	3
Potatoes, fried	1.0	1.7	2
Vegetables, raw	4.4	4.7	5
Fruit, fresh, no sugar added	7.6	6.0	12
Fruit, fresh, sugar added	1.8	3.9	2
Water	21.4	10.0	16
Fruit juice	6.7	7.8	5
Soft drinks, sugar added	2.3	5.2	2
Soft drinks, diet	0.9	3.6	0
Breakfast cereals, sugar added	2.5	3.3	5
Breakfast cereals, no sugar added	1.6	3.1	2
Milk, no sugar added	7.1	7.3	14
Milk, sugar added	3.8	5.3	7
Yoghurt, no sugar added	1.5	2.9	2
Yoghurt, sugar added	3.3	3.9	5
Fish, fresh, not fried	1.0	1.5	2
Fish, fried, fish-fingers	1.0	1.4	2
Cured meat and sausages	3.9	3.9	3
Meat, not fried[b]	2.3	2.5	2
Meat, fried[b]	2.2	2.4	2
Eggs, not fried	0.9	1.3	2
Eggs, fried	0.8	1.3	2
Mayonnaise and similar	0.6	1.5	0
Meat replacement products	0.2	1.2	0
Cheese	5.1	5.1	5
Honey, jam	1.7	2.7	2
Chocolate or nut-based spreads on bread	1.8	2.8	2
Butter or margarine on bread	3.7	5.1	7
Low-fat butter or margarine on bread	2.2	4.2	2
Ketchup and similar	1.5	2.3	2
Bread, white	6.9	6.4	5
Bread, wholemeal	3.4	4.7	5
Pasta and rice	3.0	2.6	3
Cereals, milled	0.6	1.7	0
Pizza as main dish	0.4	1.2	0
Hamburger, hot dog, kebab, falafel	1.8	3.1	2
Nuts, seeds, dried fruit	0.9	1.8	2
Savory snacks	1.0	1.7	2
Savory pastries	0.7	1.5	2
Chocolate, candy bars	2.1	2.8	2
Candy and sweets, no chocolate	1.9	3.1	2
Cakes, puddings, cookies	2.5	3.2	2
Ice cream	1.7	2.4	2

Abbreviations: CEHQ, Children's Eating Habits Questionnaire; IQR, inter quartile range. [a]Excluding fried potatoes, including legumes (pulses). [b]All meat including poultry.

Dietary assessment

We used the Children's Eating Habits Questionnaire (CEHQ) to assess diet. This is a reproducible and validated[16–18] screening instrument, completed by parents, or other caregivers, as proxy respondents for the children. A detailed description of CEHQ is available;[19] briefly, it solicits information about the frequency of consumption of 43 foods and beverages (Table 1) over the preceding month. When completing the CEHQ, parents were asked to base their answers on a typical week of the preceding month. The preceding month was chosen as opposed to the longer periods often used in adult questionnaires in order to capture children's rapidly changing diet and make it easier for parents to give accurate estimates. Frequencies of consumption were asked from the following exhaustive, close-ended, mutually exclusive alternatives: never/(less than once a week), 1–3 times per week, 4–6 times per week, once per day, twice per day, and three or more times per day. The questions on food consumption clearly distinguish healthy from unhealthy options (for example, white from wholemeal cereal products; breakfast cereals with and without added sugar and so on), thereby making it possible to compare consumption of these alternatives.

All centers in the eight participating countries had a CEHQ version in the local language. To ensure, as far as possible, that food items were recognized and understood, irrespective of education or cultural group, questions were accompanied by explanations and local examples.

Table 2. Baseline characteristics of children by follow-up status[a]

	Children followed-up (n = 9427)	*Children lost to follow-up (n = 5562)*	*Total baseline cohort (n = 14 989)*
Mean age (s.d.) years	6 (1.8)	6 (1.8)	6 (1.8)
Girls, *N* (%)	4659 (49)	2708 (49)	7367 (49)
Mean weight (s.d.) kg	23 (7)	23 (7)	23 (07)
Mean height (s.d.) m	117 (13)	117 (13)	117 (13)
Mean BMI (s.d.) kg/m^2	16.4 (2.4)	16.5 (2.6)	16.4 (2.5)
Overweight, *N* (%)[b]	1129 (12)	752 (14)	1881 (13)
Obese, *N* (%)[b]	604 (6)	412 (7)	1016 (07)
Low-income family, *N* (%)[c]	2154 (25)	1510 (31)	3664 (27)
Mean physical activity (s.d.) hour per week[d]	18 (11)	18 (11)	18 (11)
Country N *(%)*			
Italy	1521 (16)	683 (12)	2204 (15)
Estonia	1251 (13)	396 (7)	1647 (11)
Cyprus	1049 (11)	590 (11)	1639 (11)
Belgium	1111 (12)	712 (13)	1823 (12)
Sweden	1358 (14)	386 (7)	1744 (12)
Germany	1010 (11)	973 (17)	1983 (13)
Hungary	991 (11)	1498 (27)	2489 (17)
Spain	1136 (12)	324 (6)	1460 (10)

[a]Two years (mean) after baseline assessment, a second set of anthropometric measurements was obtained. [b]Overweight and obesity defined from body mass index (BMI) *z*-scores in accordance with International Obesity Task Force criteria.[21] [c]Family income classified into five country-specific categories (1, low; 2, low/medium; 3, medium; 4, medium/high; 5, high). Low income was defined as categories 1 plus 2; 1655 children with missing information on family income were excluded from these estimates. [d]Five hundred and twelve children had missing information on physical activity and were excluded from these estimates.

Questionnaires with <50% of missing replies were included in the analysis and the missing items were imputed as zero consumption except water as a drink. Water is often consumed outside parental control and was often not reported by parents. For this reason, we imputed the frequency of water consumption as the mean frequency of water consumption, by age group, body mass index (BMI) and country (779 water imputations).

Anthropometry

Height was measured to the nearest 0.1 cm with a calibrated stadiometer (SECA 225, Telescopic Height Measuring Instruments, (Seca GmbH & Co. KG, Hamburg, Germany)). Body weight was measured in light underwear, using scales (Tanita BC 420 SMA Digital Weighing Scale, Tanita Europe, GmbH; Sindelfingen, Germany) accurate to 0.1 kg. BMI was calculated as weight (kg) divided by height squared (m^2).

Weight status was assessed as BMI *z*-scores. The BMI *z*-score accounts for developmental differences between boys and girls of different ages by measuring each child's BMI relative to the sex and age-specific standard reference population.[20] BMI *z*-scores were used to classify children as underweight, normal weight, overweight or obese, according to the International Obesity Task Force criteria.[21] Prevalent overweight and obese children were those with overweight and obese BMI *z*-scores at baseline.

Outcome

The outcome of interest was adverse change in weight status between baseline and follow-up. Two approaches were used to determine this change:

(a) Incident cases of overweight/obesity (combined category). These were defined as children not overweight/obese at baseline but overweight/obese at follow-up. Prevalent overweight and obese children who remained overweight and obese during the follow-up (746 stable overweight and 468 stable obese) were excluded from this analysis.

(b) Change in BMI, defined as the difference between BMI at follow-up and at baseline.

Statistical methods

PCA was used to reduce the 43 food items (Table 1) to a small number of components (DPs) that explained the maximum fraction of the variance. DPs were derived by PCA of the whole baseline sample (14 989). After varimax orthogonal rotation—which typically associates each loading variable (food group) with one component, thereby increasing interpretability—principal component scores were generated. The Kaiser–Meyer–Olkin statistic was used to assess the adequacy of sampling for the predictors (food groups) used in the PCA. The Kaiser–Meyer–Olkin sampling adequacy was >0.6 for all 43 food groups (values between 0.6 and 1.0 support PCA use).

The number of DPs retained was based on eigenvalues, scree plot and factor interpretability. For comparability and interpretability of our results, food items with factor loadings >0.20 were considered to contribute to a DP. DPs were named after the most important loading variables. To assess stability, DPs were also extracted from the follow-up sample of 9427 children.

We also derived SDPs.[14,22] Briefly, for each explanatory DP from the original PCA, food variables with high (>0.20) factor loadings on a given DP were standardized and summed. The SDP was the sum of the unweighted standardized food variables. Pairwise associations between the resulting SDPs and original DPs were estimated (Pearson's correlation). Children were categorized according to tertiles of DP and SDP scores based on the follow-up population.

Table 3. Structures of the four dietary components identified by principal component analysis ($n = 14\,989$)

Dietary component[a]	*Loading coefficients on food groups*[b]		*Assigned name of dietary pattern*	*Variance explained (%)*
	Food group	*Loading coefficient*[b]		
Component **1**	Hamburger, hot dog, kebab, falafel	0.44	Snacking	10
	Butter or margarine on bread	0.31		
	Savory pastries	0.27		
	Chocolate, candy bars	0.25		
	Bread, white	0.25		
	Vegetables, cooked	−0.22		
Component **2**	Chocolate or nut-based spreads on bread	0.38	Sweet and fat	6
	Cakes, puddings, cookies	0.35		
	Candy and sweets, no chocolate	0.33		
	Meat, fried	0.28		
	Soft drinks, sugar added	0.24		
	Mayonnaise and similar	0.24		
	Soft drinks, diet	0.21		
	Cured meat and sausages	0.21		
Component **3**	Vegetables, raw	0.37	Vegetables and wholemeal	5
	Bread, wholemeal	0.35		
	Vegetables, cooked	0.31		
	Fruit, fresh, no sugar added	0.31		
	Milk, no sugar added	0.24		
	Breakfast cereals, no sugar added	0.24		
	Low-fat butter or margarine on bread	0.23		
Component **4**	Fish, fresh, not fried	0.39	Protein and water	4
	Water	0.30		
	Fish, fried, fish-fingers	0.28		
	Eggs, not fried	0.23		
	Meat, not fried	0.23		
	Pasta and rice	0.23		
	Pizza as main dish	0.21		
	Butter or margarine on bread	−0.23		

[a]Dietary components from principal component analysis ordered by proportion of variance explained. [b]Food groups ordered by size of loading coefficient. Food groups with loadings >0.20 are presented in the table.

We used mixed-effects logistic regression models with country as the grouping variable to estimate odds ratios (ORs) with 95% confidence intervals (95% CIs) of incidence of overweight/obesity being associated with a DP or an SDP. We used multivariate linear regression mixed-effects models with country as the grouping variable to assess whether DPs and SDPs were associated with changes in BMI over time.

We used the likelihood ratio test to compare mixed-effects models with standard regression models. Specifically, for each DP, mixed effect models were compared with models with only fixed-effect estimators, and the null hypothesis that differences in coefficient between countries were not systematic. As the likelihood ratio test showed a significant systematic effect for country (not shown), mixed-effects regression was chosen for all analyses. Trends across tertiles were tested using tertile medians as a continuous variable. Baseline age (year, continuous), BMI (continuous) and sex were included in all models as *a priori* person-level covariates. Physical activity (hours/week, continuous) and income (four country-specific categories) were also included as covariates.

We used the likelihood ratio test to test whether covariates interacted with associations between DPs and outcomes. We tested sex, age (2–<6 vs 6–<10 years), income (four country-specific categories) and physical activity (three categories). All tests were two-tailed; *P*-values ⩽0.05 were considered significant. The analyses were performed with Stata software (version 11.2, Stata Corp, College Station, TX, USA).

RESULTS

Table 1 shows the 43 food groups assessed by the CEHQ and also mean frequencies of consumption (times per week). Table 2 shows the baseline characteristics of the children and differences between those recontacted and those lost to follow-up. Thirteen percent of the children were overweight and 7% were obese at baseline. There were no major differences between children recontacted and those lost in terms of sex, age or physical activity level; however, those lost were more likely to be overweight (14% vs 12%) or obese (7% vs 6%) and had lower family income (all $P<0.001$). The proportion lost to follow-up varied with country, from 60% (Hungary) and (49%) Germany to 24% (Estonia) and 22% (Sweden).

After running PCA on the 43 dietary groups, the Scree test allowed us to identify four major patterns with the largest eigenvalues that explained 25% of food intake variance and could be interpreted meaningfully in terms of nutritional characteristics. High scores on the DP snacking corresponded to high consumption of street foods (for example, sandwiches), savory pastries and chocolate bars. The second DP was called sweet and fat for its high loadings on chocolate spreads, biscuits and sweets/candy, and also fried meat and soft drinks. The third, vegetables and wholemeal, was characterized by high consumption of vegetables,

Table 4a. Risk[a] of becoming overweight/obese[b] in children according to tertiles[c] of dietary pattern intake[d]

Population/cases			*Basic model*[e]	*Fully adjusted model*[f]
			8223[g]*/849*[b]	
Dietary pattern[d]		*Overweight/obese (N)*	*OR*[a] *(95% CIs)*	*OR*[a] *(95% CIs)*
Snacking				
1st tertile	−4.5 to −1.0	271	1.00	1.00
2nd tertile	−1.0 to 0.2	292	1.19 (0.97–1.45)	1.09 (0.88–1.35)
3rd tertile	0.2 to 26.8	286	1.23 (0.96–1.57)	1.18 (0.91–1.52)
P-trend[h]			0.12	0.22
Continuous (per unit of score)			1.04 (0.99–1.09)	1.03 (0.97–1.09)
Sweet and fat				
1st tertile	−4.7 to −0.9	298	1.00	1.00
2nd tertile	−0.9 to 0.3	298	1.07 (0.88–1.31)	1.08 (0.88–1.33)
3rd tertile	0.3 to 27.2	253	1.04 (0.84–1.28)	0.97 (0.77–1.22)
P-trend[h]			0.78	0.74
Continuous (per unit of score)			1.02 (0.97–1.07)	1.01 (0.95–1.07)
Vegetables and wholemeal				
1st tertile	−8.4 to −0.8	416	1.00	1.00
2nd tertile	−0.8 to 0.5	242	0.69 (0.57–0.84)	0.76 (0.62–0.94)
3rd tertile	0.5 to 15.3	191	0.64 (0.51–0.80)	0.69 (0.54–0.88)
P-trend[h]			<0.001	0.003
Continuous (per unit of score)			0.90 (0.85–0.96)	0.93 (0.87–0.99)
Protein and water				
1st tertile	−4.7 to −0.6	220	1.00	1.00
2nd tertile	−0.6 to 0.5	291	1.03 (0.84–1.28)	1.00 (0.80–1.25)
3rd tertile	0.5 to 37.5	338	0.96 (0.76–1.22)	0.95 (0.74–1.23)
P-trend[h]			0.70	0.59
Continuous (per unit of score)			1.00 (0.94–1.06)	1.00 (0.93–1.06)

[a]Odd ratios (ORs) with 95% confidence intervals (CIs) from mixed-effect logistic regression (observations on children nested into countries). [b]Outcome 'overweight/obese' defined as becoming overweight ($n=644$) or obese ($n=205$) over the 2 years since baseline. [c]Tertiles of dietary pattern intake calculated on population re-examined after 2 years. [d]Dietary patterns identified by principal component analysis. [e]Adjusted by age (continuous), sex and baseline body mass index (BMI; continuous). Effect of country is accounted for by mixed logistic regression model with country as the grouping variable. [f]Additionally adjusted by baseline BMI (continuous), physical activity (hours of physical activity per week, continuous) and income (low, low/medium, medium, medium/high and high, based on country-specific distributions). The effect of country is accounted for by the mixed logistic regression model with country as the grouping variable. [g]Children overweight at baseline who remained overweight at follow-up ($n=736$) were excluded from this analysis. Children obese at baseline who remained obese at follow-up ($n=468$) were also excluded. [h]Significance of trend across tertiles tested using tertile medians as continuous variable.

Table 4b. Risk[a] of becoming overweight/obese[b] in children according to tertiles[c] of simplified dietary pattern intake[d]

Population/cases			*Basic model*[e]	*Fully adjusted model*[f]
			8223[g]*/849*[b]	
Simplified dietary pattern[d]		*Overweight/obese (N)*	*OR*[a] *(95% CIs)*	*OR*[a] *(95% CIs)*
Snacking				
1st tertile	− 12.2 to − 2.0	271	1.00	1.00
2nd tertile	− 2.0 to 0.6	292	1.03 (0.84–1.26)	1.01 (0.81–1.24)
3rd tertile	0.6 to 52.7	286	1.23 (0.98–1.54)	1.20 (0.94–1.52)
P-trend[h]			0.06	0.11
Continuous (per unit of score)			1.03 (1.00–1.05)	1.02 (0.99–1.05)
Sweet and fat				
1st tertile	− 5.1 to − 2.2	298	1.00	1.00
2nd tertile	− 2.2 to 0.3	298	1.05 (0.87–1.27)	0.98 (0.80–1.20)
3rd tertile	0.3 to 59.6	253	1.11 (0.90–1.37)	1.05 (0.84–1.32)
P-trend[h]			0.61	0.61
Continuous (per unit of score)			1.01 (0.99–1.03)	1.01 (0.95–1.04)
Vegetables and wholemeal				
1st tertile	− 6.1 to − 1.8	416	1.00	1.00
2nd tertile	− 1.8 to 1.2	242	0.77 (0.64–0.93)	0.80 (0.65–0.98)
3rd tertile	1.2 to 20.8	191	0.63 (0.50–0.78)	0.64 (0.51–0.82)
P-trend[h]			< 0.001	< 0.001
Continuous (per unit of score)			0.94 (0.92–0.97)	0.95 (0.92–0.98)
Protein and water				
1st tertile	− 8.6 to − 1.6	220	1.00	1.00
2nd tertile	− 1.6 to 1.0	291	0.96 (0.78–1.18)	0.96 (0.77–1.20)
3rd tertile	1.0 to 65.9	338	1.00 (0.80–1.25)	1.03 (0.81–1.31)
P-trend[h]			0.95	0.77
Continuous (per unit of score)			1.01 (0.98–1.03)	1.01 (0.98–1.04)

[a]Odd ratios (ORs) with 95% confidence intervals (CIs) from mixed-effect logistic regression (observations on children nested into countries). [b]Outcome 'overweight/obese' defined as becoming overweight ($n = 644$) or obese ($n = 205$) over the 2 years since baseline. [c]Tertiles of dietary pattern intake calculated on population re-examined after 2 years. [d]Simplified dietary patterns derived from those identified by principal component analysis.[14] [e]Adjusted by age (continuous), sex and baseline body mass index (BMI; continuous). Effect of country is accounted for by mixed logistic regression model with country as the grouping variable. [f]Additionally adjusted by baseline BMI (continuous), physical activity (hours of physical activity per week, continuous) and income (low, low/medium, medium, medium/high and high, based on country-specific distributions). The effect of country is accounted for by the mixed logistic regression model with country as the grouping variable. [g]Children overweight at baseline who remained overweight at follow-up ($n = 736$) were excluded from this analysis. Children obese at baseline who remained obese at follow-up ($n = 468$) were also excluded. [h]Significance of trend across tertiles tested using tertile medians as continuous variable.

fruits, wholemeal cereal products and unsweetened milk. The fourth, protein and water, was characterized by high consumption of fish, meat, eggs and water. The detailed structures of the four DPs with their principal loading coefficients are shown in Table 3.

PCA was also run on the recontacted children ($n = 9427$) using the same criteria: the four DPs extracted from subsample explained the same variance as the DPs from the full sample (Table 3) and were made up of closely similar food groups (results not shown in the Table).

SDPs were extracted as sums of food items with high loadings on the four DPs and named in the same way. Each SDP correlated with its corresponding DP ($r \geqslant 0.9$ in all cases).

A mean of 2 years later (5th and 95th percentiles 1.8 and 2.2 years, respectively), 644 (7%) of the 9427 recontacted children had become overweight and 205 (2%) had become obese. Associations between DP and risk of becoming overweight/obese (single category) are shown in Table 4a. High intake of vegetables and wholemeal was significantly associated with lower risk of becoming overweight/obese. For the fully adjusted model, the OR was 0.69 (95% CIs: 0.54–0.88) for the highest tertile of intake compared with the lowest. The test for trend was significant ($P = 0.003$). None of the other DPs were significantly associated with the risk of becoming overweight/obese in any model.

Tests for interaction showed that the effects of DP on risk of becoming overweight/obese were not significantly affected by sex, age group, income, physical activity or BMI status at baseline (all $P > 0.05$, data not shown). Thus, we do not present results stratified by these variables.

To assess whether the inhomogeneous between country loss to follow-up (Table 2) influenced the results, we performed a sensitivity analysis in which one country at a time was excluded from the DP models; in none of the cases did the results differ from those presented in Table 4a (results not shown in tables).

Results for SDP are shown in Table 4b. The only SDP significantly associated with overweight/obesity was vegetables and wholemeal. For the fully adjusted model, the OR was 0.64 (95% CIs: 0.51–0.82) for the highest tertile intake compared with the lowest, with *P*-trend < 0.001).

The association of DP intake with longitudinal change in BMI is shown in Table 5a. For the fully adjusted model, high intake of vegetables and wholemeal was associated with smaller increment in BMI (0.73 vs 0.80 kg/m^2 for the second vs first tertile of intake; $P = 0.04$); however, there was no clear trend (*P*-trend = 0.18). High intake of the SDP vegetables and wholemeal was also associated with smaller increase in BMI (0.72 vs + 0.82 kg/m^2 for the third vs first tertile of intake; *P*-trend = 0.03; Table 5b). No other DP or SDP was associated with longitudinal change in BMI in any model.

Table 5a. Change in BMI[a] in children according to tertiles[b] of dietary pattern score[c]

Dietary pattern	Tertile range[b]	N	Basic model[d]		Fully adjusted model[e]	
			Mean change[f]	P-value[g]	Mean change[f]	P-value[g]
Snacking						
T1	−4.5 to −1.0	3143	0.74		0.73	
T2	−1.0 to 0.2	3142	0.78	0.19	0.76	0.51
T3	0.2 to 26.8	3142	0.80	0.16	0.78	0.35
P-trend[h]			0.18		0.36	
Sweet and fat						
T1	−4.7 to −0. 9	3143	0.75		0.73	
T2	−0.9 to 0.3	3142	0.76	0.78	0.76	0.55
T3	0.3 to 27.2	3142	0.79	0.30	0.78	0.26
P-trend[h]			0.29		0.26	
Vegetables and wholemeal						
T1	−8.4 to −0.8	3143	0.84		0.80	
T2	−0.8 to 0.5	3142	0.73	0.00	0.73	0.04
T3	0.5 to 15.3	3142	0.75	0.03	0.74	0.11
P-trend[h]			0.05		0.18	
Protein and water						
T1	−4.7 to −0.6	3143	0.75		0.73	
T2	−0.6 to 0.5	3142	0.76	0.68	0.74	0.19
T3	0.5 to 37.5	3142	0.81	0.15	0.80	0.16
P-trend[h]			0.15		0.11	

[a]Change in body mass index (BMI) calculated as (BMI at follow-up—BMI at baseline). [b]Tertiles of dietary pattern intake calculated on population re-examined after 2 years ($n = 9427$). [c]Dietary pattern identified by the principal component analysis. [d]Adjusted by age (continuous), sex and baseline BMI (continuous). Effect of country accounted for by mixed logistic regression model with country as the grouping variable. [e]Additionally adjusted by physical activity (hours of physical activity per week, continuous) and income (low, low/medium, medium, medium/high and high, based on country-specific distributions). Effect of country accounted for by mixed logistic regression model with country as the grouping variable. [f]Mean change in BMI by tertiles of dietary pattern intake at baseline. [g]*P*-value for comparison of tertiles of BMI change, first tertile as a reference. [h]Significance of trend across tertiles tested using tertile medians as the continuous variable.

Table 5b. Change in BMI[a] in children according to tertiles[b] of simplified dietary pattern score[c]

Simplified dietary pattern	Tertile range[b]	N	Basic model[d]		Fully adjusted model[e]	
			Mean change[f]	P-value[g]	Mean change[f]	P-value[g]
Snacking						
T1	−12.2 to −2.0	3144	0.76		0.75	
T2	−2.0 to 0.6	3145	0.75	0.83	0.74	0.72
T3	0.6 to 52.7	3142	0.80	0.33	0.77	0.62
P-trend[h]			0.28		0.57	
Sweet and fat						
T1	−5.1 to −2.2	3145	0.76		0.75	
T2	−2.2 to 0.3	3140	0.77	0.87	0.74	0.94
T3	0.3 to 59.6	3142	0.78	0.69	0.78	0.39
P-trend[h]			0.69		0.36	
Vegetables and wholemeal						
T1	−6.1 to −1.8	3143	0.84		0.82	
T2	−1.8 to 1.2	3142	0.74	0.00	0.73	0.03
T3	1.2 to 20.8	3142	0.74	0.00	0.72	0.02
P-trend[h]			0.01		0.03	
Protein and water						
T1	−8.6 to −1.6	3181	0.74		0.73	
T2	−1.6 to 1.0	3106	0.76	0.62	0.74	0.45
T3	1.0 to 65.9	3140	0.81	0.09	0.80	0.06
P-trend[h]			0.10		0.06	

[a]Change in body mass index (BMI) calculated as (BMI at follow-up—BMI at baseline). [b]Tertiles of dietary pattern intake calculated on population re-examined after 2 years ($n = 9427$). [c]Simplified dietary patterns derived from those identified by principal component analysis.[14] [d]Adjusted by age (continuous), sex and baseline BMI (continuous). Effect of country accounted for by mixed logistic regression model with country as the grouping variable. [e]Additionally adjusted by physical activity (hours of physical activity per week, continuous) and income (low, low/medium, medium, medium/high and high, based on country-specific distributions). Effect of country accounted for by mixed logistic regression model with country as the grouping variable. [f]Mean change in BMI by tertiles of dietary pattern intake at baseline. [g]*P*-value for comparison of tertiles of BMI change, first tertile as a reference. [h]Significance of trend across tertiles tested using tertile medians as the continuous variable.

DISCUSSION

This multicenter cohort study has identified four DPs that satisfactorily (25% of food variance explained) capture eating habits in a heterogeneous cohort of European children. The first pattern (snacking) consisted of a combination of fast foods/sandwiches (including hamburgers, kebabs and so on) and snacks likely to be consumed outside meal times. Sweet and fat consisted of a combination of sugar-rich foods (sweets/candy, biscuits and soft drinks) and high-fat foods (chocolate spreads and fried meat). Vegetables and wholemeal consisted of a combination of raw vegetables, cooked vegetables (including potatoes not fried and legumes), whole cereals, fresh fruit, milk and breakfast cereal (the latter three with no added sugar). Protein and water was characterized by high consumption of foods rich in animal protein (meat, fish and eggs) and high frequency of water consumption, and can be interpreted as a traditional way to feed (overfeed) a child (with a cooking parent) using expensive protein food sources. The two DPs snacking and sweet and fat explained most (16%) of the variance in food intake. DPs that resemble snacking and sweet and fat have recently been identified for children and adolescents in Germany,[23] the United Kingdom,[24,25] Greece,[26] Norway,[27] Spain,[28] Sweden,[29] Portugal[9] and Finland.[30] That these two patterns, typifying 'Western' eating habits, were found is not unexpected, in view of the globalization of food markets[31–33] and pervasive advertising for many of the constituents of these patterns (much of it directed at children). What is surprising, even alarming, is that these patterns were fairly uniformly prevalent in our heterogeneous cohort of children from eight European countries.

The third DP (in terms of variance explained) was vegetables and wholemeal, which may be regarded as a healthy DP. The only other European cohort study on DPs in children[27]—from a single country—also identified a similar DP. Studies on the effects of consuming components of this pattern (vegetables, legumes, fruit, plain milk and wholemeal cereals) indicate that it is associated with a reduced risk of becoming or being overweight.[34–39] Our finding that vegetables and wholemeal was associated with reduced incidence of overweight is consistent with the results of a 5-year follow-up study on US girls, which identified a pattern characterized by high intake of fruit, vegetables, milk and whole grains, and found that this pattern was associated with smaller increases in waist circumference.[40]

Although there is a large body of evidence that sugar- and fat-dense diets tend to lead to obesity,[24,41–44] we failed to find significant associations of the DPs snacking and sweet and fat, with the risk of becoming overweight/obese. This is probably related to the dietary questionnaire we used that, like most instruments that assess children's diet, uses replies from proxy respondents (mostly parents). And as most foods of the snacking and sweet and fat patterns are eaten out of the home, out of meal times and out of parental control, the questionnaire would have been unable to adequately capture their consumption frequencies. In fact, the questionnaire was only designed to capture information on parent-supervised meals. Inability to accurately capture snacking is therefore a limitation of our dietary instrument. We intend to address this in the next follow-up of the study by getting the children to respond to the questionnaire and integrating the replies with those provided by the parent.

The IDEFICS study population was not representative of the childhood population in the countries studied, and like many cohort studies, our study may therefore suffer from volunteer bias. For example, parents with less knowledge or concern about their children's diet/health, and parents of overweight or obese children, may be less motivated to take part in such a study. Under-representation of low-income and low-education children was in fact expected and steps were taken to overcome it in Italy, Cyprus and Germany by specifically seeking recruits from schools in areas where low-income families and minority/immigrant groups were present. However, as we have no systematic information about non-participants, we cannot know to what extent this was successful, and we acknowledge this as a possible study limitation. A further limitation is that 35% of our cohort was not available for follow-up (most refused) and low-income families were prominent among those not recontacted. These shortcomings probably limit the generalizability of our results to the general population.

We did not obtain data on parental obesity and could not assess it as a potential confounder or effect modifier. This is therefore a study limitation as data indicate that children whose parents are overweight or obese are at increased risk of becoming obese themselves.[45]

A known problem with explanatory PCA is that the DPs obtained from it are not generally reproducible.[12] To address this problem, we extracted DPs from the follow-up subpopulation. The four DPs found closely resembled those extracted from the whole population and explained the same proportion of the total variance, indicating that the identified DPs are reproducible, at least in a subgroup of the original population.

To further address this PCA limitation, we also constructed SDPs, which were found to be closely similar to the original DP (correlation$\geqslant$0.9) indicating that our DPs were able to well describe the so-called simple structure[14] of the data variables. This finding also suggests that the vegetables and wholemeal SDP can be used in other populations as an indicator of reduced risk of overweight/obesity.

To our knowledge, this is the first multicenter longitudinal European study to assess the effects of DPs on overweight/obesity in children. The longitudinal design, wide variety of dietary habits, diverse cultural backgrounds in eight European countries and use of a validated dietary instrument are strengths of our study. The extraction of SDPs, which were closely similar to SPs indicates that our results can be applied to etiological studies on other populations with reproducible risk estimates.

To conclude, we have found that a DP rich in vegetables, wholemeal cereals, fruit and plain milk is protective against overweight/obesity. This finding is robust is indicated by the fact that a simplified version of this pattern was also found to be protective against overweight/obesity. We suggest that these results should be used to produce guidelines to counteract the obesity epidemic in European children, provided they are confirmed by further studies. Finally, we suggest that in future studies information on children's diet from parents should be integrated with that obtained directly from children in order to better capture intake of snacks and other foods eaten out of the home.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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