Dietary energy density as a marker of dietary quality in Swedish children and adolescents: the European Youth Heart Study

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Word count: 3053

Running title: Dietary energy density and diet quality

Keywords: 24-h recall; dietary patterns; epidemiology; foods; nutrients

Abstract

Objective: To investigate if dietary energy density is associated with measures of dietary quality (food group, micronutrient and macronutrient intakes) in children and adolescents.

Methods: 551 children (mean age 9.6y, 52% girls) and 569 adolescents (15.5y, 55% girls), sampled from schools in Sweden, completed a single 24-h dietary recall. Dietary energy density (kJ/g) was calculated as the energy from all food consumed divided by the weight of all food consumed. Beverages were excluded from the calculation. Food and micronutrient intakes were adjusted for energy intake. A one-way ANOVA tested for differences in food group and nutrient intakes across age- and gender-specific tertiles of energy density. Discriminant analysis was used to confirm the groupings formed by tertiles.

Results: Subjects with low energy density diets were significantly more likely to consume fruits; vegetables; pasta, rice, potatoes; cereals; and less likely to consume sweetened drinks; sweets and chocolate. After energy adjustment, their intakes of many foods recommended in Swedish food-based-dietary-guidelines were higher and intakes of nutrient-poor foods were lower. The macronutrient energy profile (% energy) of low energy density diets was closest to the recommended level. Low energy density diets contained greater amounts of most micronutrients. Discriminant analysis confirmed the existence of heterogeneous dietary patterns and the likelihood of correct classification by energy density in 65% of cases.

Conclusions: Lower dietary energy density is associated with better dietary quality in children and adolescents. Energy density has advantages over other whole-diet analysis methods and may be suitable as a simple proxy of diet quality.

Introduction

No simple, well-accepted criteria exist that allow diets to be classified as healthy or unhealthy. Attempts to assess overall diet quality have often relied on scores or indexes (Kant 1996) and more recently, data-driven methods (e.g. cluster or factor analyses) (Hoffmann et al 2004, Hu 2002, Kant 2004, Newby and Tucker 2004). These approaches attempt to capture the dietary pattern rather than focusing on certain foods or nutrients. The disadvantages are that data must be structured in a way that allows the score to be calculated or, in the case of data-driven methods, that the results are sample-specific. Dietary energy density has the advantage of being simply calculated and available from all types of dietary data where food and beverage energy and intakes are available.

The energy density of a food/diet is a measure of the amount of energy provided per unit weight and primarily determined by its water and fat content (Drewnowski 2003, Stubbs et al 2000). Dietary energy density has been associated with higher dietary quality in adults (Kant and Graubard 2005b, Ledikwe et al 2006b, Maillot et al 2007, Schröder et al 2008b), and also with more objective measures of health, such as the metabolic syndrome, overweight and predictors of obesity in adults and children (Howarth et al 2006, Kant and Graubard 2005b, Ledikwe et al 2006a, Mendoza et al 2006, Mendoza et al 2007).

The aim of this study was to examine the association of dietary energy density with dietary quality, namely food group intake, vitamin and mineral intakes and macronutrient energy profile, in Swedish children and adolescents. The ability of energy density to discriminate heterogeneous dietary patterns in the population was also tested.

Subjects and methods

Participants

Subjects were Swedish participants of the European Youth Heart Study, conducted in 1998-99. Over two thousand (n = 2 313) children (from grade 3 (9 years old)) and adolescents (grade 9 (15 years old)) were sampled from classes selected from forty-two schools in southern Stockholm and Örebro, and 1 137 students consented to participate (Wennlöf et al 2003). Permission was obtained from the local ethical committees (Huddinge University Hospital no. 474/98, Örebro City Council no. 690/98). Written consent was provided by a parent or legal guardian; verbal consent was provided by the subjects. Data collection was performed at the school.

Dietary assessment

All subjects completed a single interviewer-mediated 24-h recall. The younger children kept a 1-d qualitative food diary with the assistance of their parents on the day before the interview, to aid as a prompt in case of difficulties with the recall. A food atlas with pictures of common foods in various portion sizes was available during the interview, along with standard household units to help estimate quantities accurately. Data from the recall was analysed using software (StorMats, version 4.02; Rudans Lättdata, Västerås, Sweden) based on the Swedish Food Administration's nutritional database (version 99.1; www.slv.se). Each food consumed was allocated to a food group based on nutritional or dietary similarities and intakes are presented at food group level. The food groups were originally based on the Swedish Food Administration's groups but were modified to allow more specific classification in some cases and less in others. The "milk, fil, yoghurt" group includes fil, a soured-milk product similar to yoghurt, common in Nordic countries. "Sweetened drinks" refers to carbonated or cordial-based drinks; fruit juices are concentrated or fresh juices. The “other sweet foods” group includes desserts, ice-cream, sweet soups, jams and added sugar. “Burgers, sausages” are processed meat products and are a subsection of the “meat, meat dishes” group. “Cereals” refer to breakfast cereals (both sweetened and unsweetened). Fried potatoes are included in the “chips, crisps” group. Someone who reported eating any amount of a food group was considered a consumer.

Calculation of energy density

Energy density was calculated as energy (kJ) divided by weight (g). Food was defined as solid food and liquids consumed as food (e.g. soups, yoghurt). All beverages, both energy-containing (e.g. milk, sweetened drinks, fruit juices) and non-energy-containing (e.g. water, coffee, diet beverages) were excluded. Because the energy density differed by age and gender, tertiles were created that were age- and gender-specific. The diets of these groups were referred to as low, middle and high energy density diets.

Recalls of suspected poor quality or inadequate energy

On completion, the recall was immediately rated by the interviewer based on the subject’s perceived interest and motivation and the level of detail provided. Interviews with a score of less than three (out of five) were suspected to be of low quality. The plausibility of energy intakes reported was tested by comparing the reported intakes to a theoretical intake that is predicted from basal metabolic requirements (BMR), and age- and gender-specific physical activity levels, assuming weight stability. A confidence interval is constructed around the predicted intake that takes into account the number of days of diet recorded (Goldberg et al 1991). BMR was estimated (Schofield 1985) using weight and height that had been measured using standardised techniques, and reference physical activity levels were taken from Black (2000). Subjects with energy intakes below the lower confidence interval cut-offs were considered possible under-reporters, and these cut-offs were equivalent to a ratio of reported energy to BMR of 0.97, 0.98, 0.98 and 1.03 in 9-year-old girls and boys, and 15-year-old girls and boys, respectively. Due to the uncertainty in identifying under-reporters, particularly when only one day of dietary data is available (Black 2000), we chose not to exclude these subjects. Instead, we considered the effect exclusion might have on the results.

Statistical analysis

An initial correlation analysis confirmed a positive and significant association between energy intake and both food and nutrient intakes. As energy was also a component of the predictor variable - energy density - any association between foods and/or nutrients with energy density might have been due to the effect of increasing energy. To overcome this, food group and micronutrient intakes were regressed on total energy intakes and the residuals of these linear regressions were used as the response variables in subsequent analyses (Willett et al 1997). The residuals are by definition uncorrelated with energy and represent the differences between the observed and predicted intakes, i.e. the difference between an individual's actual food or nutrient intake and what it would be expected to be, given their energy intake.

The association of energy density tertiles with food group and micronutrient intake residuals were analysed by one-way ANOVA. Differences in energy density between age- and gender-subgroups were investigated by one-way ANOVA with Tukey’s post-hoc test. A χ^2 test checked for differences in the frequency of food group consumers across tertiles. Energy density (after square-root transformation to normalise the distribution) was tested between under- and adequate reporters with a Student’s t-test.

To further check that the tertiles represented heterogeneous dietary patterns, we performed discriminant function analysis. This tests whether cases are classified as predicted from a set of discriminating variables (the food residuals) into predefined groups of a criterion variable (the energy density tertiles). The predicted classification was compared to the original classification. It also calculates structure coefficients of the discriminating variables, which indicate how much they predict the groups.

Prior to regressing the foods/nutrients on energy, the intakes were transformed (square root or natural log) so that the residuals of the regression were as homogeneous as possible across tertiles, a requirement of both discriminant analysis and ANOVA. Due to the skewness of the data, intakes of food groups are presented in Tables 2a and 2b as geometric means and 95% confidence intervals, for consumers only. The geometric mean is equivalent to the antilog of the arithmetic mean of log-transformed data. All other tables use (arithmetic) mean and s.d. All analysis was performed using SPSS for Windows, version 16 (SPSS Inc, Chicago, US) and the level of significance was set at $P < 0.05$.

Results

Data was available for 551 children (52% girls, mean age 9.6 years) and 569 adolescents (55% girls, mean age 15.5 years). The prevalence of overweight was 12% (highest in 9-year-old boys at 14%; lowest in 15-year-old girls at 9%), and the prevalence of obesity was 2% (highest in 15-year-old boys at 3%; lowest in 15-year-old girls at 1%).

As the diet increased in energy density, energy intake increased, and total food intake decreased, across each tertile, in all age- and gender-subgroups (Table 1). These relationships were linear, except in 15-year-old boys. Only the low energy density diet group met the population goals for energy from macronutrients (Nordic Council of Ministers 2004, WHO 2003)(Figure 1).

Significant differences between energy density tertiles were seen in both the proportion of food group consumers and in the amounts consumed (Tables 2a and 2b). χ^2 tests showed that, for each of the following food groups, in at least three of the age- and gender-subgroups subjects with the lowest energy density were more likely to consume: fruit; vegetables; pasta, rice and potatoes; and cereals, and were less likely to consume sweets and chocolate, and sweetened drinks. After adjustment for energy, intakes of most food groups differed significantly across tertiles of energy density (Table 2b). The food group that differed most across tertiles, with the largest F-value, was fruit, followed by pasta, rice, potatoes; vegetables; sweets and chocolate; and milk, fil, yoghurt. Low, mid and high energy density diets also differed significantly in terms of micronutrient and fibre intake (Tables 3a and 3b).

The discriminant function analysis confirmed that significant differences between energy density tertiles existed (overall Wilks' λ = 0.49, P<0.001). The largest structure coefficients were for fruit (0.430); pasta, rice, potatoes (0.387); vegetables (0.352); sweets and chocolate (-0.275); sweetened drinks (-0.245); and milk, fil, yoghurt (0.220). The discriminant analysis was also able to classify subjects into groups that agreed well with the energy density tertiles. Using all available food intake data, 65% of subjects were classified to the "correct" (same) group as when only the dietary energy density variable was used, exceeding the value for classification based on chance (33%). Reanalysis with the extreme tertiles only (i.e. low and high) correctly classified 89%.

Potential energy under-reporting occurred more in the older age-group (data not shown). Under-reporters had significantly lower dietary energy density compared to adequate reporters in the older age-group only (1.57 vs 1.71 kJ/g, P = 0.010), however removing all under-reporters (n = 84) did not change any associations between energy density and either food groups or micronutrients. While the younger age group were more likely to have a lower quality interview, energy density did not differ between low and high quality recalls, and excluding these recalls (n = 149) also had no effect on the main analysis.

Discussion

Associations between dietary energy density and diet quality

The low energy density diet had a macronutrient energy profile closest to population goals and higher intakes of most micronutrients examined. In the majority of age- and gender-subgroups, it was characterised by higher and more frequent intakes of many of the food groups recommended in Sweden. The discriminatory analysis confirmed that the tertiles, particular the two extreme tertiles, were considerably different from each other. Taken together, the overall picture of a lower energy density diet is one of higher dietary quality.

To the best of our knowledge, no other studies comprehensively describing dietary quality and energy density in children under free-living conditions have been published, although Johnson *et al.* (2008a) did report a relationship between dietary energy density and percent energy from total fat (positive) and fibre (negative) in a sample of UK children. Also in children, a cross-sectional association between energy density and selected predictors of obesity (Mendoza et al 2006), and a longitudinal association with overweight (Johnson et al 2008a, McCaffrey et al 2008), have been reported. In adults, low energy density diets have been associated with higher diet quality (based on micronutrient, macronutrient and food intakes) in two large US cohorts: the NHANES III and the CSFII 1994-1996 surveys (Kant and Graubard 2005b, Ledikwe et al 2006b). In almost 2 000 French adults, dietary energy density was found to correlate with the mean adequacy ratio, an index of quality based on recommended nutrient intakes (Maillot et al 2007). Cucó *et al.* (2001) defined energy density as kJ per cm^3, and included beverages, and found high energy density was associated with higher intakes of fat and certain food groups in Spanish adults. Using kJ/g and excluding beverages, Schröder *et al.* also found low energy density diets were of higher quality in Spanish adults, including elderly (Schröder et al 2008a, Schröder et al 2008b).

Both the ANOVA and the discriminant analysis suggested that fruit; pasta, rice and potatoes; vegetables; milk, fil and yoghurt; sweets and chocolate; and sweetened drinks are the most important food groups in determining dietary energy density. Johnson *et al.* (2008b) noted in their study that fruit and vegetables (combined) had twice as heavy a loading on a dietary pattern score that included energy density than crisps and confectionary did. They propose that this should "reinforce efforts to encourage consumption of fruit and vegetables" rather than "focusing on the exclusion" of energy-dense foods, but whether this would be any more effective from a public health perspective is open to debate (Verbeke 2008). For many foods the trend across energy density tertiles was clear, but for burgers and sausages, and crisps and chips, it was not. These foods may reflect home-cooking as well as fast food consumption and so the association with diet quality may not be as straightforward.

The mean energy density values in our study are slightly lower than those published by Johnson *et al.* (2008a) and McCaffrey *et al.* (2008) but the dietary assessment methods used differed from ours and their subjects were younger. Mendoza *et al.* (2006) reported much lower values but did not exclude all beverages in their calculations. As with our younger age-group, no significant gender differences in energy density were reported in these studies. Despite also consuming the most foods and beverages, 15-year-old boys had significantly more energy dense diets than either the children or 15-year-old girls. Their mean energy intake was 12.4 MJ, over 3.8 MJ more than the 15-year-old girls (data not shown). Differences of a similar magnitude have been seen in another study of Swedish 15-year-olds (Sjöberg and Hulthén 2004). Over the life course, energy density has been shown to decline after 15-17 years of age and 13-15 years in U.S. and Spanish adolescents, respectively (Drewnowski 2000, Martí-Henneberg et al 1999).

Defining a healthy diet

There is no accepted way to identify a “healthy” diet. Defining a food or food group as healthy is also challenging (Drewnowski 2005, Lobstein and Davies 2008) but food-based dietary guidelines provide some direction (Becker 1999, FAO/WHO 1998). The Nordic Nutrition Recommendations (NNR) recommend the consumption of fruits and vegetables, cereals, fish, milk and milk products (mainly lean varieties) and potatoes (Nordic Council of Ministers 2004). They advise that the consumption of energy dense foods should be limited. More recently, an interest in whole-diet analysis has led to the development of dietary pattern methods that can be broadly classified as data-driven and knowledge-driven. The former are sample-specific and require subjective interpretation of the patterns that emerge (Hu 2002, Newby and Tucker 2004); the latter, such as scores and indexes, are based on *a priori* assumptions about diet and health, and are not applicable in every setting. Some require information on portions, compliance with recommended daily allowances or intakes of foods or beverages (e.g. alcoholic), which may not be appropriate in all countries or age groups (Kant 1996, Kant 2004, Kant and Graubard 2005a). Energy density has the advantage of being easy to calculate in every dietary study where energy and weight of food and beverages consumed is available. If these results are replicated in other studies, using different dietary assessment methods and in other populations, the use of energy density as a simple proxy marker for a diet of better quality might be supported. It could be used to identify upper and lower quantiles within a population and to thereby discriminate between diets that are generally of lower and higher quality, respectively.

Methodological considerations

The most appropriate method of calculating dietary energy density remains to be defined. Not only are beverages much less energy dense than most foods, but the regulation of beverage intakes is different to that of food (Rolls et al 2005) . We chose to exclude all beverages from the calculation, and this has been recommended to enhance comparability with other studies (Johnson et al 2009, Ledikwe et al 2005). We repeated the analysis using energy density calculated with milk, and with milk and other energy-containing beverages included. The association with 3-6 food groups (out of 20) and 2-3 micronutrients (out of 13) changed; some became associated, some lost association (data not shown), but our overall conclusion did not change.

It should be noted that high energy-dense foods are not nutritionally equal. For example, a person with a high intake of “healthy” fats would be as likely to be in the high energy dense diet category as someone with a high intake of saturated fats, and this is one limitation of dietary energy density. The relatively large sample size and the use of both an objective and subjective method of identifying recalls of potentially lower quality are strengths of the study. The limitations of 24-h recalls in capturing habitual intake at individual level are well known (Beaton et al 1997, Bingham 1991), due to the large day-to-day variation in intake that exists. However, for the purpose of this study, a 24-h recall on a reasonably large group, with no obvious bias, was deemed appropriate to demonstrate an association with energy density and dietary quality.

Conclusions

The use of dietary energy density to categorise the diets resulted in groups characterised by quite different dietary patterns. Subjects with lower energy density diets are more likely to consume recommended food groups, have higher intakes of micronutrients and recommended food groups and have the most favourable macronutrient energy profile. Replication of these findings in other studies could support the use of dietary energy density as a simple marker of dietary quality.

Acknowledgements

We thank Associate Prof. Olle Carlsson and Prof. Juni Palmgren for their suggestions regarding the statistical analysis. We also thank the participants of this study and colleagues who collected the data. This work was supported by Stockholm County Council.

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Figure 1 Mean percent energy from macronutrients across tertiles of energy density

Error bars indicate SEM. SEM was multiplied by a factor of two, and bars are one-sided, for clarity.
Recommended upper limits for saturated fat and sucrose: 10%; population goals
for protein: 15%; fat: 30%, and carbohydrates: 55% (NNR, 2004)
All means differed significantly across tertiles ($P < 0.001$)

Table 1 Energy density, food intake and energy intake across energy density tertiles, by age and gender

			Energy density[1]	Food only[2]		All food and beverages	
			kJ/g	MJ	g	MJ	g
	Tertile	n	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)
Girls, 9 years [a]	Low	95	5.21 (0.60)	6.57 (1.84)	1261 (319)	7.90 (1.90)	2139 (494)
	Mid	96	6.62 (0.34)	6.83 (1.76)	1034 (268)	8.29 (1.95)	2048 (562)
	High	95	8.65 (1.17)	6.93 (1.92)	817 (256)	8.49 (2.12)	1815 (448)
Boys, 9 years [a]	Low	88	5.15 (0.56)	6.70 (1.97)	1307 (387)	8.32 (2.26)	2320 (688)
	Mid	89	6.57 (0.37)	7.41 (1.99)	1133 (316)	9.12 (2.30)	2267 (624)
	High	88	8.68 (1.16)	7.92 (2.06)	930 (274)	9.44 (2.27)	1983 (543)
Girls, 15 years [a]	Low	104	5.12 (0.58)	6.64 (2.05)	1312 (438)	7.89 (2.36)	2708 (952)
	Mid	104	6.61 (0.44)	7.15 (2.27)	1082 (339)	8.63 (2.54)	2399 (723)
	High	104	9.17 (1.43)	7.78 (2.72)	870 (330)	9.28 (3.05)	2196 (810)
Boys, 15 years [b]	Low	85	5.65 (0.66)	9.72 (3.43)	1727 (587)	11.63 (3.78)	3408 (1102)
	Mid	86	7.37 (0.43)	10.70 (3.19)	1456 (439)	13.19 (3.72)	3386 (1115)
	High	86	9.43 (1.17)	9.95 (3.31)	1073 (386)	12.49 (3.72)	2916 (897)

[1] Calculated from food only

[2] All beverages excluded

Different superscripts indicate significant differences in energy density between age and gender groups

1 MJ = 1000 kJ = 239 kcals

Table 2a Intakes of food groups across diets of low, mid and high energy density in 9 year olds (n = 551), by gender

		Girls									Boys								
		Low			Mid			High			Low			Mid			High		
		%[1]	Mean[2]	CI[2]	%	Mean	CI	%	Mean	CI	%	Mean	CI	%	Mean	CI	%	Mean	CI
Food group (g)																			
Milk, fil, yoghurt	b	97	470	394-560	96	432	380-491	94	462	404-529	99	630	551-721	99	603	527-690	92	436	377-505
- full fat		60	377	321-443	47	264	215-324	46	299	250-357	66	420	357-494	58	331	273-402	50	247	198-310
- reduced fat		77	294	239-363	77	371	323-427	76	385	331-448	83	361	294-444	78	507	436-589	72	376	317-445
Cheese	b	41	33	25-42	53	33	25-43	46	35	25-47	28	25	18-36	51	47	38-59	53	47	35-62
Bread		93	61	52-70	97	76	65-90	98	91	77-107	89	67	56-79	94	92	78-109	97	119	103-138
Meat, meat dishes		79	118	93-151	88	125	104-150	83	107	89-128	89	131	105-165	84	139	113-171	87	130	109-154
- burgers, sausages		58	111	90-136	69	117	97-142	57	93	75-115	72	102	81-130	64	120	95-151	66	110	87-139
Fish, fish dishes	b	35	84	60-119	33	55	41-73	28	42	26-67	30	60	40-89	37	56	37-84	19	36	19-68
Pasta, rice, potatoes	b	80	225	194-259	84	200	174-231	74	138	118-161	91	235	204-271	84	217	185-254	72	146	124-173
Cereals	a	51	43	30-63	34	45	30-68	24	37	23-59	50	47	33-68	40	74	50-109	38	62	40-94
Pizza, pies, pancakes		16	170	128-225	21	175	139-221	27	186	154-223	16	138	89-214	18	193	144-260	30	204	172-241
Vegetables	b	88	71	58-87	80	48	39-59	81	34	28-42	80	58	46-72	72	65	51-82	55	33	24-44
Fruit	a,b	83	222	189-261	63	158	133-187	42	132	111-157	75	178	144-219	51	129	100-165	43	116	94-143
Fruit juice	a	36	226	176-292	45	202	158-260	26	202	164-250	40	222	180-273	27	277	222-345	33	234	158-347
Sweetened drinks	a	39	216	173-271	54	250	193-323	58	316	269-372	43	311	264-366	35	300	252-358	52	328	267-404
Spreads and oils	b	89	11	10-13	90	13	11-16	91	16	13-19	80	13	11-15	91	15	12-17	94	19	16-22
Chips, crisps		16	54	22-136	21	63	33-122	27	62	39-97	10	51	17-152	16	83	44-158	22	49	30-83
Other sweet foods	b	62	47	33-69	72	50	37-67	63	51	39-68	74	66	47-92	63	65	46-93	80	65	51-83
Cakes, biscuits		42	43	32-57	50	41	32-53	50	45	34-60	39	33	23-46	32	39	27-58	39	57	43-75
Sweets, chocolate	a,b	55	11	8-16	74	15	12-19	83	23	18-29	53	8	6-11	72	13	9-17	65	23	17-32

[1] Percent (%) consuming food group in each tertile

[a, b] $\chi 2$ for trend in % consumers across low, mid and high energy density diets significant in girls and boys, respectively

[2] Mean and confidence interval (CI) is the geometric mean and 95% confidence interval, for consumers only

Table 2b Intakes of food groups across diets of low, mid and high energy density in 15 year olds (n = 569), by gender

	Girls									Boys									ANOVA		
	Low			Mid			High			Low			Mid			High					
	%[1]	Mean[2]	CI[2]	%	Mean	CI	%	Mean	CI	%	Mean	CI	%	Mean	CI	%	Mean	CI	F	P-value[3]	
Food group (g)																					
Milk, fil, yoghurt	90	443	371-529	90	449	384-525	85	402	347-465	98	737	632-860	90	717	602-854	91	647	556-754	27	< 0.001	↓
- full fat [b]	41	262	196-350	41	232	179-301	32	227	174-297	53	438	347-553	53	441	348-560	31	398	278-569	22	< 0.001	↓
- reduced fat	77	399	337-472	79	376	316-447	71	374	321-436	76	630	541-733	74	507	404-636	84	519	439-614	2	0.113	-
Cheese	63	28	23-35	56	29	23-38	71	38	30-47	58	50	41-62	65	51	40-67	56	72	56-92	4	0.014	↑
Bread	95	75	66-86	90	95	84-108	93	95	81-111	92	119	99-144	93	141	119-168	98	159	137-184	17	< 0.001	↑
Meat, meat dishes [a]	68	135	114-159	84	106	87-130	72	102	82-129	89	190	155-231	87	244	207-287	79	159	126-199	10	< 0.001	↓
- burgers, sausages	50	120	97-147	61	104	85-126	44	122	103-144	65	151	122-188	66	205	166-252	53	162	128-204	7	0.001	↓
Fish, fish dishes	29	80	55-116	38	70	53-92	24	53	32-87	26	100	65-155	24	80	46-137	19	44	22-86	9	< 0.001	↓
Pasta, rice, potatoes [a,b]	84	207	183-233	81	183	163-205	58	158	139-180	94	330	288-379	79	270	237-308	56	200	164-243	85	< 0.001	↓
Cereals [a,b]	44	47	33-68	35	45	32-64	23	49	33-73	59	81	59-111	35	49	32-75	24	49	29-82	19	< 0.001	↓
Pizza, pies, pancakes [a]	10	155	109-219	28	162	131-200	20	159	118-215	11	235	168-328	15	213	143-318	22	203	151-272	8	0.001	↑
Vegetables [a,b]	91	138	119-161	80	96	80-115	70	59	49-73	81	109	88-134	77	79	67-93	53	75	60-93	69	< 0.001	↓
Fruit [a,b]	78	244	201-297	65	139	110-175	36	116	87-154	60	190	148-244	41	144	112-185	24	133	107-166	105	< 0.001	↓
Fruit juice	40	254	184-352	41	247	183-332	35	277	188-406	33	273	183-407	31	344	260-456	35	257	163-405	1	0.239	-
Sweetened drinks [a,b]	34	213	151-299	54	314	262-375	62	333	277-400	51	348	287-422	67	491	398-606	73	556	468-660	19	< 0.001	↑
Spreads and oils [a]	74	11	9-13	81	13	11-15	89	13	11-15	81	14	11-17	90	18	15-21	93	21	18-26	19	< 0.001	↑
Chips, crisps [a]	14	42	22-81	23	62	35-108	38	67	47-96	19	104	57-190	28	146	119-178	29	125	83-189	7	0.001	↑
Other sweet foods	57	58	41-83	70	43	31-59	58	52	38-72	64	48	33-69	70	86	60-124	58	45	33-63	3	0.043	↓
Cakes, biscuits [b]	30	34	24-47	34	54	41-70	39	55	41-74	22	44	27-72	40	50	37-67	38	67	51-86	6	0.004	↑
Sweets, chocolate [a]	64	17	13-23	74	26	21-33	86	51	40-64	69	20	15-27	71	30	23-40	73	44	32-62	43	< 0.001	↑

See Table 2a footnotes

[3] One-way ANOVA for all subjects (n = 1 120), with energy density tertiles as the independent variable, and residuals of food groups regressed on energy as dependents

Arrow indicates direction of change in residuals as dietary energy density increases from low to high

Table 3a Intakes of nutrients across diets of low, mid and high energy density in 9 year olds (n = 551), by gender

	Girls			Boys		
	Low	Mid	High	Low	Mid	High
Nutrient						
Vitamin C (mg)	130 (89)	92 (66)	66 (64)	122 (102)	80 (70)	72 (74)
Folic acid (µg)	224 (79)	193 (57)	179 (65)	223 (95)	212 (81)	185 (67)
Vitamin B12 (µg)	5.0 (2.7)	4.4 (2.0)	4.7 (2.7)	6.2 (10.3)	5.6 (2.7)	5.0 (2.8)
Vitamin E (mg)	6.4 (2.3)	6.4 (2.5)	7.1 (3.1)	6.5 (2.5)	6.8 (2.4)	7.3 (3.0)
Vitamin D (µg)	4.5 (2.6)	4.7 (2.9)	5.4 (3.3)	4.9 (2.9)	6.7 (9.2)	5.5 (3.5)
Retinol equivalents (µg)	1139 (756)	931 (500)	1045 (648)	1174 (2128)	1119 (653)	1106 (933)
Iron (mg)	8.7 (3.2)	8.7 (3.8)	8.3 (3.4)	10.5 (5.7)	11.5 (8.3)	9.6 (5.8)
Calcium (mg)	1173 (468)	1115 (522)	1109 (500)	1224 (512)	1417 (591)	1191 (538)
Zinc (mg)	10.3 (3.5)	10.5 (3.9)	10.1 (3.7)	11.4 (4.6)	12.2 (4.6)	11.3 (4.3)
Selenium (µg)	32 (16)	28 (11)	28 (12)	33 (17)	37 (18)	28 (14)
Sodium (mg)	3119 (1120)	3004 (956)	2562 (823)	3011 (1140)	3333 (1061)	3056 (1007)
Cholesterol (mg)	269 (131)	252 (102)	282 (154)	263 (144)	310 (177)	308 (156)
Fibre (g)	16.1 (6.2)	14.1 (5.6)	13.5 (5.4)	15.8 (5.5)	15.0 (6.2)	14.1 (5.1)

Results are presented as mean (s.d.)

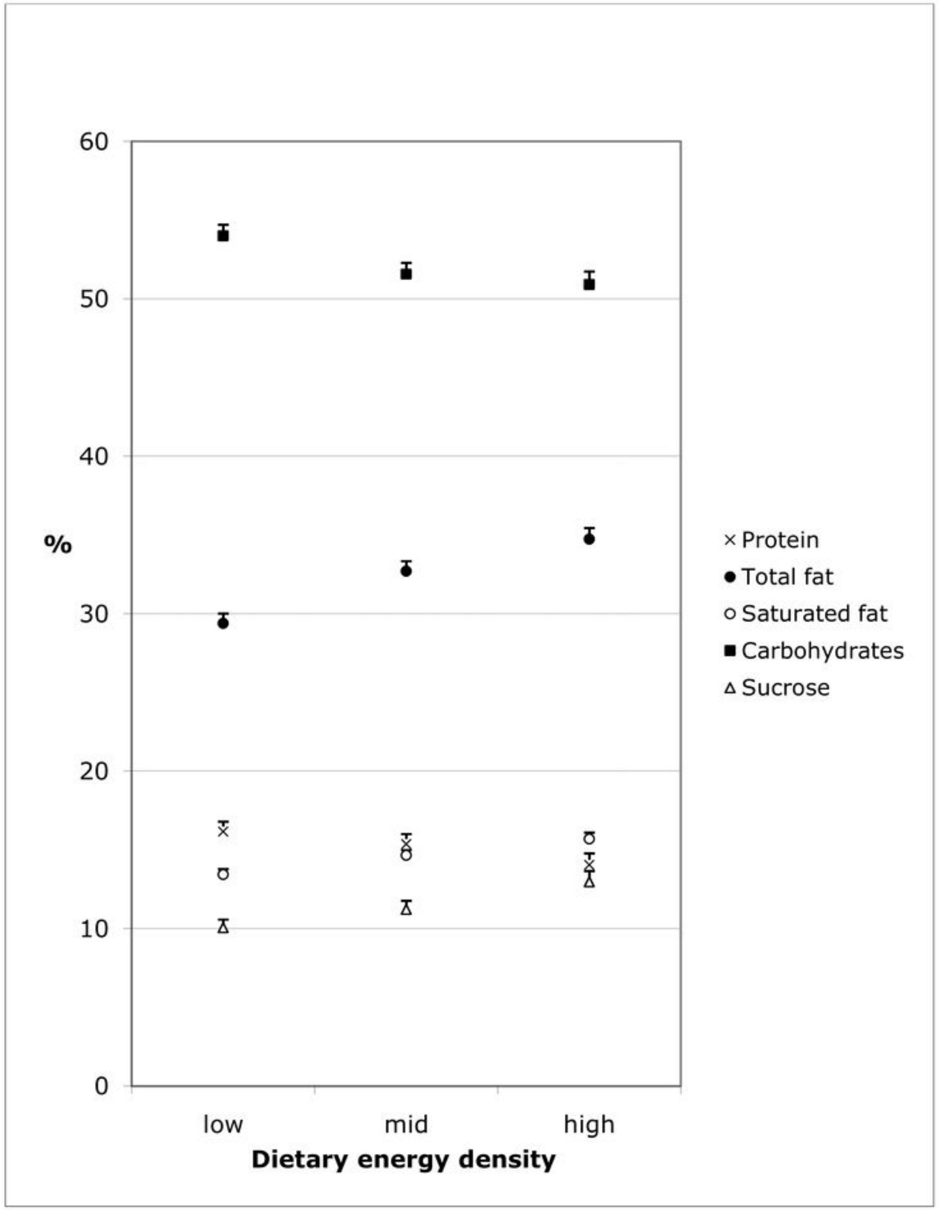
Table 3b Intakes of nutrients across diets of low, mid and high energy density in 15 year olds (n = 569), by gender

	Girls			Boys			ANOVA		
	Low	Mid	High	Low	Mid	High	F	P-value[1]	
Nutrient									
Vitamin C (mg)	165 (131)	108 (94)	87 (89)	148 (132)	120 (114)	85 (93)	75	< 0.001	↓
Folic acid (µg)	259 (115)	221 (95)	189 (97)	314 (121)	287 (109)	260 (121)	117	< 0.001	↓
Vitamin B12 (µg)	4.0 (2.3)	4.7 (2.7)	4.0 (2.5)	8.1 (11.0)	7.1 (4.6)	8.3 (23.5)	16	< 0.001	↓
Vitamin E (mg)	7.3 (3.4)	7.4 (3.6)	9.1 (15.1)	8.8 (4.0)	10.5 (4.7)	9.6 (4.1)	1	0.419	-
Vitamin D (µg)	4.3 (3.0)	5.3 (3.8)	4.8 (3.6)	5.9 (2.9)	6.7 (3.0)	7.1 (4.5)	2	0.096	-
Retinol equivalents (µg)	1043 (630)	1015 (646)	877 (594)	1548 (2191)	1374 (1075)	1605 (3128)	9	< 0.001	↓
Iron (mg)	9.7 (3.4)	9.7 (4.4)	9.2 (4.3)	14.4 (6.3)	13.9 (5.3)	12.3 (8.1)	32	< 0.001	↓
Calcium (mg)	1172 (575)	1168 (527)	1233 (658)	1766 (812)	1789 (854)	1732 (929)	11	< 0.001	↓
Zinc (mg)	10.0 (4.3)	10.6 (3.9)	10.4 (4.6)	16.9 (7.5)	18.5 (10)	15.1 (6.3)	21	< 0.001	↓
Selenium (µg)	30 (21.3)	31 (16.2)	26 (17)	42 (21)	44 (22.2)	34 (15.4)	31	< 0.001	↓
Sodium (mg)	2924 (1315)	2925 (925)	2806 (1228)	4740 (1814)	4671 (1707)	3805 (1423)	52	< 0.001	↓
Cholesterol (mg)	216 (129)	255 (132)	254 (187)	320 (170)	395 (177)	338 (178)	1	0.258	-
Fibre (g)	19.4 (9.4)	15.8 (7.1)	13.7 (7.4)	23.2 (9.7)	19.8 (8.3)	17.6 (7.3)	90	< 0.001	↓

Results are presented as mean (s.d.)

[1] One-way ANOVA for all subjects (n = 1 120), with tertiles as independent variable, and residuals of nutrients as dependents

Arrow indicates direction of change in residuals as dietary energy density increases from low to high


60
50
40
30
20
10
0
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low
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Dietary energy density
Protein
Total fat
Saturated fat
Carbohydrates
Sucrose