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Dietary energy density and its association with the nutritional quality of the diet of children and teenagers

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Abstract

To examine the relationship between dietary energy density (DED) and the nutritional quality of the diet, using data from the Irish National Children's Food Survey (NCFS) and the National Teens' Food Survey (NTFS), two cross-sectional studies of food consumption were carried out between 2003 and 2006. Data from the NCFS and NTFS were used to examine the intakes of nutrients and foods among those with low- (NCFS <7·56, NTFS <7·65 kJ/g), medium- (NCFS 7·56–8·75, NTFS 7·66–8·85 kJ/g) and high-energy-dense diets (NCFS >8·75, NTFS >8·85 kJ/g). A 7-d food diary was used to collect food intake data from children (*n* 594) and teenagers (*n* 441). DED (kJ/g) was calculated including food alone and excluding beverages. Participants with lower DED consumed more food (weight) but not more energy. They also consumed less fat and added sugars and more protein, carbohydrates, starch and dietary fibre and had higher intakes of micronutrients. Participants with lower DED had food intake patterns that adhered more closely to food-based dietary guidelines. Low DED was associated with multiple individual indicators of a better nutritional quality of the diet, including higher intakes of dietary fibre and micronutrients and a generally better balance of macronutrients, as well as being associated with food intake patterns that were closer to healthy eating guidelines. Taken together, these findings support the conclusion that a low DED may be an indicator of a better nutritional quality of the diet.

Key words: **Children: Teenagers: Diet quality: Energy density: Dietary guidelines**

Dietary energy density (DED) is defined as the amount of available energy per unit of weight in the diet. It is generally expressed as kJ/g. Experimental studies in human subjects and a recent systematic review have shown that the consumption of high-energy-dense diets may lead to increased energy intake and weight gain[1–3] and evidence has been accumulating for an association between lower DED and better nutritional quality of the diet.

To the best of the authors' knowledge, only one study has comprehensively examined the association between DED and the nutritional quality of the diet in children and teenagers when food is consumed *ad libitum*[4] and no study has examined this association using a nationally representative sample of children and teenagers. In Swedish children and teenagers, it was found that low-energy-density diets contained higher amounts of protein, carbohydrates, fibre and most of the micronutrients and lower amounts of energy, fats and sucrose[4]. In American children aged 2–8 years the associations between DED and food intakes and some dietary characteristics were examined. It was found that young children with lower DED consumed more food (g) and less energy, more portions of fruit and vegetables, had a lower energy intake from fat and consumed less added sugar than those with higher DED[5]. In studies of adults, the intakes of protein, carbohydrates and dietary fibre decreased with increasing DED and the intakes of energy and fats and added sugar increased with increasing DED[6–9]. Furthermore, more favourable eating patterns, e.g. eating patterns more in line with food-based dietary guidelines, consuming more fruit and vegetables and consuming less

Abbreviations: DED, dietary energy density; NCFS, National Children's Food Survey; NTFS, National Teens' Food Survey; %TE, % total energy.

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low-nutrient-dense foods, have also been reported for adults with lower DED[6,8,10], while better adherence to food-based dietary guidelines has been reported in children and teenagers with lower DED[4]. It has also been proposed that DED could be used as a marker of the nutritional quality of the diet[4].

The present paper therefore examines the association of DED with the nutritional quality of the diet, using nationally representative data for Irish children and teenagers.

Methods

The National Children's Food Survey (NCFS) 2003–2004 and the National Teens' Food Survey (NTFS) 2005–2006 were carried out to establish databases of habitual food and drink consumption in representative samples of Irish children aged 5–12 years and teenagers aged 13–17 years. A 7-d weighed food record was used to collect food intake data from 594 children (293 boys, 301 girls), while a 7-d semi-weighed food record was used to collect food intake data from 441 teenagers (224 boys, 217 girls). Participants and their parents/guardians were visited by a trained nutritionist four times, including one training visit, during the recording period. Participants with the aid of their parents/guardians (younger children requiring more aid up to 100 %) were asked to record detailed information regarding the amount and types of all foods, beverages and supplements consumed over the 7-d period and, where applicable, the cooking method used, the brand name of the food consumed, packaging size and type and details of recipes and any leftover. Data were also collected on the time and location of each eating occasion. A hierarchal method for dietary data collection and quantification was used which included weighing, photographic food atlases[11], manufacturers information and household measurements. Analyses of dietary intake data were carried out using WISP© (Tinuviel Software), which contains McCance and Widdowson's The Composition of Foods, 6th Edition and The Irish Food Composition Database[12,13]. Self-reported health and lifestyle questionnaires were completed by participants or their parents/guardians concurrent with collection of food intake data. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the St. James' Hospital and Federated Dublin Voluntary Hospitals Joint Research Ethics Committee for the NCFS and the University College Cork Clinical Research Ethics Committee of the Cork Teaching Hospitals for the NTFS. Written informed consent was given by the children, teenagers and their parents or guardians. A full description of methodologies is available elsewhere[14,15].

Sample selection

Children were selected from twenty-eight primary schools in the Republic of Ireland from a database obtained from the Department of Education and Science. The database was divided into (a) small/medium/large schools, (b) all boys/all girls/mixed, (c) disadvantage/not disadvantaged and (d) urban/rural. A random sample was selected from each category so that in the final sample the proportions of children attending each of the categories of schools reflected that of the proportions according to the database. The principal at selected schools was given detailed instructions on how to select children for participation in the survey from the school roll. Teenagers were recruited in a similar vein from thirty-two secondary schools with a divide of secondary/vocational/comprehension schools in place of the small/medium/large for children. The overall response rate was 66 % for children and 63 % for teenagers. Analysis of the demographic features of the samples has shown them to be representative samples of Irish children and teenagers with respect to age, sex, social class, socio-economic group and geographic location when compared with census data[16].

Calculation of dietary energy density

DED (kJ/g) was calculated including food only and excluding all beverages. This included all solid foods and liquid-like foods such as yoghurts and soups, and excluded all beverages: both energy-containing and non-energy-containing. This method has previously been used by other authors[4,17]. As water accounts for much of the variability in DED, it was thought that the inclusion of beverages may disproportionately affect estimates in those with high beverage consumption.

Nutritional quality of the diet

The intakes of individual nutrients were used as indicators of the nutritional quality of the diet. The intakes of macronutrients were expressed as a percentage of total energy, while micronutrients were adjusted to 10 MJ/d. Each of the 1945 foods (NCFS) and 1761 foods (NTFS) consumed during the surveys were aggregated into thirty-two food groups to examine the food intake patterns associated with DED. The intakes of food groups were adjusted to 10 MJ/d. Participants who consumed a nutritional supplement at least once over the recording days were defined as supplement users.

Under-reporters for energy

Weight and height measurements were taken by researchers in the participants' own homes. Weight was measured in duplicate using a Seca 770 digital personal weighing scale (Chasmores Ltd) to the nearest 0·1 kg. Participants were weighed having voided, wearing light clothing and without shoes. Height was measured to the nearest 0·1 cm using the Leicester portable height measure (Chasmores Ltd) with the participant's head positioned in the Frankfurt Plane. BMR was predicted for each child and teenager from published equations[18]. Minimum energy intake cut-off points, calculated as multiples of BMR, were used to identify under-reporters of energy[19]. Accordingly, 32 % of children and 64 % of teenagers were classified as under-reporters. Analyses were carried out with and without under-reporters. Results presented below are those for the total population.

Statistical analyses

As no natural cut-offs exist and DED estimates did not vary significantly with age or sex within each study, the populations were split equally into three categories: low- (NCFS <7·56, NTFS <7·65 kJ/g), medium- (NCFS 7·56–8·75, NTFS 7·66–8·85 kJ/g) and high-DED (NCFS >8·75, NTFS >8·85 kJ/g). Analyses of the differences between low-, medium- and high-DED groups were carried out using a one-way ANOVA with a Tukey honestly significant difference (HSD) or Šidák *post hoc* test to test for differences in the means. Non-parametric tests, Kruskal–Wallis and Mann–Whitney *U*, were used when the assumptions of the ANOVA were not met and the variables could not be normalised by transformation to the natural log or square root.

Results

The mean weight of food and of food and beverages consumed decreased across tertile of DED ($P < 0·001$), while the mean daily intake of energy did not change significantly (Table 1).

The percentage total energy (%TE) from fat, saturated fat, monounsaturated fat and added sugars increased ($P < 0·001$) across tertile of DED, while the %TE from protein and dietary fibre (g/10 MJ) decreased ($P < 0·001$) in both populations. In teenagers alone, it was seen that as the DED increased, the %TE from both carbohydrate ($P < 0·01$) and starch ($P < 0·001$) decreased, while the %TE from polyunsaturated fats increased ($P < 0·01$). The %TE from total sugars and the unsaturated fat:saturated fat ratio did not change significantly, in either population, as DED increased (Table 1).

In children, as DED increased there was a significant decrease in intakes (energy adjusted) of vitamin A, vitamin D, vitamin B_{12}, folate, biotin, thiamin, riboflavin, niacin equivalents, vitamin B_6, pantothenic acid, vitamin C, Ca, Mg, P, K, Cu, Zn, Mn and Na ($P < 0·001$) and Fe ($P < 0·05$) (Table 2).

In teenagers, as DED increased there was a significant decrease in intakes (energy adjusted) of vitamin A, folate, biotin, vitamin D, thiamin, riboflavin, niacin equivalents, vitamin B_6, vitamin B_{12}, pantothenic acid and vitamin C, Mg, P, Fe, K, Cu, Zn and Mn decreased as DED increased ($P < 0·001$) and Ca decreased ($P < 0·05$). There was no significant difference in Na intakes across tertile of DED in teenagers (Table 2).

In both children and teenagers, an association was found between increased supplement use and lower DED. However, the overall association with the micronutrient density of the diet did not change when the intake from nutritional supplements was excluded.

Table 3 displays the mean daily intake of food groups (g/10 MJ/d). Fruit and vegetable intakes were inversely associated with DED in both children and teenagers ($P < 0·001$) as were fruit and vegetable juices intakes ($P < 0·01$).

In children, low DED was associated with higher intakes of wholemeal and brown bread, grains, rice, pasta, pizza and other cereals, yoghurts, potatoes, fresh meat and meat dishes, fish, soups and sauces ($P < 0·001$), reduced fat milks, reduced fat spread ($P < 0·05$), and lower intakes of butter and dairy spreads, chipped, fried and roasted potatoes, carbonated beverages, chocolate, non-chocolate confectionery, savoury snacks and biscuits and cakes ($P < 0·001$). In teenagers, low DED was associated with higher intakes of wholemeal and brown bread, grains, rice, pasta, pizza and other cereals, breakfast cereals, yoghurts, potatoes, fresh meat and meat dishes, soups and sauces ($P < 0·001$), tea and coffee ($P < 0·01$) and lower intakes of chips, carbonated beverages, burgers and sausages, chocolate, savoury snacks ($P < 0·001$), white bread ($P < 0·01$) and diet carbonated beverages ($P < 0·05$) (Table 3).

With the removal of under-reporters from the analyses, mean DED was estimated for children as 8·26 (1·39) kJ/g and for teenagers as 8·35 (1·63) kJ/g. Neither was significantly different from the total population estimates of 8·26 (1·44) kJ/g for children and 8·26 (1·51) kJ/g for teenagers. When analyses of associations were repeated excluding those children and teenagers who were classified as under-reporters, variations in the associations of DED with the nutritional quality of the diet were minimal.

Discussion

In these two national, detailed nutrition surveys of Irish children and teenagers, DED was inversely associated with multiple individual markers of the nutritional quality of the diet. Lower DED is generally considered to be associated with a healthier diet[4–10] and it has been proposed for use as a possible proxy of dietary quality[4]. This study adds to the evidence for the use of DED as a marker of a better nutritional quality of the diet, examining the data from children and teenagers for whom there is minimal evidence and also using dietary intake data from weighed/semi-weighed 7-d food diaries, whereas previous evidence has been from FFQ and 24-h recall dietary data.

In Irish children and teenagers, low DED was associated with a generally better macronutrient profile: higher (energy-adjusted) intakes of protein and dietary fibre and lower intakes of total fat, saturated fat, monounsaturated fat and added sugars. In Irish teenagers (but not children), low DED was also associated with higher intakes of carbohydrates and starch and lower intakes of polyunsaturated fat. Similar results were reported in Swedish children and teenagers, finding that low DED was associated with higher (energy adjusted) intakes of carbohydrates, protein and fibre and lower intakes of total fat, saturated fat and sucrose[4]. Studies in adults have also reported low DED to be associated with higher intakes of protein, carbohydrates and dietary fibre and lower intakes of fat and saturated fat[7–10].

In examining a broad range of vitamins and minerals, this study showed that lower DED was associated with a higher micronutrient density of the diet in children and teenagers. Previous studies have found that children and teenagers with low DED had higher intakes of most of the micronutrients examined than those with high DED[4]. In adults, it has been reported that those with a low DED had higher, energy-adjusted intakes of vitamins A, C and B_6, folate, Fe,

Table 1. Daily intake of energy, macronutrients, dietary fibre and weight of food consumed, by tertile of energy density of diets in Irish children (*n* 594) and teenagers (*n* 441)
(Mean values and standard deviations)

	Children								Teenagers							
	Low		Medium		High				Low		Medium		High			
Mean dietary energy density (kJ/g)	6·77		8·17		9·85				6·63		8·25		9·88			
Tertile cut-offs	<7·56		7·56–8·75		>8·75				<7·65		7·66–8·85		>8·85			
n	198		198		198				147		147		147			
	Mean	SD	Mean	SD	Mean	SD	*P**		Mean	SD	Mean	SD	Mean	SD	*P**	
Weight of food excluding beverages (g/d)	845^{a}	197	702^{b}	158	603^{c}	150	0·000	↓	1055^{a}	402	864^{b}	252	731^{c}	216	0·000	↓
Weight of all food and beverages (g/d)	1678^{a}	414	1549^{b}	371	1473^{b}	364	0·000	↓	2204^{a}	791	$1995^{a,b}$	617	1852^{b}	564	0·000	↓
Energy (MJ)	6·9	1·4	6·9	1·5	7·2	1·6	0·095		8·1	2·5	8·4	2·4	8·5	2·4	0·116	
Protein (%TE)	$14·6^{a}$	2·2	$13·7^{b}$	1·8	$12·5^{c}$	2·1	0·000	↓	$15·8^{a}$	2·5	$14·7^{b}$	2·4	$13·6^{c}$	2·3	0·000	↓
Fat (%TE)	$32·6^{a}$	4·2	$34·5^{b}$	3·9	$34·7^{b}$	4·3	0·000	↑	$33·8^{a}$	4·9	$35·2^{b}$	4·7	$37·8^{c}$	4·6	0·000	↑
Saturated fat (%TE)	$13·6^{a}$	2·5	$14·5^{b}$	2·4	$14·7^{b}$	2·6	0·000	↑	$13·1^{a}$	2·6	$13·8^{b}$	2·5	$14·9^{c}$	2·6	0·000	↑
Monounsaturated fat (%TE)	$10·5^{a}$	1·7	$11·4^{b}$	1·7	$11·6^{b}$	1·9	0·000	↑	$10·9^{a}$	2	$11·4^{b}$	1·9	$12·6^{c}$	2	0·000	↑
Polyunsaturated fat (%TE)	4·6	1·1	4·8	1·2	4·9	1·5	0·115		$5·3^{a}$	1·6	$5·4^{a}$	1·6	$5·9^{b}$	1·9	0·006	↑
Unsaturated fat:saturated fat	1·14	0·23	1·13	0·23	1·15	0·28	0·712		1·28	0·29	1·24	0·26	1·27	0·28	0·485	
Carbohydrate (%TE)	52·4	4·9	51·3	4·5	52·2	5	0·050		$49·8^{a}$	5·2	$49·2^{a,b}$	5	$47·9^{b}$	4·9	0·007	↓
Total sugar (%TE)	23·9	5·4	23·6	4·7	24·3	5·7	0·584		20·4	5	20·2	5	20·6	4·9	0·739	
Added sugars (%TE)	$12·4^{a}$	4·9	$14·4^{b}$	4·5	$17·0^{c}$	5·8	0·000	↑	$10·4^{a}$	4·3	$12·6^{b}$	4·7	$14·4^{c}$	5	0·000	↑
Starch (%TE)	27·5	4·8	26·7	4	26·7	4·8	0·120		$28·6^{a}$	4·5	$28·1^{a}$	4·3	$26·5^{b}$	4·4	0·000	↓
Dietary fibre (g/10 MJ)	$20·2^{a}$	4·1	$17·6^{b}$	3·6	$15·4^{c}$	3·8	0·000	↓	$21·7^{a}$	6·3	$18·7^{b}$	4·4	$16·0^{c}$	3·3	0·000	↓

%TE, % total energy.
^{a,b,c} Mean values with unlike superscript letters were significantly different between groups. Arrows denote the direction of association with increasing dietary energy density.
* As determined by ANOVA.

Table 2. Daily vitamin and mineral intakes (per 10 MJ energy) from all sources by tertile of energy density of diets in Irish children (*n* 594) and teenagers (*n* 441)
(Mean values and standard deviations)

	Children								Teenagers							
	Low		Medium		High				Low		Medium		High			
Mean dietary energy density (kJ/g)	6·77		8·17		9·85				6·63		8·25		9·88			
Tertile cut-offs	<7·56		7·56–8·75		>8·75				<7·65		7·66–8·85		>8·85			
n	198		198		198				147		147		147			
	Mean	SD	Mean	SD	Mean	SD	*P**		Mean	SD	Mean	SD	Mean	SD	*P**	
Vitamins																
Vitamin A (μg/10 MJ per d)	1379[a]	913	1015[b]	586	656[c]	392	0·000	↓	1331[a]	708	888[b]	459	643[c]	383	0·000	↓
Vitamin D (μg/10 MJ per d)	4·3[a]	4	3·1[b]	3·2	2·4[c]	2·8	0·000†	↓	4·7[a]	3·6	2·6[b]	2·1	2·3[b]	1·7	0·000†	↓
Thiamin (mg/10 MJ per d)	2·5[a]	3·7	2·1[b]	0·7	2·0[c]	0·6	0·000†	↓	3·5[a]	6·1	2·2[b]	1·3	2·0[c]	2·6	0·000†	↓
Riboflavin (mg/10 MJ per d)	2·9[a]	3·7	2·6[b]	0·9	2·4[c]	0·8	0·000†	↓	3·8[a]	6·3	2·4[b]	1·4	2·1[c]	1	0·000†	↓
Niacin equivalents (mg/10 MJ per d)	43·8[a]	11·3	40·4[b]	8·8	37·8[c]	8·8	0·000†	↓	50·5[a]	13·9	44·3[b]	10·2	38·9[c]	9·2	0·000†	↓
Vitamin B_6 (mg/10 MJ per d)	3·3[a]	3·8	2·8[b]	0·9	2·6[c]	0·9	0·000†	↓	4·6[a]	6·1	3·1[b]	1·6	2·5[c]	0·9	0·000†	↓
Vitamin B_{12} (μg/10 MJ per d)	6·9[a]	4	6·2[b]	2·5	5·6[c]	2·2	0·000†	↓	6·9[a]	5	5·9[a]	2·1	5·2[b]	2·3	0·000†	↓
Folate (μg/10 MJ per d)	363[a]	156	313[b]	104	282[c]	82	0·000†	↓	402[a]	189	315[b]	104	270[c]	106	0·000†	↓
Biotin (μg/10 MJ per d)	43·4[a]	52·8	34·7[b]	27	30·2[c]	17·5	0·000†	↓	52·4[a]	66·7	31·2[b]	18·2	29·2[c]	25·8	0·000†	↓
Pantothenic acid (mg/10 MJ per d)	8·5[a]	4·9	7·4[b]	2·4	6·9[c]	2·3	0·000†	↓	9·2[a]	7·3	7·1[b]	2·8	6·1[c]	2	0·000†	↓
Vitamin C (mg/10 MJ per d)	166·4[a]	129·1	116·3[b]	71·3	92·1[c]	53·5	0·000	↓	175[a]	159·3	107·8[b]	116·5	75·5[c]	53·5	0·000	↓
Minerals																
Ca (mg/10 MJ per d)	1288[a]	323	1231[a,b]	314	1165[b]	322	0·000	↓	1098[a]	298	1102[a]	293	1013[b]	300	0·011	↓
Mg (mg/10 MJ per d)	298[a]	43	275[b]	36	255[c]	38	0·000	↓	311[a]	58	278[b]	40	250[c]	34	0·000	↓
P (mg/10 MJ per d)	1545[a]	252	1472[b]	209	1357[c]	233	0·000	↓	1538[a]	252	1449[b]	219	1344[c]	220	0·000	↓
Fe (mg/10 MJ per d)	13·8[a]	3·7	13·4[b]	4·1	13·0[c]	4	0·048†	↓	17·8[a]	19·2	15·8[b]	21	12·0[c]	6·1	0·000†	↓
K (mg/10 MJ per d)	3460[a]	454	3111[b]	370	2819[c]	396	0·000	↓	3522[a]	537	3192[b]	397	2912[c]	427	0·000	↓
Cu (mg/10 MJ per d)	1·3[a]	0·6	1·2[b]	0·4	1·0[c]	0·3	0·000†	↓	1·4[a]	0·6	1·2[b]	0·3	1·0[c]	0·4	0·000†	↓
Zn (mg/10 MJ per d)	10·1[a]	2	9·6[b]	2·4	8·5[c]	2	0·000†	↓	11·8[a]	4·4	10·3[b]	2·3	9·1[c]	2·1	0·000†	↓
Mn (mg/10 MJ per d)	2·6[a]	0·9	2·3[b]	0·7	2·0[c]	0·6	0·000	↓	3·1[a]	1·3	2·6[b]	0·8	2·2[c]	0·8	0·000	↓
Na (mg/10 MJ per d)	3053[a]	566	2997[a]	526	2856[b]	517	0·001	↓	3150	590	3053	558	2977	555	0·117	

[a,b,c] Mean values with unlike superscript letters were significantly different between groups. Arrows denote the direction of association with increasing dietary energy density.
* As determined by ANOVA, unless otherwise specified.
† As determined by a Kruskal–Wallis test.

Table 3. Mean daily food group intakes (g/10 MJ) by tertile of energy density of diets in Irish children (*n* 594) and teenagers (*n* 441)
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n	198		198		198				147		147		147			
	Mean	SD	Mean	SD	Mean	SD	*P**		Mean	SD	Mean	SD	Mean	SD	*P**	
Fruit and vegetables																
Fruit	155·0^{a}	110·8	99·2^{b}	72	46·2^{c}	48·5	0·000†	↓	141·6^{a}	174·2	49·2^{b}	56·9	29·3^{c}	46·5	0·000†	↓
Vegetables and vegetable dishes	102·1^{a}	76·8	61·1^{b}	42·7	34·6^{c}	33·2	0·000	↓	111·4^{a}	83·2	71·1^{b}	52	44·8^{c}	41·4	0·000	↓
Fruit and vegetable juices	167·3^{a}	181·1	120·9^{b}	140·6	114·8^{b}	150	0·003†	↓	135·6^{a}	170·5	108·5^{a,b}	140·6	80·8^{b}	124·3	0·002†	↓
Cereal products																
White bread and rolls	85·5	50·2	92·9	48·9	91	46·6	0·162		68·2^{a}	48·7	78·8^{a,b}	50·7	85·5^{b}	47·2	0·005	↑
Wholemeal and brown bread and rolls	25·2^{a}	43·5	16·2^{b}	30·8	9·8^{c}	21·3	0·000†	↓	34·0^{a}	46·7	20·9^{b}	34·6	13·5^{b}	27·4	0·000†	↓
Grains, rice, pasta, pizza and other cereals	100·4^{a}	80·5	76·4^{b}	60·2	71·8^{b}	65·9	0·000	↓	127·6^{a}	109·6	108·7^{a}	82·5	83·7^{b}	75·9	0·000	↓
Breakfast cereals	58·6	61·3	48·3	37	55·4	39·1	0·201		72·2^{a}	81·2	53·8^{a}	56·9	34·2^{b}	33·7	0·000	↓
Dairy products																
Whole milk	329·4	251·9	345·4	243·7	338	250·6	0·797†		234·1	236·9	240·1	218	224·5	235·8	0·588†	
Reduced fat milks	53·4^{a}	136·2	32·8^{b}	113·6	28·8^{b}	108·2	0·011†	↓	51·5	132·6	57·5	133	39·2	122·6	0·326†	
Cheeses	10·7	13·3	11·2	13·2	10·7	16·4	0·126		14	17·2	13·1	18·2	13·1	18·7	0·424	
Yoghurts	78·1^{a}	76·1	61·2^{b}	62·4	31·6^{c}	39·4	0·000	↓	39·6	51	24·8	39·7	13·2	24·6	0·000	↓
Butter and spreads																
Reduced fat spreads (<40 %)	2·8^{a}	5·4	2·5^{a,b}	5·3	1·6^{b}	4·7	0·023†	↓	3·2	7·2	3	8·2	2·2	5·4	0·862†	
Butter and dairy spreads (>40 %)	8·4^{a}	9	10·0^{b}	8·7	12·4^{b}	11·3	0·000†	↑	8·9	9·6	10·3	11·8	13·3	14·6	0·098†	
Potatoes and potato dishes																
Potatoes (boiled, baked, mashed)	108·3^{a}	79·4	70·3^{b}	59·8	50·6^{c}	49·9	0·000†	↓	113·6^{a}	91·5	87·2^{b}	65·8	56·0^{c}	51·5	0·000†	↓
Potato products	5·5	17·2	9·0	20·1	9·0	20·3	0·053		7·2	20·9	7·9	17·4	8·7	19·6	0·577	
Chipped, fried and roasted potatoes	47·5^{a}	40·7	57·7^{b}	45·3	66·4^{b}	47·2	0·000	↑	62·2^{a}	59·6	80·0^{b}	55·7	92·7^{b}	70·1	0·000	↑
Beverages																
Tea and coffee	435·2	321·4	436·1	298·3	377	257·1	0·188		805·9^{a}	638	636·0^{b}	490·2	596·6^{b}	479·6	0·004	↓
Carbonated beverages	120·3^{a}	147·7	166·7^{b}	155·8	234·6^{c}	232·5	0·000	↑	144·5^{a}	179	220·1^{b}	206·5	322·1^{c}	261·9	0·000	↑
Diet carbonated beverages	20·4	56·1	27·2	67	16·9	55·3	0·395†		21·8^{a}	75·9	34·7^{b}	79	28·5^{a}	96·8	0·019†	↑
Squashes, cordials and fruit juice drinks	103·9	148·9	92·3	114·7	118·2	125·5	0·102†		41·6	89·4	42·6	68·5	40·1	72·8	0·400†	
Meat, fish and eggs																
Fresh meat and meat dishes	102·3^{a}	70·2	88·8^{a}	56·9	62·1^{b}	50·3	0·000†	↓	158·4^{a}	79·4	143·5^{a}	73·5	99·8^{b}	58·1	0·000†	↓
Burgers, sausages and meat products	53·5	39·7	57·6	37·4	58·1	39·2	0·267†		46·8^{a}	36·5	60·8^{b}	44·6	74·4^{c}	50·2	0·000†	↑
Fish and fish dishes	20·4^{a}	28·3	10·9^{b}	15·4	7·7^{c}	13·3	0·000	↓	19·1	29·9	10·8	26·4	7·6	13·7	0·057	
Eggs and egg dishes	11·9	18·6	11·4	18·1	9·2	16·2	0·164		10·3	18·4	10·6	17·1	10·3	18·2	0·552	

Confectionery and savoury snacks															
Sugars, syrups and preserves	8·1	9·9	8·1	10·7	9·5	15·1	0·867		8·1	12·6	10·1	16·7	8·6	13·1	0·542	
Chocolate confectionery	19·9[a]	21·3	22·5[a]	20·6	29·9[b]	25·4	0·000†	↑	19·0[a]	20·7	22·0[b]	19·4	32·3[c]	26·1	0·000†	↑
Non-chocolate confectionery	15·4[a]	20·7	22·7[b]	29	24·4[b]	29·2	0·001†	↑	11·5	18·5	16·5	25·1	12·8	17·8	0·392†	
Savoury snacks	14·3[a]	14	18·7[b]	14·3	21·2[b]	18·5	0·000	↑	11·7[a]	14·6	15·1[a]	16·6	21·9[b]	21·4	0·000	↑
Biscuits, cakes and pastries	30·4[a]	22·8	41·0[b]	25·3	38·0[b]	29	0·000	↑	25·7	29·4	27·5	28·8	28·5	31·4	0·494	
Creams, ice creams and chilled desserts	44	51	38·8	41·5	32·3	34·2	0·166		27	36·4	26·2	32·4	24·4	32·6	0·772	
Miscellaneous																
Soups and sauces	49·9[a]	58·5	33·1[b]	40·3	23·4[c]	29·6	0·000	↓	79·8[a]	77·8	46·1[b]	39·8	37·7[b]	38·3	0·000	↓
Nuts, seeds, herbs and spices	1·2	3·7	0·9	4·8	1·1	3·5	0·395		1·6	4·6	1	4·1	0·6	2·9	0·578	

DED, dietary energy density.
a,b,c Mean values with unlike superscript letters were significantly different between groups. Arrows denote direction of association with increasing DED.
* As determined by ANOVA, unless otherwise specified.
† As determined by a Kruskal–Wallis test.

Ca and K than their high DED counterparts[7] and also that there were higher intakes of folate, vitamin C, carotenoids, vitamin B_6, Ca and Fe in those with lower DED[6]. Higher compliance with dietary recommendations for micronutrient intakes has been associated with having a lower DED[8,9]. In a study of American men and women those with low DED were reported to have a higher prevalence of multivitamin/multimineral supplement use[7]. The association of increased use of nutritional supplements with DED was also examined in the current study and was found to be associated with lower DED in Irish children and teenagers. This is not to detract from the association with increased micronutrient intake, as the association of lower DED with increased micronutrient density of the diet was found to be independent of nutritional supplement usage.

This better nutritional quality associated with lower DED may be explained by the differences in food intake patterns which were generally closer to healthy eating guidelines[20,21]. Children and teenagers with low DED, compared with those with high DED, consumed more fruit, vegetables, fruit and vegetable juices, wholemeal bread, grains, rice, pasta, pizza and other cereals, breakfast cereals (teenagers only), fresh meat, potatoes (mashed/boiled/baked), yoghurts and (in children only) fish and low-fat dairy products, and less chipped potatoes, carbonated beverages, confectionery and butter (children only) and (in teenagers only) white bread and processed meat. Similar results to the current analyses were found in Swedish children and teenagers; those with lower DED were more likely to consume fruit, vegetables, pasta, rice and potatoes and cereals and less likely to consume sweets and chocolate and sweetened drinks and generally followed the Nordic Nutrition Recommendations better than those with high DED[4]. It had also been reported that adults consuming diets with low DED tend to be closer to dietary recommendations established by the Spanish Society of Community Nutrition than those with high DED[8]. In a study of Spanish adults, those with low DED showed a trend towards a healthier lifestyle, as characterised by more leisure-time physical activity, lower prevalence of smoking, sedentary lifestyle and alcohol consumption[8].

Some exceptions to the association of low DED with better nutritional quality of the diet were noted in this study. Firstly, Na intakes were slightly higher with lower DED in children but not in teenagers. These intakes, however, are estimated from food consumption data and do not take into account discretionary salt added in cooking or at the table and as such do not reflect total intakes. Secondly, lower DED was associated with lower intakes of monounsaturated fat and polyunsaturated fat (teenagers only). To investigate this further the association of DED with the unsaturated fat:saturated fat ratio was also examined. The lack of association shown in this analysis suggests that the lower intakes of unsaturated fats seen with lower DED reflect the association of DED with lower total fat. Similarly, lower unsaturated fat intakes were reported in Swedish children and teenagers and Spanish adults with lower DED with a decrease in the unsaturated fat-to-saturated fat ratio with increasing DED also reported for Spanish adults[5,8]. Although some differences in the associations of DED with food intakes were noted between children and teenagers, no differences in the direction of the association of macro- and micronutrients with DED were shown, in keeping with the notion of DED as an indicator of overall dietary quality.

DED is a useful marker of the nutritional quality of the diet as it is easy to calculate, is applicable to most data and can be used in the place of multiple individual markers of dietary quality or cumulative scores. One difficulty with its use is the determination of cut-off points: at what level does DED begin to reflect a less healthy diet? This study categorised individuals according to tertile of DED but these are sample specific cut-off points and do not represent healthy and unhealthy ends of the spectrum but rather less and more healthy within the study group. This does not undermine the usefulness of DED as a marker as it can be readily used in a continuous form.

The limitations of the study merit consideration here. The cross-sectional nature of the data collection prevents the determination of the direction of associations. The percentages of under-reporters for energy in the study populations were high, particularly in teenagers; however, upon repeating the analyses without their inclusion, the associations with a better nutritional quality of the diet remained significant. No well-accepted method for calculating the DED exists, limiting the findings of this study to the method of ‘food only’. The food-only method for calculating DED was used, as water contributes to the weight of the diet but not energy intake; it was thought that the inclusion of beverages may have a disproportionate effect on DED and misclassify high beverage consumers; this also allowed for comparisons with other publications. Strengths of these analyses include the detailed level in which dietary intake data were collected, making use of 7-d weighed/semi-weighed diaries collected by trained nutritionists, and the use of a sample which was nationally representative of age, sex, social class, socio-economic group and geographic location.

This study shows that in children and teenagers in Ireland, low DED was associated with multiple individual indicators of a better nutritional quality of the diet, including higher intakes of dietary fibre and micronutrients and a generally better balance of macronutrients. Low DED was also associated with food intake patterns that were generally closer to healthy eating guidelines, as well as with supplement use. Taken together, these findings support the conclusion that a low DED may be a useful indicator of a better nutritional quality of the diet.

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