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

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Abstract

45

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),
50 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.

55 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
60 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
65 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

70 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
75 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.

80 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
85 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
90 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.

130

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

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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
145 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
150 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).
155 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
160 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.

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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
170 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
175 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)
180 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' $\lambda = 0.49$, $P < 0.001$). 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.

210 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%.

215 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
220 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

225 *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, 230 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 235 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 240 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 245 as kJ per cm³, 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).

250 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
255 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
260 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
265 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).
270 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).

275 *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

300 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
305 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
310 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.
315 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

320 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
325 dietary quality.

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References

- 335 Beaton GH, Burema J, Ritenbaugh C (1997). Errors in the interpretation of dietary assessments. *Am J Clin Nutr* **65**: 1100S-1107S.
- Becker W (1999). Dietary guidelines and patterns of food and nutrient intake in Sweden. *Br J Nutr* **81 Suppl 2**: S113-117.
- 340 Bingham SA (1991). Limitations of the various methods for collecting dietary intake data. *Ann Nutr Metab* **35**: 117-127.
- Black AE (2000). The sensitivity and specificity of the Goldberg cut-off for EI:BMR for identifying diet reports of poor validity. *Eur J Clin Nutr* **54**: 395-404.
- 345 Cucó G, Arija V, Martí-Henneberg C, Fernández-Ballart J (2001). Food and nutritional profile of high energy density consumers in an adult Mediterranean population. *Eur J Clin Nutr* **55**: 192-199.
- 350 Drewnowski A (2000). Sensory control of energy density at different life stages. *Proc Nutr Soc* **59**: 239-244.
- Drewnowski A (2003). The role of energy density. *Lipids* **38**: 109-115.
- 355 Drewnowski A (2005). Concept of a nutritious food: toward a nutrient density score. *Am J Clin Nutr* **82**: 721-732.
- FAO/WHO (1998). Preparation and use of food-based dietary guidelines. Report of a Joint FAO/WHO consultation. *Technical Report Series, No 880*. WHO: Geneva.
- 360 Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA *et al* (1991). Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. *Eur J Clin Nutr* **45**: 569-581.
- 365 Hoffmann K, Schulze MB, Schienkiewitz A, Nöthlings U, Boeing H (2004). Application of a new statistical method to derive dietary patterns in nutritional epidemiology. *Am J Epidemiol* **159**: 935-944.
- 370 Howarth NC, Murphy SP, Wilkens LR, Hankin JH, Kolonel LN (2006). Dietary energy density is associated with overweight status among 5 ethnic groups in the multiethnic cohort study. *J Nutr* **136**: 2243-2248.
- 375 Hu FB (2002). Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol* **13**: 3-9.
- Johnson L, Mander AP, Jones LR, Emmett PM, Jebb SA (2008a). A prospective analysis of dietary energy density at age 5 and 7 years and fatness at 9 years among UK children. *Int J Obes (Lond)* **32**: 586-593.

- 380 Johnson L, Mander AP, Jones LR, Emmett PM, Jebb SA (2008b). Energy-dense, low-fiber, high-fat dietary pattern is associated with increased fatness in childhood. *Am J Clin Nutr* **87**: 846-854.
- Johnson L, Wilks DC, Lindroos AK, Jebb SA (2009). Reflections from a systematic review of dietary energy density and weight gain: is the inclusion of drinks valid? *Obes Rev*.
- 385
- Kant AK (1996). Indexes of overall diet quality: a review. *J Am Diet Assoc* **96**: 785-791.
- Kant AK (2004). Dietary patterns and health outcomes. *J Am Diet Assoc* **104**: 615-635.
- 390
- Kant AK, Graubard BI (2005a). A comparison of three dietary pattern indexes for predicting biomarkers of diet and disease. *J Am Coll Nutr* **24**: 294-303.
- Kant AK, Graubard BI (2005b). Energy density of diets reported by American adults: association with food group intake, nutrient intake, and body weight. *Int J Obes (Lond)* **29**: 950-956.
- 395
- Ledikwe JH, Blanck HM, Khan LK, Serdula MK, Seymour JD, Tohill BC *et al* (2005). Dietary energy density determined by eight calculation methods in a nationally representative United States population. *J Nutr* **135**: 273-278.
- 400
- Ledikwe JH, Blanck HM, Kettel Khan L, Serdula MK, Seymour JD, Tohill BC *et al* (2006a). Dietary energy density is associated with energy intake and weight status in US adults. *Am J Clin Nutr* **83**: 1362-1368.
- 405
- Ledikwe JH, Blanck HM, Khan LK, Serdula MK, Seymour JD, Tohill BC *et al* (2006b). Low-energy-density diets are associated with high diet quality in adults in the United States. *J Am Diet Assoc* **106**: 1172-1180.
- 410
- Lobstein T, Davies S (2008). Defining and labelling 'healthy' and 'unhealthy' food. *Public Health Nutr*: 1-10.
- Maillot M, Darmon N, Vieux F, Drewnowski A (2007). Low energy density and high nutritional quality are each associated with higher diet costs in French adults. *Am J Clin Nutr* **86**: 690-696.
- 415
- Martí-Henneberg C, Capdevila F, Arija V, Pérez S, Cuco G, Vizmanos B *et al* (1999). Energy density of the diet, food volume and energy intake by age and sex in a healthy population. *Eur J Clin Nutr* **53**: 421-428.
- 420
- McCaffrey TA, Rennie KL, Kerr MA, Wallace JM, Hannon-Fletcher MP, Coward WA *et al* (2008). Energy density of the diet and change in body fatness from childhood to adolescence; is there a relation? *Am J Clin Nutr* **87**: 1230-1237.
- 425
- Mendoza JA, Drewnowski A, Cheadle A, Christakis DA (2006). Dietary energy density is associated with selected predictors of obesity in U.S. Children. *J Nutr* **136**: 1318-1322.
- Mendoza JA, Drewnowski A, Christakis DA (2007). Dietary energy density is associated with obesity and the metabolic syndrome in U.S. adults. *Diabetes Care* **30**: 974-979.

- 430 Newby PK, Tucker KL (2004). Empirically derived eating patterns using factor or cluster analysis: a review. *Nutr Rev* **62**: 177-203.
- 435 Nordic Council of Ministers (2004). Nordic Nutrition Recommendations 2004. In: Ministers NCo (ed). Nordic Council of Ministers: Copenhagen.
- Rolls BJ, Drewnowski A, Ledikwe JH (2005). Changing the energy density of the diet as a strategy for weight management. *J Am Diet Assoc* **105**: S98-103.
- 440 Schofield WN (1985). Predicting basal metabolic rate, new standards and review of previous work. *Human Nutrition: Clinical Nutrition* **39C**: 5-41.
- 445 Schröder H, Covas M, Elosua R, Mora J, Marrugat J (2008a). Diet quality and lifestyle associated with free selected low-energy density diets in a representative Spanish population. *Eur J Clin Nutr* **62**: 1194-1200.
- Schröder H, Vila J, Marrugat J, Covas MI (2008b). Low energy density diets are associated with favorable nutrient intake profile and adequacy in free-living elderly men and women. *J Nutr* **138**: 1476-1481.
- 450 Sjöberg A, Hulthén L (2004). Assessment of habitual meal pattern and intake of foods, energy and nutrients in Swedish adolescent girls: comparison of diet history with 7-day record. *Eur J Clin Nutr* **58**: 1181-1189.
- 455 Stubbs J, Ferres S, Horgan G (2000). Energy density of foods: effects on energy intake. *Crit Rev Food Sci Nutr* **40**: 481-515.
- 460 Wennlöf AH, Yngve A, Sjöström M (2003). Sampling procedure, participation rates and representativeness in the Swedish part of the European Youth Heart Study (EYHS). *Public Health Nutr* **6**: 291-299.
- Verbeke W (2008). Impact of communication on consumers' food choices. *Proc Nutr Soc* **67**: 281-288.
- 465 WHO (2003). Diet, nutrition and the prevention of chronic diseases. A joint WHO/FAO Expert Consultation. WHO Technical Report Series no. 916. WHO: Geneva.
- 470 Willett WC, Howe GR, Kushi LH (1997). Adjustment for total energy intake in epidemiologic studies. *Am J Clin Nutr* **65**: 1220S-1228S; discussion 1229S-1231S.

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% (NRR, 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

| | Tertile | n | Energy density ¹ | | Food only ² | | All food and beverages | |
|------------------------------|---------|-----|-----------------------------|--------------|------------------------|--------------|------------------------|-------------|
| | | | kJ/g | | MJ | g | MJ | g |
| | | | Mean (s.d.) | 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 only² 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

| Food group (g) | | Girls | | | | | | | | | Boys | | | | | | | | |
|-----------------------|----------------|----------------|-------------------|-----------------|-----|------|---------|------|------|---------|------|------|---------|----|------|---------|----|-----|---------|
| | | Low | | | Mid | | | High | | | Low | | Mid | | High | | | | |
| | | % ¹ | Mean ² | CI ² | % | Mean | CI | % | Mean | CI | % | Mean | CI | % | Mean | CI | | | |
| 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} χ^2 for trend in % consumers across low, mid and high energy density diets significant in girls and boys, respectively² 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

| Food group (g) | Girls | | | | | | | | | Boys | | | | | | ANOVA | | | | | |
|-----------------------|------------------|-------------------|-----------------|-----|------|---------|------|------|---------|------|------|---------|----|------|---------|-------|----------------------|---------|-----|---------|---|
| | Low | | | Mid | | | High | | | Low | | Mid | | High | | F | P-value ³ | | | | |
| | % ¹ | Mean ² | CI ² | % | Mean | CI | % | Mean | CI | % | Mean | CI | % | Mean | CI | | | | | | |
| 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 | ^{ab} 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 | ^{ab} 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 | ^{ab} 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 | ^{ab} 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 | ^{ab} 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

³One-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

| <i>Nutrient</i> | Girls | | | Boys | | |
|--------------------------|-------------|------------|------------|-------------|-------------|-------------|
| | Low | Mid | High | Low | Mid | High |
| 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

| <i>Nutrient</i> | Girls | | | Boys | | | ANOVA | |
|--------------------------|-------------|------------|-------------|-------------|-------------|-------------|-------|----------------------|
| | Low | Mid | High | Low | Mid | High | F | P-value ¹ |
| 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.)

¹One-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

