Published in final edited form as:

Pediatr Obes. 2016 April ; 11(2): 128–135. doi:10.1111/ijpo.12034.

Relationship between dietary energy density and dietary quality in overweight young children: a cross-sectional analysis

S. A. Poole¹, C. N. Hart², E. Jelalian³, and H. A. Raynor¹

¹Department of Nutrition, University of Tennessee, Knoxville, TN, USA

²Center for Obesity Research and Education, Temple University, Philadelphia, PA, USA

³Bradley Hasbro Children's Research Center, Providence, RI, USA

Summary

Background—Observational research has found that lower energy density (ED) diets are related to reduced intake of fat and greater intake of fruits and vegetables. No study has examined the relationship between dietary ED and dietary quality, as determined by the Healthy Eating Index-2005 (HEI), in children who are overweight and obese.

Objective—Examine the relationship between dietary ED and HEI, determined from 3-d food records, in 156 children, aged 4–9 years, who had 85th percentile body mass index presenting for family-based obesity treatment.

Method—Dietary ED, in kcal/g, was calculated using two methods: food and all beverages consumed (food+bev) and food only consumed (food). For calculation of HEI, all components of the HEI were included except oils.

Results—Participants were classified as consuming a low-ED, medium-ED or high-ED diet using tertile cut-off points with ED calculated using food and beverages_(food+bev) or food only_(food). After controlling for group difference in child sex and race and parent sex, LOW_{food+bev} and LOW_{food} had significantly ($P < 0.05$) higher total HEI scores, and total fruit, total vegetable and saturated fat HEI scores than HIGH_{food+bev} and HIGH_{food}, with higher scores indicating greater quality.

Conclusions—Lower dietary ED is associated with higher dietary quality in children presenting for obesity treatment. Additional research investigating an ED prescription on dietary quality in children who are overweight or obese is needed to better understand this relationship.

Keywords

Dietary quality; energy density; Healthy Eating Index; paediatric obesity

Address for correspondence: Dr HA Raynor, Department of Nutrition, University of Tennessee, 1215 W. Cumberland Avenue, JHB 229, Knoxville, TN 37996-1920, USA. hraynor@utk.edu.

Conflict of Interest Statement

The authors declare no conflict of interests.

Introduction

Little is known about specific food choices individuals make when a diet lower in energy density (ED) is consumed. ED, as defined by the number of kilocalories per gram of food, is predominately influenced by the water and fat content of foods and beverages consumed (1,2). Therefore, consuming a greater number of foods naturally high in water, such as fruits and vegetables and broth-based soups, and/or fewer foods naturally high in fat content, such as high-fat cheeses and meats, should be related to a diet lower in ED. In adults, observational studies have found that diets lower in ED are associated with consuming less energy from fat, sugar-sweetened beverages and desserts; and consuming greater amounts of fruits, vegetables, whole grains, legumes and fibre (3–7). A prescription providing dietary ED goals has been examined in only one randomized controlled trial (RCT), in which adults were randomly assigned to one of three groups: low-ED (dietary goals focused on ED of foods); low-energy, low-fat (dietary goals focused on energy and fat); or low-ED, low-energy, low-fat (dietary goals focused on ED of foods, energy and fat) (8). At the completion of this 3-month trial, participants receiving a low-ED prescription were consuming more daily servings of fruits than participants only receiving a low-energy, low-fat prescription.

In children, only one observational study has examined the relationship between dietary ED and quality (9). In this study, children aged 2–8 years of varying weight status were categorized in regard to quartiles of the ED of the reported diet. Results indicated children reporting a lower ED diet (Quartile 1) consumed less fat and sugar and more fruits, vegetables and milk/dairy products than children consuming a higher ED diet (Quartile 4).

Thus, while little research has examined the relationship between types of foods consumed and ED, extant findings indicate that when children and adults consume a diet lower in ED, food choices made could improve the dietary quality (3–9). However, no study has examined the relationship between dietary ED and diet quality in a sample of children who are overweight and obese. As these children may be at higher risk for consuming a diet lower in dietary quality (10,11), examining dietary factors that are associated with higher dietary quality can potentially aid in developing the optimum dietary prescription for children who are overweight and obese.

Therefore, the purpose of this cross-sectional analysis was to examine the relationship between dietary ED, macronutrient intake and dietary quality, as determined by the Healthy Eating Index (HEI) (12), in children aged 4–9 years at the start of a 6-month, family-based, behavioural paediatric weight management programme. The HEI is a standard tool used to measure diet quality by assessing adherence to the *Dietary Guidelines for Americans*. As the data for these analyses were collected from 2005 to 2007, the HEI-2005 was used as this version reflects dietary standards that were in place when data were collected (12,13). Data for the cross-sectional analyses combined baseline data from two RCTs that examined the efficacy of the 1997 United States paediatric obesity treatment recommendations for primary care (13). It was hypothesized that prior to treatment, overweight and obese children consuming a lower ED diet would also consume a diet that scored higher on the HEI.

Methods

Study design and participants

This study was a cross-sectional, secondary data analysis investigating the relationship between dietary ED and diet quality. The primary dependent variables were macronutrient intake and HEI score. The sample consisted of 156 children who were overweight or obese with baseline data on the variables of interest. For the initial trials, participants were recruited from Rhode Island, Connecticut and Massachusetts between November 2005 and September 2007 using direct mailings, advertisements, community fairs, posters, flyers or through paediatric referral inviting them to participate in a 6-month, family-based behavioural paediatric weight management RCT (13). Recruitment materials were advertised for a programme to help children adopt healthy eating and activity patterns and provided a telephone number for interested parents to call. Both trials were registered at [ClinicialTrials.gov](https://clinicaltrials.gov) (NCT00259324 and NCT00200265). A more detailed description of the trial methodologies can be found in the manuscript for the main trials (13).

Child eligibility requirements for both trials were: aged 4–9 years, had 85th percentile for body mass index (BMI) as determined by CDC (Centers for Disease Control and Prevention) growth charts (14), reporting having no dietary or physical activity restrictions, with participating parent able to read and speak English. Families reporting having a psychological disorder which would impair participation, or planning to move outside of the research study area during the course of the programme, were ineligible to participate. The trials were approved by the Institutional Review Board of The Miriam Hospital in Providence, RI.

Procedures

After initially screening potentially eligible families via phone, families who remained interested attended the orientation, where informed consent and assent (children 8 years) were obtained and families were trained on completing measures. Baseline assessments were scheduled, during which height and weight were measured, questionnaires were completed, and food records were reviewed.

Measures

All dependent measures were collected in either a medical school research setting or in a primary care setting by trained staff prior to randomization.

Participant characteristics—Basic demographic information (i.e. child and parent gender, age, race, ethnicity and education level) was parent reported.

Anthropometrics—Child weight was assessed using an electronic scale (Healthometer Professional, Sunbeam Product Inc., Boca Raton, FL, USA), with height measured using a stadiometer (SECA, ITIN Scale Company, Brooklyn, NY, USA). Standard procedures were used with participants wearing light clothing and no shoes. For children, BMI percentile for age was plotted using age- and sex-appropriate CDC growth charts with BMI z-scores calculated by standardizing the BMI value in relation to the population mean and standard

deviation for children's age and sex using CDC growth charts (14). Children with a BMI 85th percentile for age and sex were considered overweight/obese and deemed eligible to participate.

Dietary intake—Child's dietary intake was assessed using 3-d food diaries (one weekend day and two weekdays) that were completed by a parent who had received training in how to estimate portions consumed (via provided two-dimensional food diagrams) and how to record intake. If during these 3 d children were under supervision of another adult, the parent was to obtain information from the other adult regarding child consumption. Food diaries were reviewed for completion by trained researchers to confirm all foods and beverages consumed. Dietary data were analyzed using the Nutrition Data System Software for Research (NDS-R) developed by the Nutrition Coordinating Center, University of Minnesota, Minneapolis, Minnesota (15). For all dietary variables, mean consumption over the course of 3 d was calculated. Dietary ED (kcal g⁻¹) was calculated from reported foods and beverages (ED_{food+bev}) and food only (ED_{food}) (2). Other dietary variables examined were percentage energy from fat, carbohydrate and protein.

To examine diet quality, the HEI-2005 tool was used (12). This tool is validated for individuals aged 2 years or older and includes 12 dietary components that are scored to calculate the compliance to the dietary guidelines, with a maximum score of 100. Each component is standardized per 1000 kcal and has a minimum score of 0 and a maximum score ranging from 5 to 20. Components are divided into 'adequacy components' and 'moderation components'. The components of total fruit, whole fruit, total vegetables, dark green and orange vegetables and legumes, total grains, whole grains, milk, meat and beans, and oils are all included in the 'adequacy components', as optimal intakes of these groups are required to have a nutritionally adequate diet. For these components, the minimum score is set to 0 for no intake of that food group and then increases proportionally up to the maximum score as the intake of that component increases up to the set standard. The components for saturated fat; sodium; and calories from solid fats, alcoholic beverages, and added sugars (SoFAAS) are included as 'moderation components' as these components are to be limited in the diet. A reverse scoring system is used for these, where individuals consuming at or below the standard intakes receive a maximum score and scores decrease proportionally as intakes for that component increase up to a set standard for a zero score.

For this investigation, all components of the HEI were included with the exception of the oils category, which includes non-hydrogenated vegetable oils and oils from fish, nuts and seeds. NDS-R coding schemes made it difficult to determine the total grams of oils meeting the defined criteria included in the child's diet, as monounsaturated and polyunsaturated fats reported by NDS-R include oils that are found in meats and vegetable oils. Therefore, it was impossible to determine the true source of the oil. Thus, scores for all other components were calculated and totalled, allowing for a maximum score of 90.

Statistical analyses

Similar to a study conducted by Ledikwe *et al.* (3), tertile cut-offs were used to classify participants as consuming a low-, medium- and high-ED diet. For dietary ED determined

using food and beverages consumed, the cut-offs were the following: $LOW_{\text{food+bev}}$: 1.05 kcal g⁻¹; $MED_{\text{food+bev}}$: 1.06–1.27 kcal g⁻¹; and $HIGH_{\text{food+bev}}$: 1.28 kcal g⁻¹. For dietary ED determined using food only consumed, the cut-offs were the following: LOW_{food} : 1.82 kcal g⁻¹; MED_{food} : 1.83–2.18 kcal g⁻¹; and $HIGH_{\text{food}}$: 2.19 kcal g⁻¹. For demographic measures of children and parents, analyses of variance were used to analyze differences in interval/ratio data between ED tertiles, and chi-square analyses were used to analyze associations in nominal measures between ED tertiles. As significant associations between ED tertiles were found for child sex and race and parent sex, these variables were entered as covariates in subsequent analyses.

The relationship between ED tertiles and percentage energy from fat, carbohydrate, and protein, and child HEI score were analyzed using analyses of covariance with a between-subjects factor of ED tertile and child sex and race and parent sex as covariates. Data were analyzed using SPSS for Windows (version 21.0, 2012, IBM SPSS, Armonk, NY, USA) with an $\alpha < 0.05$ for significance set *a priori* (16). Post hoc pair-wise comparisons with Bonferroni adjustments were used for significant outcomes. All data are presented as $M \pm SD$.

Results

Demographics

Child and parent characteristics are presented in Table 1. Children were 61.5% female, 84.6% white, 16.0% Latino and aged 7.2 ± 1.6 years, with a mean BMI percentile of 96.2 ± 2.8 and mean z-BMI of 2.3 ± 0.6 . Parents were 92.3% female, 89.1% white, 15.4% Latino and aged 38.1 ± 5.8 years, and 80.1% completed at least some college education.

No differences were found in child and parent baseline characteristics between ED tertiles, with the exception of child sex and race and parent sex. Statistical significance was found for child sex, $\chi^2(2, N = 156) = 6.98, P < 0.05$, with $MED_{\text{food+bev}}$ having a smaller proportion of females than $LOW_{\text{food+bev}}$. Significance was also found for child race, $\chi^2(2, N = 156) = 18.99, P < 0.05$, with $HIGH_{\text{food}}$ having a larger proportion of black children than both LOW_{food} and MED_{food} . Furthermore, significance was also found for parent sex, $\chi^2(2, N = 156) = 7.37, P < 0.05$, with LOW_{food} containing a smaller proportion of females than MED_{food} . Child sex and race and parent sex were included as covariates in all subsequent analyses.

Dietary intake

Energy density and macronutrients—ED and macronutrient intake by tertile for both $ED_{\text{food+bev}}$ and ED_{food} are presented in Table 2. As expected, each $ED_{\text{food+bev}}$, $F(2, 151) = 159.36, p < 0.001$, and ED_{food} , $F(2, 151) = 290.52, P < 0.001$, tertile were significantly different from each other for mean ED. Significant differences were found for fat intake, $F(2, 151) = 12.78, P < 0.001$, with $LOW_{\text{food+bev}}$ consuming less percentage energy from fat than $MED_{\text{food+bev}}$ and $HIGH_{\text{food+bev}}$. This relationship was also found between ED_{food} tertiles, $F(2, 151) = 10.66, P < 0.001$. Additionally, significant differences occurred in carbohydrate intake, $F(2, 151) = 5.38, P < 0.01$, with $LOW_{\text{food+bev}}$ consuming more energy

from carbohydrates than $HIGH_{food+bev}$. No significant differences were found between ED_{food} tertiles for percentage energy from carbohydrates. No significant differences were found between $ED_{food+bev}$ tertiles for percentage energy from protein consumed. However, significant differences were found between ED_{food} tertiles, $F(2, 151) = 12.85$, $P < 0.001$, with LOW_{food} and MED_{food} consuming a greater percentage of energy from protein than $HIGH_{food}$.

Dietary quality—Mean HEI scores by $ED_{food+bev}$ and ED_{food} tertiles are presented in Table 3. Mean HEI scores differed significantly between $ED_{food+bev}$ tertiles, $F(2, 151) = 5.26$, $P < 0.01$, with $LOW_{food+bev}$ having a higher score than $HIGH_{food+bev}$. Significant HEI scores were also found for ED_{food} , $F(2, 151) = 30.00$, $P < 0.001$, with LOW_{food} having a higher HEI score than MED_{food} and $HIGH_{food}$.

As differences were found between HEI scores, additional exploratory analyses were conducted to determine what components of the HEI may differ between tertiles. Analyses of covariance, with a between-subjects factor of ED tertile and child sex and race and parent sex as covariates, were used to analyze differences in components of the HEI. Results are shown in Table 3.

Fruits: Total fruit scores were significantly different in $ED_{food+bev}$, $F(2, 151) = 3.52$, $P < 0.05$, with children in $LOW_{food+bev}$ scoring higher than $HIGH_{food+bev}$. Significant differences were also found for ED_{food} , $F(2, 151) = 10.13$, $P < 0.001$, with LOW_{food} scoring higher on total fruits than MED_{food} and $HIGH_{food}$. Significant differences were found for whole fruit in $ED_{food+bev}$, $F(2, 151) = 4.08$, $P < 0.05$, with $LOW_{food+bev}$ scoring higher than $HIGH_{food+bev}$. For ED_{food} , significant differences were found between all tertiles, $F(2, 151) = 21.08$, $P < 0.001$, with LOW_{food} scoring the highest and $HIGH_{food}$ scoring the lowest whole fruit scores.

Vegetables: For $ED_{food+bev}$, significant differences were found for total vegetables, $F(2, 151) = 4.15$, $P < 0.05$, and dark green and orange vegetables and legumes, $F(2, 151) = 3.27$, $P < 0.05$, with children in $LOW_{food+bev}$ scoring significantly higher than $HIGH_{food+bev}$ in both components. For ED_{food} , significant differences were found between all tertiles for total vegetables, $F(2, 151) = 23.55$, $P < 0.001$, and for dark green and orange vegetables and legumes, $F(2, 151) = 17.46$, $P < 0.001$, with LOW_{food} scoring the highest and $HIGH_{food}$ scoring the lowest in both components.

Meats and beans: No differences were found for $ED_{food+bev}$ tertiles. However, significant differences were found for ED_{food} , $F(2, 151) = 3.99$, $P < 0.05$, with LOW_{food} scoring higher than $HIGH_{food}$.

Saturated fat: For $ED_{food+bev}$, significant differences were found, $F(2, 151) = 7.61$, $P < 0.001$, with $LOW_{food+bev}$ scoring higher than $HIGH_{food+bev}$. Significant differences were also found for ED_{food} , $F(2, 151) = 5.05$, $P < 0.01$, with LOW_{food} scoring higher than MED_{food} and $HIGH_{food}$.

Sodium: No differences were found between $ED_{\text{food+bev}}$ tertiles. However, differences were found for ED_{food} , $F(2, 151) = 3.88$, $P < 0.05$, with LOW_{food} scoring significantly lower than $HIGH_{\text{food}}$.

Calories from solid fats, alcoholic beverages, and added sugars: No differences were found between $ED_{\text{food+bev}}$ tertiles. However, differences were found for ED_{food} , $F(2, 151) = 5.33$, $P < 0.01$, with LOW_{food} scoring significantly higher than MED_{food} and $HIGH_{\text{food}}$. No differences were found in scores of the other components by ED tertile.

Discussion

This is the first study investigating the relationship between ED and dietary quality in a sample of families starting participation in a family-based paediatric weight management intervention. Results indicated that children who are overweight and obese and who report consuming a lower ED diet also report consuming a higher quality diet, as determined by the HEI. Specifically, a lower ED diet, with ED scored with all foods and beverages consumed or food only consumed, was associated with greater HEI scores for fruits, vegetables and saturated fat. These findings support the previous research conducted in children and adults of varying weight status that found that a lower ED diet is related to dietary choices that improve diet quality (3–9). However, it is challenging to compare the level of dietary ED in this study to the previous study examining the relationship between dietary ED and diet quality in children, as the method of determining dietary ED cut points was dissimilar and means or ranges of dietary ED were not provided in the previous study (9). As anticipated, in the current study, calculating ED using two methods led to different ranges of dietary ED, with ED_{food} having higher scores of dietary ED than $ED_{\text{food+bev}}$. Currently, there is no standard definition for calculating ED (2).

Other studies have examined the diet quality, assessed by either the HEI-2005 or a modified version of the HEI-2005, in young children. Garriguet investigated the diet quality in Canadian children of varying weight status aged 4–8 years using HEI-2005 modified to reflect the Canadian dietary guidelines (17). This adaptation of the HEI-2005 included 11 components, where total fruits and vegetables were combined into one category; the oils category was changed to unsaturated fats; and the SoFAAS category was changed to a category called ‘other food’. Furthermore, scoring criteria was modified to reflect Canadian guidelines. Results from this study found that Canadian children aged 4–8 years had an average HEI score of 65.4.

O'Neil *et al.* investigated the diet quality in children and adolescents completing the National Health and Nutrition Examination Survey (NHANES) 1999–2004 (18). This study investigated the diet quality using the HEI-2005 in 3686 children aged 6–12 years. This study found that children had a mean HEI score of 49.33. Finally, Hiza *et al.* examined the diet quality of Americans of varying age and socioeconomic status using the HEI-2005 (19). This study population included 8272 individuals completing the 2003–2004 NHANES, with 3286 of these participants being children and adolescents aged 2–17 years. This study found that children aged 6–11 had a mean HEI score of 55.

The mean HEI score of this investigation was 54.3 ± 9.7 . When compared to scores reported in previous investigations, the mean score of this investigation was lower than the score reported in a Canadian sample, higher in comparison to O'Neil and colleagues, and similar to the mean score reported by Hiza and colleagues (17–19). However, there are differences in coding schemes between all studies, making direct comparisons of the HEI scores between the studies challenging.

It is important to note that there may be issues of under-reporting food intake within the sample in this investigation, as under-reporting in children who are overweight and obese has been previously reported (20–22). When examining the 11 components of the HEI-2005 tool scored in this investigation, it appears that children in this investigation consistently scored relatively high in one of the 'moderation components', SoFAAS, which contribute 22% of the total HEI points possible (12). Recommendations suggest SoFAAS are to be consumed in limited amounts in the diet, thus higher scores indicated lower intakes of these dietary components. SoFAAS are typically present in problematic foods such as cookies, chips and ice cream, which have been reported to be consumed in higher amounts in U.S. children's diet (23–25). The higher score for SoFAAS suggests that components in the 'moderation' category may have been under-reported in children's food records, thus elevating total HEI scores in the present sample. A lower reporting of SoFAAS may also be due to parents not being aware of consumption of these foods, particularly when children are in the care of other adults who may not report this information even when asked.

The strengths of the study include dietary data collected from 3-d food records as opposed to using 1-d dietary recall, which has been done in previous investigations (9,17–19); therefore, ED could be calculated over the average of 3 d for a better representation of the diet. NDS-R was used to determine the dietary and food group intake. The limitations of the study included use of a cross-sectional study design, which limits the ability to determine causal relationships. Second, dietary data measures were collected via self-report, which may have contributed to under-reporting of 'moderation components' consumed. As all children in the sample were overweight or obese, this limited the ability to examine the association between dietary ED and weight status. To better understand how dietary ED is related to dietary quality in children, and to enable better understanding of how these factors are associated with paediatric obesity risk, future research should compare dietary ED and quality in children who are overweight and obese to children who are of a healthy weight status. Future research should also examine how other factors, such as parental age, education, income level and food preferences; food insecurity; and child sex and food preferences may impact a child's dietary ED as well as its association with dietary quality.

Lower dietary ED is associated with greater dietary quality in overweight and obese children presenting for obesity treatment. As intervention research regarding dietary ED in adults suggests that a low-ED prescription leads to greater improvements in diet quality as compared to a low-energy, low-fat diet (8), a low-ED dietary prescription may also improve the diet quality in children. Additional research investigating the effect of an ED prescription on dietary quality in overweight and obese children, within the context of a family-based paediatric weight management intervention, is needed to better understand this relationship.

Acknowledgements

SP and HR conceived the study and SP carried out the study. CN, EJ and HR obtained funding and assisted in acquisition of data. SP and HR performed the data analysis and interpreted the data. SP wrote the first draft of the manuscript and generated the tables. CN, EJ and HR critically revised the manuscript. SP, CN, EJ and HR approved of the final version of the manuscript. This research was supported by grants DK074919 from the National Institute of Diabetes and Digestive and Kidney Diseases and ADA 7-05-HFC-27 from the American Diabetes Association.

References

1. U.S. Department of Agriculture and U.S. Department of Health and Human Services. Dietary Guidelines for Americans, 2010. 7th edn.. U.S. Government Printing Office; Washington, D.C.: 2010.
2. Ledikwe J, Blanck H, Kettel-Khan L, et al. Dietary energy density determined by weight calculation methods in a nationally representative United States population. *J Nutr.* 2005; 135:273–278. [PubMed: 15671225]
3. Ledikwe J, Blanck H, Khan L, et al. Low-energy-density diets are associated with high diet quality in adults in the United States. *J Am Diet Assoc.* 2006; 106:1172–1180. [PubMed: 16863711]
4. Raynor HA, Van Walleghen EL, Bachman JL, Looney SM, Phelan S, Wing RR. Dietary energy density and successful weight loss maintenance. *Eat Behav.* 2011; 12:119–125. [PubMed: 21385641]
5. Drewnowski A, Monsivais P, Maillot M, Darmon N. Low-energy-density diets are associated with higher diet quality and higher diet costs in French adults. *J Am Diet Assoc.* 2007; 107:1028–1032. [PubMed: 17524726]
6. Rolls B. The relationship between dietary energy density and energy intake. *Physiol Behav.* 2009; 97:609–615. [PubMed: 19303887]
7. Ledikwe JH, Rolls BJ, Smiciklas-Wright H, et al. Reductions in dietary energy density are associated with weight loss in overweight and obese participants in the PREMIER trial. *Am J Clin Nutr.* 2007; 85:1212–1221. [PubMed: 17490955]
8. Raynor HA, Van Walleghen EL, Bachman JL, Looney SM, Phelan S, Wing RR. The effects of an energy density prescription on diet quality and weight loss: a pilot randomized controlled trial. *J Acad Nutr Diet.* 2012; 112:1397–1402. [PubMed: 22575072]
9. Vernarelli J, Mitchell D, Jartman T, Rolls B. Dietary energy density is associated with body weight status and vegetable intake in U.S. children. *J Nutr.* 2011; 141:2204–2210. [PubMed: 22049295]
10. Nicklas TA, Baranowski T, Cullen KW, Berenson G. Eating patterns, dietary quality, and obesity. *J Am Coll Nutr.* 2001; 20:599–608. [PubMed: 11771675]
11. Jennings A, Welch A, van Sluijs Esther MF, Griffin SJ, Cassidy A. Diet quality is independently associated with weight status in children aged 9–10 years. *J Nutr.* 2011; 141:453–459. [PubMed: 21270356]
12. Guenther PM, Reedy J, Krebs-Smith SM. Development of the Healthy Eating Index-2005. *J Am Diet Assoc.* 2008; 108:1896–1901.
13. Raynor HA, Osterholt KM, Hart CN, Jelalian E, Viver P, Wing RR. Efficacy of U.S. pediatric obesity primary care guidelines: two randomized trials. *Pediatr Obes.* 2012; 7:28–38. [PubMed: 22434737]
14. Kuczmarski R, Ogden C, Guo S, et al. 2000 CDC growth charts for the United States: methods and development. *Vital and Health Stat* 11 2002. 246:1–190.
15. Schakel S. Maintaining a nutrient database in a changing marketplace: keeping pace with changing food products- a research perspective. *J Food Comp Anal.* 2001; 14:315–322.
16. SPSS, Inc. SPSS for Windows. Release 21.0. Vol. IL. SPSS, Inc.; Chicago: 2012.
17. Garriguet D. Diet quality in Canada. *Health Rep.* 2009; 20:41–52. [PubMed: 19813438]
18. O'Neil CE, Nicklas TA, Zhanovec M, Cho SS, Kleinman R. Consumption of whole grains is associated with improved diet quality and nutrient intake in children and adolescents: the National Health and Nutrition Examination Survey 1999–2004. *Public Health Nutr.* 2011; 14:347–355. [PubMed: 20923597]

19. Hiza HA, Casavale KO, Guenther PM, Davis CA. Diet quality of Americans differs by age, sex, race/ethnicity, income, and education level. *J Acad Nutr Diet*. 2013; 113:297–306. [PubMed: 23168270]
20. Bandini L, Schoeller D, Cyr H, Dietz W. Validity of reported energy intake in obese and nonobese adolescents. *Am J Clin Nutr*. 1990; 52:421–425. [PubMed: 2393004]
21. Waling M, Larsson C. Energy intake of Swedish over-weight and obese children is underestimated using a diet history interview. *J Nutr*. 2008; 139:522–527. [PubMed: 19158227]
22. Champagne CM, Baker NB, DeLany JP, Harsha DW, Bray GA. Assessment of energy intake underreporting by doubly labeled water and observations on reported nutrient intakes in children. *J Am Diet Assoc*. 1998; 98:426–433. [PubMed: 9550166]
23. National Cancer Institute. Sources of energy among US population, 2005–2006. 2014. <http://appliedresearch.cancer.gov/diet/foodsources/energy/>
24. Carlson JA, Crespo NC, Sallis JF, Patterson RE, Elder JP. Dietary-related and physical activity-related predictors of obesity in children: a 2-year prospective study. *Child Obes*. 2012; 8:110–115. [PubMed: 22799510]
25. Montoye AH, Pfeiffer KA, Alaimo K, et al. Junk food consumption and screen time: association with childhood adiposity. *Am J Health Behav*. 2013; 37:395–403. [PubMed: 23985186]

Table 1Child and parent characteristics by ED tertile (M $\pm$ SD)

			Low ED (LOW)	Medium ED (MED)	High ED (HIGH)	Overall (N = 156)
Age (years)	ED _{food+bev}	Child	7.4 ± 1.7	7.1 ± 1.7	7.1 ± 1.4	7.2 ± 1.6
		Parent	38.2 ± 6.8	39.1 ± 5.5	36.9 ± 4.9	38.1 ± 5.8
	ED _{food}	Child	7.1 ± 1.8	7.6 ± 1.4	7.0 ± 1.4	7.2 ± 1.6
		Parent	38.4 ± 5.9	37.8 ± 5.9	38.0 ± 5.8	38.1 ± 5.8
Child z-BMI	ED _{food+bev}		2.2 ± 0.5	2.3 ± 0.6	2.3 ± 0.6	2.3 ± 0.6
	ED _{food}		2.3 ± 0.6	2.2 ± 0.4	2.3 ± 0.6	2.3 ± 0.6
Child BMI percentile	ED _{food+bev}		96.0 ± 2.1	96.1 ± 3.9	96.4 ± 1.9	96.2 ± 1.9
	ED _{food}		96.0 ± 2.2	96.4 ± 1.5	96.0 ± 2.2	96.2 ± 1.9
Sex (% female)	ED _{food+bev}	Child	75.0 ^a	50.0 ^b	59.6 ^{a,b}	61.5
		Parent	88.5	96.2	92.3	92.3
	ED _{food}	Child	68.6	60.4	55.8	61.5
		Parent	84.3 ^a	98.1 ^b	94.2 ^{a,b}	92.3
Race (%)						
White	ED _{food+bev}	Child	88.5	78.8	86.5	84.6
		Parent	90.4	86.5	90.4	89.1
	ED _{food}	Child	90.2	81.1	82.7	84.6
		Parent	92.2	84.9	90.4	89.1
Black	ED _{food+bev}	Child	7.7	11.5	7.7	9.0
		Parent	9.6	5.8	5.8	7.1
	ED _{food}	Child	7.8 ^a	3.8 ^a	15.4 ^b	9.0
		Parent	5.9	5.7	9.6	7.1
Asian	ED _{food+bev}	Child	0.0	1.9	1.9	1.3
		Parent	0.0	1.9	1.9	1.3
	ED _{food}	Child	0.0	3.8	0.0	1.3
		Parent	0.0	3.8	0.0	1.3
American Indian	ED _{food+bev}	Child	0.0	1.9	1.9	0.6
		Parent	0.0	0.0	0.0	0.0
	ED _{food}	Child	0.0	1.9	0.0	0.6
		Parent	0.0	0.0	0.0	0.0
Other	ED _{food+bev}	Child	3.8	3.8	3.8	3.8
		Parent	0.0	5.8	1.9	2.6
	ED _{food}	Child	0.0	9.4	1.9	3.8
		Parent	2.0	5.7	0.0	2.6
Hispanic or Latino (%)	ED _{food+bev}	Child	11.5	17.3	19.2	16.0
		Parent	17.3	15.4	13.5	15.4
	ED _{food}	Child	13.7	15.1	19.2	16.0
		Parent	17.6	15.1	13.5	15.4

		Low ED (LOW)	Medium ED (MED)	High ED (HIGH)	Overall (N = 156)
Education (% some college or higher)	ED _{food+bev}	78.8	82.7	78.9	80.1
	ED _{food}	84.4	71.7	84.6	80.1

Values with different superscripts are significantly different from each other using post hoc pair-wise comparisons with Bonferroni adjustments. ED, energy density; ED_{food+bev}, energy density using all foods and beverages, $N = 52$ for all tertiles; ED_{food}, energy density using food only, $N = 51, 53, 52$ (LOW, MED and HIGH, respectively).

Table 2Daily dietary ED and macronutrient composition intake by ED tertile (M $\pm$ SD)

		Low ED (LOW)	Medium ED (MED)	High ED (HIGH)	Overall (N = 156)
ED (kcal g ⁻¹)	ED _{food+bev}	0.89 $\pm$ 0.14 ^a	1.13 $\pm$ 0.08 ^b	1.45 $\pm$ 0.21 ^c	1.16 $\pm$ 0.27
	ED _{food}	1.56 $\pm$ 0.19 ^a	1.99 $\pm$ 0.11 ^b	2.46 $\pm$ 0.22 ^c	2.01 $\pm$ 0.41
Energy from fat (%)	ED _{food+bev}	28.9 $\pm$ 5.0 ^a	31.7 $\pm$ 4.9 ^b	33.9 $\pm$ 4.8 ^b	31.5 $\pm$ 5.3
	ED _{food}	29.1 $\pm$ 5.4 ^a	32.0 $\pm$ 4.3 ^b	33.5 $\pm$ 5.0 ^b	31.5 $\pm$ 5.3
Energy from carbohydrate (%)	ED _{food+bev}	54.7 $\pm$ 6.5 ^a	52.3 $\pm$ 5.1 ^{a,b}	50.9 $\pm$ 5.6 ^b	52.6 $\pm$ 5.9
	ED _{food}	53.7 $\pm$ 6.2	51.9 $\pm$ 5.5	52.2 $\pm$ 6.1	52.6 $\pm$ 5.9
Energy from protein (%)	ED _{food+bev}	16.3 $\pm$ 3.7	15.8 $\pm$ 2.4	15.1 $\pm$ 2.6	15.8 $\pm$ 3.0
	ED _{food}	17.0 $\pm$ 3.3 ^a	16.0 $\pm$ 2.5 ^a	14.3 $\pm$ 2.5 ^b	15.8 $\pm$ 3.0

Values with different superscripts are significantly different from each other using post hoc pair-wise comparisons with Bonferroni adjustments. ED, energy density; ED_{food+bev}, energy density using all foods and beverages, *N* = 52 for all tertiles; ED_{food}, energy density using food only, *N* = 51, 53, 52 (LOW, MED and HIGH, respectively).

Table 3HEI score and component scores by ED tertile (M $\pm$ SD)

		Low ED (LOW)	Medium ED (MED)	High ED (HIGH)	Overall (N = 156)
Total score (0–90)	ED _{food+bev}	57.0 $\pm$ 10.2 ^a	55.0 $\pm$ 9.5 ^{a,b}	50.9 $\pm$ 8.5 ^b	54.3 $\pm$ 9.7
	ED _{food}	61.4 $\pm$ 8.5 ^a	53.2 $\pm$ 7.9 ^b	48.5 $\pm$ 8.1 ^b	54.3 $\pm$ 9.7
Total fruits (includes 100% fruit juice) (0–5)	ED _{food+bev}	3.0 $\pm$ 1.6 ^a	2.5 $\pm$ 1.7 ^{a,b}	2.0 $\pm$ 1.5 ^b	2.5 $\pm$ 1.7
	ED _{food}	3.4 $\pm$ 1.6 ^a	2.0 $\pm$ 1.5 ^b	2.1 $\pm$ 1.6 ^b	2.5 $\pm$ 1.7
Whole fruit (0–5)	ED _{food+bev}	3.2 $\pm$ 1.7 ^a	2.3 $\pm$ 2.0 ^{a,b}	2.1 $\pm$ 1.8 ^b	2.6 $\pm$ 1.9
	ED _{food}	3.8 $\pm$ 1.6 ^a	2.5 $\pm$ 1.8 ^b	1.5 $\pm$ 1.5 ^c	2.6 $\pm$ 1.9
Total vegetables (0–5)	ED _{food+bev}	1.9 $\pm$ 1.4 ^a	1.5 $\pm$ 1.1 ^{a,b}	1.2 $\pm$ 0.9 ^b	1.5 $\pm$ 1.2
	ED _{food}	2.3 $\pm$ 1.3 ^a	1.4 $\pm$ 1.1 ^b	0.8 $\pm$ 0.6 ^c	1.5 $\pm$ 1.2
Dark green and orange vegetables and legumes (0–5)	ED _{food+bev}	3.3 $\pm$ 1.6 ^a	2.9 $\pm$ 1.7 ^{a,b}	2.4 $\pm$ 1.6 ^b	2.8 $\pm$ 1.7
	ED _{food}	3.8 $\pm$ 1.6 ^a	2.7 $\pm$ 1.7 ^b	1.9 $\pm$ 1.3 ^c	2.8 $\pm$ 1.7
Total grains (0–5)	ED _{food+bev}	4.7 $\pm$ 0.5	4.8 $\pm$ 0.4	4.9 $\pm$ 0.1	4.8 $\pm$ 0.5
	ED _{food}	4.7 $\pm$ 0.7	4.8 $\pm$ 0.5	4.8 $\pm$ 0.4	4.8 $\pm$ 0.5
Whole grains (0–5)	ED _{food+bev}	2.4 $\pm$ 1.5	2.3 $\pm$ 1.8	2.5 $\pm$ 1.7	2.4 $\pm$ 1.7
	ED _{food}	2.4 $\pm$ 1.7	2.4 $\pm$ 1.7	2.3 $\pm$ 1.6	2.4 $\pm$ 1.7
Milk (0–10)	ED _{food+bev}	8.4 $\pm$ 2.6	8.8 $\pm$ 2.2	8.6 $\pm$ 1.8	8.6 $\pm$ 2.2
	ED _{food}	8.8 $\pm$ 2.2	8.6 $\pm$ 2.3	8.3 $\pm$ 2.2	8.6 $\pm$ 2.2
Meats and beans (0–10)	ED _{food+bev}	6.3 $\pm$ 3.3	6.4 $\pm$ 2.9	5.2 $\pm$ 3.1	5.9 $\pm$ 3.2
	ED _{food}	6.8 $\pm$ 2.8 ^a	6.3 $\pm$ 3.2 ^a	4.7 $\pm$ 3.1 ^b	5.9 $\pm$ 3.2
Saturated fats (0–10)	ED _{food+bev}	6.3 $\pm$ 2.7 ^a	5.1 $\pm$ 2.8 ^{a,b}	3.9 $\pm$ 3.2 ^b	5.1 $\pm$ 3.1
	ED _{food}	6.3 $\pm$ 2.7 ^a	4.6 $\pm$ 3.3 ^b	4.4 $\pm$ 3.0 ^b	5.1 $\pm$ 3.1
Sodium (0–10)	ED _{food+bev}	2.5 $\pm$ 2.1	2.9 $\pm$ 1.6	2.5 $\pm$ 1.8	2.6 $\pm$ 1.8
	ED _{food}	2.1 $\pm$ 1.9 ^a	2.7 $\pm$ 1.9 ^{a,b}	3.0 $\pm$ 1.5 ^b	2.6 $\pm$ 1.8
SoFAAS (0–20)	ED _{food+bev}	14.9 $\pm$ 4.8	15.3 $\pm$ 3.9	15.4 $\pm$ 3.9	15.2 $\pm$ 4.2
	ED _{food}	16.7 $\pm$ 3.0 ^a	14.7 $\pm$ 4.6 ^b	14.3 $\pm$ 4.4 ^b	15.2 $\pm$ 4.2

Possible points for total score and each component included in parentheses. Values with different superscripts are significantly different using post hoc pair-wise comparisons with Bonferroni adjustments. HEI, Healthy Eating Index; ED, energy density; ED_{food+bev}, energy density using all foods and beverages, N = 52 for all tertiles; ED_{food}, energy density using food only, N = 51, 53, 52 (LOW, MED and HIGH, respectively); SoFAAS, calories from solid fats, alcoholic beverages, and added sugars.