Is dietary energy density associated with adiposity in children?

Conclusion

Moderately strong evidence from methodologically rigorous longitudinal cohort studies of children and adolescents suggests that there is a positive association between dietary energy density and increased adiposity in children.

Grade: Moderate-Strong

Overall strength of the available supporting evidence: Strong; Moderate; Limited; Expert Opinion Only; Grade not assignable For additional information regarding how to interpret grades, click here.

Evidence Summary Overview

This conclusion is based on a review of five prospective studies, conducted in the United Kingdom and Germany, which examined the association between dietary energy density (kJ per gram or kcal per gram) and adiposity among youth (Alexy, 2004; Johnson, 2008a; Johnson, 2008b; Johnson, 2009; McCaffrey, 2008). All of the studies included actual calculations of energy density, as well as an objective measure of adiposity. Cross-sectional studies were not included in the review. Four of the longitudinal studies (two study cohorts), found a positive association between dietary energy density (DED) and adiposity (Johnson, 2008a; Johnson, 2008b; Johnson, 2009; McCaffrey, 2008), whereas one longitudinal study reported no association (Alexy, 2004).

In the first published prospective analysis of the effect of energy-dense diets on body fatness and weight status in children, Johnson et al (2008a) assessed the association of dietary energy density with direct measures of adiposity at ages five, seven and nine years. Implausible energy intake reports were identified and adjusted for in the analysis. Results showed that mean dietary energy density at age seven years was higher among children with excess adiposity compared to the remaining sample (9.1±0.12 vs. 8.8±0.06kJ per gram) and was prospectively associated with excess adiposity at age nine years. A rise in dietary energy density of 1kJ per gram at seven years of age increased the odds of increased adiposity at age nine years by 36% (OR=1.36, 95% CI: 1.09 to 1.69). Among younger children, age five years, however, higher dietary energy density was not associated with excess adiposity at age nine years. This finding may reflect better compensation for high energy intake at younger ages, a control that appears to weaken with age as environmental, social and cultural cues for eating increase (Johnson, 2008a). In the same cohort, a dietary pattern at ages five and seven years characterized by high energy density, low dietary fiber density, and a high percent of energy from fat, was associated with a 0.15kg and a 0.28kg higher fat mass at nine years of age after controlling for confounders. Children at seven years of age who were in the highest quintile of pattern score (dietary energy density = 10.67±1.20) were more than four times more likely to have excess adiposity at age nine years, compared to children initially in the lowest quintile (dietary energy density = 7.24±0.87) (Johnson, 2008b). Finally, in a third report from the ALSPAC cohort at ages 10 to 13 years, Johnson et al (2009) evaluated the effect of dietary energy density in relation to the effect of variants in a genotype associated with fat mass and obesity [the FTO genotype (rs9939609, A allele)]. In this study, each 1kJ per g higher dietary energy density at age 10 years was associated with 0.16±0.06kg more fat mass at age 13 years, and each additional high-risk

A allele of FTO independently associated with 0.35±0.13kg more fat mass at age 13 years. Thus, although genetic factors may put some children at greater risk of obesity, the independent effect of low dietary energy density in reducing adiposity could prove to be an effective strategy for obesity prevention for all children.

A smaller cohort of children followed prospectively from ages six to eight years at baseline to ages 13 to 17 years at follow-up by McCaffrey et al (2008) also found a positive association between dietary energy density and adiposity. In this study, dietary energy density was calculated by five different methods, three of which excluded all or most beverages, and two that included beverages. Results showed that dietary energy density at baseline, calculated by the three methods that excluded all or most beverages, predicted those children who had the greatest increase in fat mass index (body fat normalized for height) on follow-up. Thus, subtle differences in calculating energy density by various methods may result in a positive or null association between energy density and change in fat mass over time.

It is noteworthy that the four longitudinal studies described above that found positive associations of dietary energy density with adiposity, calculated energy density by methods that excluded all or most beverages (Johnson, 2008a; Johnson, 2008b; Johnson, 2009; McCaffrey, 2008). This method was chosen because the high water content of beverages can disproportionately contribute to the overall energy density values and have been shown to dilute associations with health outcomes (Kant, 2005; Cox, 2000; Ledikwe, 2005). In addition, they measured adiposity (fat mass) objectively by dual energy x-ray absorptiometry (DEXA) (Johnson, 2008a; Johnson, 2008b; Johnson, 2009), or by doubly-labeled water technique (McCaffrey, 2008).

One longitudinal study found no association between dietary energy density and adiposity among children who were followed annually from age two to 18 years (Alexy, 2005). Participants in this cohort were classified by dietary pattern into clusters based on percent energy from fat, with dietary energy density lowest at 3.7 (0.4) in the low fat cluster; 4.0 (0.4) in the medium fat intake; and highest at 4.1 (0.4) in the high fat cluster. Mean body mass index (BMI) during the study period differed significantly, with the highest BMI in the low-fat, low-dietary energy density cluster, a result the investigators suggest may have reflected under-reporting of energy intake among overweight subjects, difficulty in detecting minor over-consumption of energy, and lack of power due to small sample size. In addition, dietary energy density in this study was calculated by including all beverages that may have diluted associations with health outcomes; and BMI was used as a surrogate measure of adiposity that may have limited precision and specificity. In a report by Freedman et al (2009), only 77% of children with BMI at or greater than the 95th percentile had elevated percent body fat as measured by DEXA, and an even smaller percent of children (20%) with BMI between the 85th and 94th percentile had elevated body fatness.

In summary, evidence from a limited number of methodologically strong, longitudinal cohort studies of children and adolescents suggests that there is a positive association between dietary energy density and increased adiposity in children. This is based on reports that used objective measures of adiposity (DEXA or doubly-labeled water technique), carefully assessed and adjusted for under- and over-reporting of energy intake, and calculated dietary energy density by methods which excluded all or most beverages.

Evidence Summary Paragraphs

Alexy et al, 2004 (positive quality) conducted a prospective cohort study in German children from ages two to 18 years to evaluate the influence of long-term dietary fat intake on BMI. Each year, participants had height and weight measured to determine BMI, and completed a weighed three-day food record. Energy density was calculated using foods and beverages combined. The final sample included 228 subjects (114 boys, 114 girls). A cluster analysis revealed four fat intake patterns: Constant, Medium, High, and Low. Constant and Medium had similar fat intake levels, but the standard deviation (SD) was higher for the Medium cluster. The High cluster had more than 50% of subjects above the third quartile of fat intake at all ages and the Low cluster had most subjects below the first quartile for more than half the measurements. Energy density was lowest in the Low cluster (P<0.0001). During the study period, the mean BMI differed significantly between clusters, with the highest BMI in the low-fat intake cluster.

Johnson et al, 2008 (*Am J Clin Nutr*) (positive quality) conducted a longitudinal, observational cohort study in the United Kingdom to identify a dietary pattern that explained dietary energy density, fiber density, and percentage of energy intake from fat and analyzed its relation to fatness in children. Data from Children in Focus, a subsample of the Avon Longitudinal Study of Parents and Children (ALSPAC), were used in the analysis; these were children who were born in the last six months of the study period. Dietary intake was assessed at age five and seven years using three-day diet diaries and body fat mass at age nine was measured using DEXA. The final sample included 521 children with five- and nine- year data available and 682 children with seven- and nine-year data available. Pattern score at ages five and seven years was correlated with dietary energy density (R=0.8), fiber density (R=-0.7) and percentage of energy intake as fat (R=0.5) and a one-SD increase in pattern score was associated with a 0.15kg (95% CI: -0.1 to 0.45kg) and a 0.28kg (95% CI: 0.05 to 0.53kg) higher fat mass at age nine years. The adjusted odds of excess adiposity at age nine years for the highest quintile compared to the lowest quintile of dietary pattern score were 2.52 (95% CI: 1.13 to 6.08) at five years of age and 4.18 (95% CI: 2.07 to 9.38) at seven years of age.

Johnson et al, 2008 (*Int J Obes*) (positive quality) conducted a longitudinal, observational cohort study in the United Kingdom to assess whether high dietary energy density is associated with increased fat mass and risk of excess adiposity in free-living children. Data from Children in Focus, a subsample of the Avon Longitudinal Study of Parents and Children (ALSPAC) were used in the analysis; these were children who were born in the last six months of the study period. Dietary intake was assessed at age five and seven years using three-day diet diaries and body fat mass at age nine was measured using DEXA. Dietary energy density was calculated using food only, and beverages were excluded. The final sample included 521 children with five- and nine-year data available and 682 children with seven- and nine-year data available. Mean dietary energy density at age seven years, but not five years, was higher among children with excess adiposity at age nine years compared to the remaining sample (9.1±0.12 vs. 8.8±0.06 kJ per g). A 1kJ per gram rise in dietary energy density increased the odds of excess adiposity at age nine years by 36% (OR=1.36, 95% CI: 1.09 to 1.69) after controlling for potential confounding variables.

Johnson et al, 2009 (positive quality) conducted a prospective cohort study to determine whether a relationship exists between: 1) Dietary energy density (DED) and body fatness; and 2) FTO genotype status and body fatness, and to determine whether DED and FTO genotype status interact to influence body fatness in a group of adolescent British children. Dietary intake data was collected using three-day food records when children were 10.7 years old. Dietary energy density was calculated using food only and beverages were excluded. Fat mass was measured using DEXA. The final sample included 2,275 children. Fat mass index (FMI) at age 13 years was significantly higher among carriers of the high-risk A allele with each A allele associated with 0.35±0.13kg more fat mass at 13 years. DED at age 10 years was significantly associated with fat mass at age 13 years with each kJ per gram increase associated with 0.16±0.06kg more fat mass at age 13 years. There was no evidence of interaction between DED and FTO genotype at age 10 years, suggesting that the effect of DED on fat mass is not altered by the FTO genotype.

McCaffrey et al, 2008 (positive quality) analyzed prospective cohort data from Ireland to assess the relationship between the energy density of the diet in childhood and change in adiposity from childhood to adolescence. Children were aged six to eight years at baseline, and 13 to 17 years at follow-up. Fat mass was determined using doubly-labeled water, BMI was calculated using measured height and weight and dietary intake data was collected using seven-day weighed food records. Five different methods were used to calculate dietary energy density; three excluded all or most beverages while two included beverages. Dietary Energy Density at baseline, calculated by the three methods that excluded all or most beverages, predicted those children who were the fattest by adolescence [i.e., was prospectively associated with change in the fat mass index (body fat normalized for height)] ($P<0.05$). Dietary Energy Density at baseline was not associated with change in BMI, percent of body fat or waist circumference (WC) scores.

View table in new window

Author, Year, Study Design, Class, Rating	**Participants**	**Study Duration**	**Methods: Diet Assessment; Adiposity Measurement**	**Outcomes**
Alexy U, Sichert-Hellert W et al, 2004 Study Design: Prospective Cohort Study Class: B Rating:	N=228. Age: Two to 18 years.	10-year follow-up.	Dietary Energy Density (DED) calculated as kJ per gram, including all beverages. Adiposity estimated using BMI.	No differences in BMI z-score were found between clusters of diet intake either at the first or last examination per subject The mean BMI during the study period differed significantly, with the highest BMI in the low-fat, low-ED cluster.
Johnson et al 2008; Am J Clin Nutr Study Design: Prospective Cohort Study Class: B Rating:	N=521 (age five and nine years). N=682 (age seven and nine years).	Nine-year follow-up.	DED calculated as kJ per gram (excluding all beverages). Fat mass measured by DEXA.	The adjusted odds of excess adiposity at nine years was significantly ↑ for children in Q5 (higher DED; 2.52) vs. Q1 (lower DED; 4.18). Pattern score at five years and seven years was correlated with DED (R=0.8); Fiber Density (R= - 0.7); and percent E from fat (R=0.5). ↑ of one SD of pattern score at ages five and seven years, respectively was associated with a 0.15kg and a 0.28kg

				↑ fat mass at nine years after controlling for confounders.
Johnson L et al 2008; Int J Obes Study Design: Longitudinal, Observational Cohort study Class: B Rating:	N=682. Age: Seven and nine years.	Nine-year follow-up.	DED calculated as kJ per gram (excluding all beverages). Fat mass measured by DEXA.	DED tracked strongly from age five to seven years. Mean DED at seven years was higher among children with excess adiposity, compared to the remaining sample (9.1±0.12 vs. 8.8±0.06kj per gram).
Johnson L, van Jaarsveld CH et al, 2009 Study Design: Prospective Cohort Study Class: B Rating:	N=2,275. Age: 10 to 13 years.	13-year follow-up.	DED calculated as kJ per gram (excluding all beverages). Fat Mass measured by DEXA.	Mean DED at age 10 years was 8.76±1.63kg per g. Each 1kg per g ↑ DED at age 10 years was associated with 0.16±0.06kg ↑ fat mass at age 13 years.
McCaffrey TA, Rennie KL et al, 2008 Study Design: Prospective Cohort Study Class: B Rating:	N=48. Age: Six to eight years at baseline; 13 to 17 years at follow-up.	Seven- to nine-year follow-up of children.	DED was calculated by five different methods. Three excluded all or most beverages; two included beverages. Fat mass was measured by doubly-labeled water.	Dietary Energy Density at baseline, calculated by the three methods that excluded all or most beverages, predicted those children who were the fattest by adolescence [i.e., was prospectively associated with Δ in the fat mass index (body fat normalized for height)]. DED at baseline was not associated with Δ in BMI, percent body fat or WC scores.

Research Design and Implementation Rating Summary

For a summary of the Research Design and Implementation Rating results, click here.

Worksheets

Alexy U, Sichert-Hellert W, Kersting M, Schultze-Pawlitschko V. Pattern of long-term fat intake and BMI during childhood and adolescence--results of the DONALD Study. *Int J Obes Relat Metab Disord.* 2004 Oct; 28(10): 1,203-1,209.

Johnson L, Mander AP, Jones LR, Emmett PM, Jebb SA. Energy-dense, low-fiber, high-fat dietary pattern is associated with increased fatness in childhood. *Am J Clin Nutr*. 2008 Apr;87(4):846-54.

Johnson L, Mander AP, Jones LR, Emmett PM, Jebb SA. 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).* 2008 Apr;32(4):586-93. Epub 2007 Oct 2.

Johnson L, van Jaarsveld CH, Emmett PM, Rogers IS, Ness AR, Hattersley AT, Timpson NJ, Smith GD, Jebb SA. Dietary energy density affects fat mass in early adolescence and is not modified by GTO variants. *PLoS One*. 2009; 4 (3): 34, 594.

McCaffrey TA, Rennie KL, Kerr MA, Wallace JM, Hannon-Fletcher MP, Coward WA, Jebb SA, Livingstone MB. Energy density of the diet and change in body fatness from childhood to adolescence; is there a relation? *Am J Clin Nutr*. 2008 May; 87 (5): 1,230-1,237.