

Is total energy intake associated with adiposity in children?

Conclusion

Moderately strong evidence from recent prospective cohort studies that identified plausible reports of energy intake, support a positive association between total energy (caloric) intake and 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 the review of four prospective cohort studies that examined the relationship between total energy intake and adiposity in children (Fulton, 2009; Ong, 2006; Savage, 2008a; Stunkard, 2004). Three studies were conducted in the United States and one was conducted in the United Kingdom. Three of the four studies found a positive association between total energy intake and adiposity (Ong, 2006; Savage, 2008a; Stunkard, 2004). The three studies that found a positive association between total energy (caloric) intake and adiposity in children, all distinguished between plausible and implausible reports of energy intake on an individual basis.

For example, in the two-year cohort study by Savage et al, (2008a), investigators examined reported energy intake among girls at age nine years as a predictor of body mass index (BMI) at age 11 years. In this study, plausible reports of energy intake were determined by comparing reported energy intake (rEI) with predicted energy requirements (pERs). Sex- and age-specific ± 1 standard deviation (SD) cut-offs for rEI as a percent of pERs ($pER; rEI/pER \times 100$) were developed (McCrary, 2002) and updated with the 2002 Dietary Reference Intakes (DRI) values (IOM, 2002). A report was considered plausible if rEI as a percent of pER was within ± 1 SD cut-off (84.8% to 115.2% at nine years of age). Those below the lower cut-off were classified as energy intake under-reporters, and those above were classified as energy intake over-reporters. Results showed that 58.4% (N=107) were plausible energy intake reporters; compared with 16.4% (N=30) who were under-reporters; and 25.1% (N=46) who were over-reporters. Notably, nearly two-thirds of implausible reporters were overweight (BMI > 85th percentile), compared with only 31% of the total sample and 27% of the plausible energy intake reporters. Under-reporters of energy intake had significantly higher BMI, BMI z-score, and BMI percentile and reported significantly lower energy intake vs. both plausible and over-reporters. Plausible reporters who were overweight had significantly higher reported energy intake (mean 1,897, SD=242) vs. normal weight girls (mean=1,713, SD=170). Among plausible reporters, energy intake predicted 14% of variance in BMI at 11 years of age. The authors conclude that systematic bias related to under-reporting in dietary data can obscure relationships with weight status, even among young girls, and that a relatively simple analytical procedure can be used to identify the magnitude and nature of reporting bias in dietary data. Importantly, this study found that the positive association between energy intake and adiposity was observed only after excluding implausible energy intake reports, but not in the total sample which included implausible reporters, the majority of which were overweight children who under-reported energy intake.

Stunkard et al, (2004) followed a cohort of newborn infants, consisting of 40 who were considered high-risk for obesity based on high maternal pre-pregnancy BMI and 38 others who were considered low risk. Their results showed that total energy intake, and not energy expenditure, was the determinant of body weight in these infants both at one and at two years of age, as it had been at one year of age. Ong et al, (2006) also found that energy intake during infancy influenced later infant weight gain and increased obesity risk during early childhood. In this study higher energy intake at four months of age was associated with higher rates of rapid weight gain between birth and two years of age ($P < 0.0001$). In addition, higher energy intake at four months of age showed greater gains in weight SD scores between birth and one, two and three years of age ($P = 0.007$ to $P = 0.0004$). These associations were present for children who had been formula-fed, or received mixed feedings of formula plus breast milk, but were not present for exclusively breast-fed infants. Among formula or mixed-feed infants, higher energy intake at four months of age also predicted larger childhood body weight and BMI at ages one, two, three and five years. Each 420kJ per day increase in energy intake was associated with increased risk of being overweight or obese (BMI > 85th percentile) at age three

years (odds ratio [OR]: 1.46; 95% CI: 1.2-1.78); and at age five years (OR: 1.25; 95% CI: 1.0-1.55).

A fourth longitudinal study (Fulton, 2009) did not find an association between total energy intake and adiposity. In this study, which enrolled 472 children between 1991-1993, three groups of children, enrolled at either ages eight, 11 or 14 years were followed for four years to examine the relationship between physical activity, energy intake and sedentary behavior and concurrent values of BMI, fat-free mass index and fat mass index, as measured by bioimpedance. Diet was assessed at baseline and annually with a food frequency questionnaire (FFQ), which is less accurate than other methods with respect to assessing individual energy intake. In this study, neither energy intake or sedentary behavior were associated with BMI, fat mass index or fat-free mass index. However, moderate-to-vigorous physical activity was inversely related to BMI and to fat mass index. Dietary reports of energy intake in this study were not individually assessed for plausibility, based on predicted energy requirements.

Evidence Summary Paragraphs

Cohort Studies (4)

Fulton et al, 2009 (neutral quality) conducted a prospective cohort study in the US to describe the relationship between energy intake, physical activity, and sedentary behavior with BMI, fat-free mass and fat mass in children, ages 10-18 years. Children in the study were recruited between 1991 and 1993, and followed for four years. Dietary intake was assessed at baseline and yearly using a food frequency questionnaire. Body mass index was calculated using triplicate measures of weight and height taken every four months and percent body fat (%BF) was measured using bioelectrical impedance. Sexual maturation was assessed by direct examination. The final sample included 472 children (245 boys, 227 girls). Results showed that energy intake was not related to %BF in models adjusted for age or sexual maturation or BMI in any model. Sedentary behavior was unrelated to fat mass in any model, or to fat-free mass or BMI in models adjusted for age or sexual maturation. Physical activity was inversely related to fat mass and BMI ($P < 0.05$). In this study, energy intake was not related to %BF or BMI, but physical activity was inversely related to fat mass and BMI.

Ong et al, 2006 (positive quality) used prospective cohort data from the Avon Longitudinal Study of Parents and Children Study (ALSPAC) in the United Kingdom to identify factors that influence early infancy dietary energy intake, and to assess the relationship between greater energy intake at four months and childhood weight gain and obesity at five-year follow-up. Diet was assessed at four months by means of a one-day unweighed diet record completed by the infant's main caregiver. Weight and length/height were measured to month four, eight, 12, 18, 25, 31, 37, 49 and 61 months, and BMI and BMI z-scores were calculated. The final sample included 881 children (469 boys, 412 girls). Higher energy intake at four months was associated with greater weight gains between birth and ages one, two and three years ($P = 0.007$ to $P = 0.0004$); and with higher rates of rapid weight gain between zero and two years ($P < 0.0001$). These associations were independent of current weight and were seen among formula or mixed feed infants, but not among breast-fed infants. Among formula or mixed feed infants, higher energy intake at four months also predicted larger childhood body weight and BMI at ages one, two, three and five years. Each 420 kJ per day increase in energy intake was associated with increased risk of being overweight or obese (BMI > 85th percentile) at three years (OR: 1.46; 95% CI: 1.2-1.78); and at five years (OR: 1.25; 95% CI: 1.0-1.55). The authors concluded that energy intake at four months of age predicted weight gain and childhood obesity risk.

Savage JS et al, 2008 (positive quality) conducted a prospective observational cohort study in the US to examine reported energy intake (EI) at age nine years as a predictor of girls' BMI at age 11 years. Height and weight was measured to calculate BMI and dietary intake of the children was assessed at age nine years with three 24-hour recalls. Physiologically plausible reports of EI were determined by comparing reported EI with predicted energy requirements. Reports were considered plausible if reported EI as a percent of predicted energy requirements was within ± 1 SD cutoff (84.8 to 115.2% at nine years of age). Analysis of variance was used to assess differences among under-, plausible and over-reporters on measures of reported EI and weight status. The final sample included 177 non-Hispanic white girls and their parents. Results showed that there were significant differences among the three groups. Under-reporters had significantly higher BMI, BMI z-score, and BMI percentile and reported significantly lower EI in comparison to both plausible and over-reporters. When girls were grouped by weight status, a similar proportion of the total sample (31%) and sub-group of plausible reporters (27%) were classified as overweight (BMI > 85th percentile) based on age- and gender-specific growth charts. In contrast, nearly two-thirds of implausible reporters were overweight. In addition, plausible reporters who were overweight (mean 1,897, SD=242) had significantly higher reported energy intake than normal weight (mean=1,713, SD=170) girls; however, no differences in reported EI were present between normal weight and overweight girls among implausible reporters or for the total sample. The authors conclude that data from this study does not support the view that obese and overweight children consume significantly fewer calories than normal weight children. In addition, results from this study show that under-reporting of EI is common and that the

magnitude of under-reporting tends to increase as weight status increases.

Stunkard et al, 2004 (positive quality) conducted a prospective cohort study in the US to ascertain the predictors of body size at two years of age. Measurements included: Weight, length, skinfold thickness measured at months three, six, nine, 12, 18 and 24, and %BF measured at three, 12 and 24 months. Total energy expenditure (TEE) and sleeping energy expenditure (SEE) were measured at three months, along with sucking behavior. Dietary intake was assessed using three-day weighed food records kept by parents at three, six, nine, 12, 18 and 24 months of age. The final sample included 78 infants, who were split into a “high risk” group (N=40) with obese mothers and a “low risk” group (N=38) with lean mothers. Results showed that higher energy intake predicted weight gain at two years, after controlling for body length (P<0.01).

 [View table in new window](#)

Author, Year, Study Design, Class, Rating	Study Duration	Participants	Methods	Outcomes	Strengths/Limitations
Fulton et al 2009 Study Design: Cohort Study Class: B Rating: 	Four years.	N=472 children (245 boys, 227 girls). Three cohorts of children, age eight years, 11 years and 14 years were enrolled between 1991 and 1993. Location: US.	Triplicate measures of weight (balance beam scale) and height (wall-mounted stadiometer) were obtained at four months, %BF measured by BIA. Diet assessed by baseline and yearly FFQ.	Energy Intake was not related to FMI or FFMI in models adjusted for age or sexual maturation or in any model to BMI.	Strengths: More than eight exams over four-year follow-up. Data on age, gender, race/ethnicity and sexual maturation available. Limitations: Reliability and validity of FFQ used for diet assessment not provided.
Ong et al 2006 Study Design: Cohort Study Class: B Rating: 	Follow-up: Five years.	N=881 children (469 boys, 412 girls). Birth Cohort Age: Birth to five years. Avon Longitudinal Study of Parents and Children (ALSPAC). Location: United Kingdom.	Diet assessed at four months by means of a one-day unweighed diet record completed by infant’s main caregiver. Weight measured at four, eight, 12, 18, 25, 31, 37, 49 and 61 months. Length or height measured as appropriate. BMI and BMI z-scores calculated.	Higher energy intake at four months was associated with greater gains in weight SDS between birth and ages one, two and three years (P=0.007 to P=0.0004); and with higher rates of rapid weight gain between zero and two years (P<0.0001). These associations were independent of current weight, and were seen among formula or mixed	Strengths: Large sample size and five years of follow-up observations. Limitations: Only a single measure of EI (one day) available for analysis.

				<p>feed infants, but not among breastfed infants.</p> <p>Each 420kJ per day ↑ in EI was associated with ↑ risk of being overweight or obese (BMI>85th percentile) at three years (OR: 1.46; 95% CI: 1.2-1.78); and at five years (OR: 1.25; 95% CI: 1.0-1.55).</p>	
<p>Savage JS, Mitchell DC et al, 2008</p> <p>Study Design: Prospective Cohort Study</p> <p>Class: B</p> <p>Rating: </p>	<p>Follow-up: Two years.</p>	<p>N=177 girls.</p> <p>Age: Nine-years at baseline; 11 years at follow-up.</p> <p>Location: US.</p>	<p>Height and weight was measured to calculate BMI.</p> <p>Dietary intake of children was assessed at age nine years with three 24-hour recalls.</p>	<p>Results showed that under-reporters of EI had significantly ↑ BMI, BMI z-score, and BMI percentile and reported significantly ↓ EI vs. both plausible and over-reporters.</p> <p>31% of the total sample, and 27% of the plausible EI reporters were overweight (BMI>85th percentile), vs. nearly two-thirds of implausible reporters. In addition, plausible reporters who were overweight had significantly ↑ reported energy intake (mean 1,897, SD=242) vs. normal weight girls (mean=1,713, SD=170).</p>	<p>Strengths: Longitudinal cohort design, multiple days of dietary intake data and assessment of plausibility of EI.</p> <p>Limitations: Subjects all non-Hispanic white girls from highly educated families, limiting the generalizability of the sample.</p>
<p>Stunkard et al 2004</p> <p>Study Design: Prospective longitudinal</p>	<p>Follow-up: Two years.</p>	<p>N=78 infants.</p> <p>Location: US.</p>	<p>Weight (x3, digital scale), length (infant length board) and skinfold thicknesses</p>	<p>Energy Intake during six occasions over the two-year predicted weight gain, controlling for body length</p>	<p>Strengths: Six weighed three-day food records obtained over two years.</p> <p>Limitations: All subjects were white; no minorities.</p>

<p>Longitudinal cohort study</p> <p>Class: B</p> <p>Rating: </p>			<p>measured at three, six, nine, 12, 18 and 24 months; %BF measured at three, 12 and 24 months.</p> <p>TEE and SEE (sleeping energy expenditure) measured at three months, along with sucking behavior.</p> <p>Dietary intake assessed with three-day weighed food records kept by parents, at three, six, nine, 12, 18 and 24 months of age.</p>	<p>body length.</p>	
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Research Design and Implementation Rating Summary

For a summary of the Research Design and Implementation Rating results, [click here](#).

Worksheets

 [Fulton, Jante E. et al Physical Activity, Energy Intake, Sedentary Behavior, and Adiposity in Youth *Am J Prev Med* 2009;37\(1S\): S40-S49](#)

 [Ong KK, Emmett PM, Noble S, Ness A, Dunger DB; ALSPAC Study Team. Dietary energy intake at the age of 4 months predicts postnatal weight gain and childhood body mass index. 2006 *Pediatrics*. Mar;117\(3\):e503-8.](#)

 [Savage JS, Mitchell DC, Smiciklas-Wright H, Symons Downs D, Birch LL. Plausible reports of energy intake may predict body mass index in pre-adolescent girls. *J Am Diet Assoc*. 2008; 108 \(1\): 131-135.](#)

 [Stunkard AJ, Berkowitz RI, Schoeller D, Maislin G, Stallings VA. Predictors of body size in the first 2 y of life: a high-risk study of human obesity. *Int J Obes Relat Metab Disord*. 2004 Apr;28\(4\):503-13.](#)