Is energy density associated with weight loss and weight maintenance in adults?

Conclusion

Strong and consistent evidence indicates that dietary patterns that are relatively low in energy density improve weight loss and weight maintenance among adults.

Grade: 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

Energy Density and Weight Loss

Four randomized controlled weight loss trials (RCT) found that lowering food-based energy density is linked with significantly higher weight loss (De Oliveira, 2008; Ello Martin, 2007; Rolls, 2005; Saquib, 2008). In these RCTs, the average weight loss resulting from lower dietary energy density ranged from 0.8kg to 1.5kg across studies. Dietary energy density was reduced by either increasing fruit or vegetable intake (De Oliveira, 2008; Ello Martin, 2007; Saquib, 2008) or soup consumption (Rolls, 2005).

Energy Density and Weight Maintenance

Four observational prospective studies with follow-ups ranging from six months to eight years have consistently documented a positive association between energy density and weight maintenance (Bes-Rastrollo, 2008; Greene, 2006; Ledikwe, 2007; Savage, 2008b). Bes-Rastrollo et al, (2008) found that women who moved their energy density from the highest to the lowest quintile gained significantly less weight than those who moved from the lowest to the highest energy density quintile (4.7±0.09kg vs. 6.4±0.09kg, respectively). Ledikwe et al, (2007) found that pre-hypertensive and hypertensive adults who reduced their energy density the most during six months lost 5.9kg, compared to 4.0kg among those in the middle tertile and 2.4kg among those in the lowest tertile. Savage et al, (2008b) found over a six-year period that women in the highest energy density tertile gained 6.4±6.5kg compared to 2.5±6.8kg among those in the lowest energy density tertile. Greene et al, (2006) found that two years after the completion of an effective 12-week weight loss program, individuals who were able to maintain the weight loss benefit consumed fewer calories and ate a lower-energy density diet.

Evidence Summary Paragraphs

Energy Density and Weight Loss

Randomized Controlled Trials (4)

De Oliveira et al, 2008 (neutral quality) conducted an RCT in Brazil to assess the effect of caloric density on body weight, body mass index (BMI) and mid-arm circumference. All subjects were instructed to have a standardized hypo-caloric diet containing 55% carbohydrate, 15% protein and

30% fat in order to produce a 250 calorie deficit daily. Also, subjects were provided with one of three snacks with different energy densities in a random manner: Three apples (0.63kcal per gram), three pears (0.64kcal per gram) or three oat cookies (3.7kcal per gram) daily. Energy density was calculated using food and beverage intake. The final sample included 34 women (age 30-50 years, BMI=32kg/m^2). Results showed that energy density decreased significantly among women consuming apples (-1.23kcal per gram, P=0.04) and pears (-1.29kcal per gram, P=0.05) compared to those consuming oat cookies. Also, energy intake decreased significantly among women consuming apples (-25kcal, P<0.001) and pears (-20kcal, P<0.01), while women consuming the oat cookies did not reduce energy intake. After 10 weeks, fruit-group consumers decreased their body weight (-0.93kg, P=0.0001 for the apple group and -0.84kg, P=0.0004 for the pear group) compared to the group with oat cookies added to the diet, after adjusting for age and type of treatment. The oat group had a non-significant increase in body weight (+0.21kg, P=0.35). The authors concluded that reducing dietary energy density by consuming fruit can reduce energy intake and body weight.

Ello Martin et al, 2007 (positive quality) conducted an RCT in the United States to investigate the effects of reducing dietary energy density on weight loss. Subjects were randomly assigned to one of two intervention groups: One group was advised to reduce fat intake (RF), and the other group was advised to increase consumption of water-rich foods (fruits and vegetables) along with a reduction in fat intake (RF and FV). This one-year long randomized, controlled intervention was divided into two six-month phases: Phase 1 included weekly counseling sessions with a dietitian and phase 2 included monthly small group sessions plus monthly individual counseling sessions with a dietitian. Energy density was calculated on the basis of food intake alone, with beverages excluded. The final sample included 71 women. After one year, study completers in both groups had significant decreases in body weight (P<0.0001). Subjects in the RF and FV group had a significantly different weight loss (P=0.002) than did subjects in the RF group, as the RF and FV group lost 7.9±0.9kg and the RF group lost 6.4±0.9kg. Diet records indicated that both groups had similar reductions in fat intake, while the RF and FV group had a lower dietary energy density than did the RF group (P=0.019) and consumed a greater weight of food (P=0.025), especially fruit and vegetables (P=0.037). The authors concluded that reducing dietary energy density, particularly by combining increased fruit and vegetable intakes with decreased fat intake, is an effective strategy for managing body weight.

Rolls et al, 2005 (neutral quality) conducted an RCT in the United States to test the weight loss effects of energy-restricted diets that varied in energy density. All subjects were instructed to follow an energy-reduced diet. Subjects were then randomized to consume daily either one or two servings of low energy-dense soup, two servings of high energy-dense snack foods or no special food (control group). Energy density was calculated based on food intake alone, with beverages excluded. The final sample included 147 subjects who completed the one-year trial (74%). All groups showed significant weight loss at six months that was maintained at 12 months. At one year, weight loss in the control group (8.1±1.1kg) and two-soup group (7.2±0.9kg) was significantly greater than the two-snack group (4.8±0.7kg), while weight loss in the one-soup group (6.1±1.1kg) did not significantly differ from the other groups. Weight loss was significantly correlated with dietary energy density decrease from baseline at one and two months (P=0.0001) but not at six and 12 months. The authors concluded that regularly consuming foods that are low in energy density can be an effective weight management strategy.

Saquib et al, 2008 (positive quality) conducted an RCT in the United States to evaluate the association between change in energy density and change in weight. Subjects were female breast cancer survivors enrolled in the Women's Healthy Eating and Living (WHEL) Study, who were followed for a four-year period. Women were randomized to an intervention or control group; those in the intervention group were instructed through telephone counseling, monthly cooking classes

and newsletters to follow a dietary pattern with at least five vegetable servings, 16 ounces of vegetable juice, three fruit servings, 30 g of fiber and 15-20% of energy from fat, while those in the control group received printed materials of dietary guidelines from USDA and the National Cancer Institute and a bimonthly newsletter. Energy density was calculated on the basis of food intake along, with beverages excluded. The finale sample included 2,146 women (mean age=53 years). Intervention participants significantly reduced dietary energy density compared to controls ($P<0.0001$), but total energy intake and physical activity did not vary between groups. At one year, the intervention group lost weight (0.05kg, $P<0.0001$) and the control group gained weight (0.71kg), but there were no differences in weight loss between groups at four years. The authors concluded that reducing energy density did not result in reduced total energy intake, and that reducing energy density alone may not be sufficient for weight management.

Energy Density and Weight Maintenance

Cohort Studies (4)

Bes-Rastrollo et al, 2008 (positive quality) analyzed retrospective cohort data from the United States to assess the long-term relationship between change in dietary energy density and change in weight. Subjects were participants in the Nurses' Health Study II, and were followed from 1991 to 1999. Dietary intake was evaluated using a self-administered semi-quantitative food frequency questionnaire (FFQ) (133 items) in 1991, 1995 and 1999, and dietary energy density was calculated as daily intake of calories by the reported weight in grams of all food consumed. Caloric and non-caloric beverages were included in a secondary analysis. The final sample included 50,026 women (age 36.5±4.6 years). Women who had the greatest increases in dietary energy density during follow-up (fifth quintile) gained significantly more weight than those who decreases their dietary energy density (first quintile) (6.42kg vs. 4.57kg; P for trend<0.001). The authors concluded that increasing dietary energy density was associated with greater weight gain among middle-aged women over an eight-year period.

Greene et al, 2006 (positive quality) used prospective cohort study data from the United States to determine weight outcomes and associated dietary intake patterns for a sample of participants from the EatRight Weight Management Program. The EatRight program emphasized low-energy density and high-complex carbohydrate foods and during the active weight loss phase, participants lost an average of 4.0kg. Energy density was calculated based on food intake alone and beverages were excluded. Subjects were followed for a mean of 2.2 years. The final sample included 74 subjects (mean age=50 years). During the follow-up period, average weight change was +0.59kg. 78% of participants gained less than five percent of their body weight (gainers), while 46% had no weight regain or continued weight loss (maintainers). Unadjusted mean energy intake for maintainers was 1,608kcal, whereas calorie intake for gainers was 1,989kcal. Despite eating fewer calories than gainers (a difference of 244 kcal; $P=0.058$), maintainers ate a similar amount of food, resulting in a lower energy-density pattern ($P=0.016$) compared with those who regained at least five percent of body weight. These results indicate that low-energy-density eating habits are associated with long-term weight maintenance.

Ledikwe et al, 2007 (positive quality) analyzed data from an RCT conducted in the United States to examine the relationship between six-month energy density changes and changes in anthropometric, dietary and health-related measures in subjects from the PREMIER trial. Subjects were randomly assigned to one of three groups: Established (N=219), Established plus DASH (N=216) or Advice group (N=223). Each group had significant declines in energy intake, dietary energy density and body weight (all $P<0.001$). Dietary energy density was calculated based on the basis of food intake along, with beverages excluded. Weight loss for all participants at six months was significantly

correlated with lower food energy density (r=0.28, P<0.001). When groups were combined and analyzed by dietary energy density change tertiles, participants in the highest tertile of dietary energy density reduction lost more weight (5.9 kg) than those in the middle (4.0kg) or lowest (2.4kg) tertile. The authors concluded that large and modest reduction in dietary energy density were associated with weight loss.

Savage, 2008b (positive quality) analyzed prospective cohort study data from the United States to examine the relationship between energy density and weight change over six years among free-living women. Data were collected on four occasions over a six-year period, with collection occurring at two-year intervals. Weight and height were measured and BMI was calculated. Dietary intake data was collected using 24-hour recall interviews, and energy density was calculated on the basis of food intake alone, with beverages excluded. The final sample included 168 women (mean age=36 years). Energy density was positively associated with weight gain and higher BMI. Women consuming higher energy-dense diets gained an average of 6.4 kg over six years, whereas women consuming lower energy-dense diets only gained 2.5kg (P<0.01). The authors concluded that consuming a lower energy-dense diet moderates weight gain and may promote weight maintenance.

View table in new window

Author, Year, Study Design, Class, Rating	Study Name	Populations/Subjects	Methods	Outcomes
Bes-Rastrollo M, van Dam R et al, 2008 Study Design: Prospective Cohort Study Class: B Rating:	Nurses' Health Study.	N=50,026 women (age 36.5±4.6 years). Location: United States.	Subjects were followed from 1991 to 1999. Dietary intake was evaluated using a FFQ in 1991, 1995 and 1999, and dietary energy density was calculated as daily intake of calories by the reported weight in grams of all food consumed. Caloric and non-caloric beverages were included in a secondary analysis.	Women who had the greatest ↑ in dietary energy density during follow-up (fifth quintile) gained significantly more weight than those who ↓ their dietary energy density (first quintile) (6.42kg vs. 4.57kg; P for trend<0.001).
de Oliveira M, Sichieri R et al, 2008 Study Design: Randomized Controlled Trial		N=34 women (age 30-50 years, BMI=32kg/m^2). Location: Brazil.	All subjects were instructed to have a standardized hypo-caloric diet containing 55% CHO, 15% protein and 30% fat in order to produce a 250-calorie deficit	Results showed that energy density ↓ significantly among women consuming apples (-1.23kcal per gram, P=0.04) and pears (-1.29kcal

Class: A Rating:			daily. Also, subjects were provided with one of three snacks with different energy densities in a random manner: Three apples (0.63kcal per gram), three pears (0.64kcal per gram) or three oat cookies (3.7kcal per gram) daily. Energy density was calculated using food and beverage intake.	per gram, P=0.05) compared to those consuming oat cookies. Also, energy intake ↓ significantly among women consuming apples (-25kcal, P<0.001) and pears (-20kcal, P<0.01), while women consuming the oat cookies did not reduce energy intake. After 10 weeks, fruit-group consumers ↓ their body weight (-0.93kg, P=0.0001 for the apple group and -0.84kg, P=0.0004 for the pear group) compared to the group with oat cookies added to the diet, after adjusting for age and type of treatment. The oat group had a non-significant ↑ in body weight (+0.21kg, P=0.35).
Ello-Martin JA, Roe LS et al, 2007 Study Design: Randomized Controlled Trial		N=71 women. Location: United States.	Subjects were randomly assigned to one of two intervention groups: One group was advised to ↓ fat intake (RF), and the other group was advised to ↑ consumption of water-rich foods (fruits and vegetables) along	After one year, study completers in both groups had significant ↓ in body weight (P<0.0001). Subjects in the RF and FV group had a significantly

Class: A Rating:			with a reduction in fat intake (RF and FV). This one-year long randomized, controlled intervention was divided into two six-month phases: Phase 1 included weekly counseling sessions with a dietitian and phase 2 included monthly small group sessions plus monthly individual counseling sessions with a dietitian. Energy density was calculated on the basis of food intake alone, with beverages excluded.	different weight loss (P=0.002) than did subjects in the RF group, as the RF and FV group lost 7.9±0.9kg and the RF group lost 6.4±0.9kg. Diet records indicated that both groups had similar ↓ in fat intake, while the RF and FV group had a lower dietary energy density than did the RF group (P=0.019) and consumed a greater weight of food (P=0.025), especially fruit and vegetables (P=0.037).
Greene LF, Malpede CZ et al, 2006 Study Design: Prospective Cohort Study Class: B Rating:		N=70 (mean age=50 years). Location: United States.	The EatRight program emphasized low-energy density and high-complex CHO foods. Energy density was calculated based on food intake alone, and beverages were excluded. Subjects were followed for a mean of 2.2 years.	Despite eating fewer calories than gainers (a difference of 244kcal; P=0.058), maintainers ate a similar amount of food, resulting in a lower energy-density pattern (P=0.016), compared with those who regained at least 5% of body weight.

Ledikwe JH, Rolls BJ et al, 2007 Study Design: Randomized Controlled Trial Class: A Rating: 	PREMIER	Subjects were randomly assigned to one of three groups: Established (N=219), Established plus DASH (N=216) or Advice group (N=223). Location: United States.	Dietary energy density was calculated based on the basis of food intake along, with beverages excluded.	Weight loss for all participants at six months was significantly correlated with lower food energy density (r=0.28, P<0.001). When groups were combined and analyzed by dietary energy density change tertiles, participants in the highest tertile of dietary energy density reduction lost more weight (5.9kg) than those in the middle (4.0kg) or lowest (2.4kg) tertile.
Rolls et al 2005 Study Design: Randomized Controlled Trial (RCT) Class: A Rating: 		N=147. Location: United States.	All subjects were instructed to follow an energy-reduced diet. Subjects were then randomized to consume daily either one or two servings of low energy-dense soup, two servings of high energy-dense snack foods or no special food (control group). Energy density was calculated based on food intake alone, with beverages excluded.	All groups showed significant weight loss at six months that was maintained at 12 months. At one year, weight loss in the control group (8.1±1.1kg) and two-soup group (7.2±0.9kg) was significantly greater than the two-snack group (4.8±0.7kg), while weight loss in the one-soup group (6.1±1.1kg) did not significantly differ from the other groups. Weight

				loss was significantly correlated with dietary energy density ↓ from baseline at one and two months (P=0.0001), but not at six and 12 months.
Saquib et al 2008 Study Design: Randomized Controlled Trial Class: A Rating: 		N=2,146 women (mean age=53 years). Location: United States.	Subjects were female breast cancer survivors enrolled in the Women's Healthy Eating and Living (WHEL) Study, who were followed for a four-year period. Women were randomized to an intervention or control group; those in the intervention group were instructed through telephone counseling, monthly cooking classes and newsletters to follow a dietary pattern with at least five vegetable servings, 16oz of vegetable juice, three fruit servings, 30g of fiber and 15-20% of energy from fat, while those in the control group received printed materials of dietary guidelines from USDA and the National Cancer Institute and a bimonthly newsletter. Energy density was calculated on the basis of food intake along, with beverages excluded.	Intervention participants significantly ↓ dietary energy density compared to controls (P<0.0001), but total energy intake and physical activity did not vary between groups. At one year, the intervention group lost weight (0.05kg, P<0.0001) and the control group gained weight (0.71kg), but there were no differences in weight loss between groups at four years.

Savage et al 2008 Study Design: Prospective cohort study Class: B Rating:		N=168 women (mean age=36 years). Location: United States.	Data were collected on four occasions over a six-year period, with collection occurring at two-year intervals. Weight and height were measured and BMI was calculated. Dietary intake data was collected using 24-hour recall interviews, and energy density was calculated on the basis of food intake alone, with beverages excluded.	Energy density was positively associated with weight gain and higher BMI. Women consuming higher energy-dense diets gained an average of 6.4kg over six years, whereas women consuming lower energy-dense diets only gained 2.5kg (P<0.01).

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

Worksheets

Bes-Rastrollo M, van Dam RM, Martinez-Gonzalez MA, Li TY, Sampson LL, Hu FB. Prospective study of dietary energy density and weight gain in women *Am J Clin Nutr*. 2008 Sep; 88 (3): 769-777.

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Ello-Martin JA, Roe LS, Ledikwe JH, Beach AM, Rolls BJ. Dietary energy density in the treatment of obesity: A year-long trial comparing two weight-loss diets. *Am J Clin Nutr*. 2007 Jun; 85(6): 1,465-1,477.

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(5): 1,212-1,221.

Rolls BJ, Roe LS, Beach AM, Kris-Etherton PM. Provision of foods differing in energy density affects long-term weight loss. *Obes Res.* 2005 Jun;13(6):1052-60.

Saquib N, Natarajan L, Rock CL, Flatt SW, Madlensky L, Kealey S, Pierce JP. The impact of a long-term reduction in dietary energy density on body weight within a randomized diet trial. *Nutr Cancer.* 2008; 60(1):31-8.

Savage JS, Marini M, Birch LL. Dietary energy density predicts women's weight change over 6 y. *Am J Clin Nutr.* 2008 Sep; 88(3):677-84.