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Beverage Consumption and Adult Weight Management: A Review

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Abstract

Total energy consumption among United States adults has increased in recent decades, and energy-containing beverages are a significant contributor to this increase. Because beverages are less satiating than solid foods, consumption of energy-containing beverages may increase energy intake and lead to weight gain; trends in food and beverage consumption coinciding with increases in overweight and obesity support this possibility. The purpose of this review is to present what is known about the effect of beverage consumption on short-term (i.e., meal) energy intake, as well as longer-term effects on body weight. Specific beverages addressed include water, other energy-free beverages (diet soft drinks, coffee and tea), and energy-containing beverages (soft drinks, juices and juice drinks, milk and soy beverages, alcohol). Existing evidence, albeit limited, suggests that encouraging water consumption, and substituting water and other energy-free beverages (diet soft drinks, coffee and tea) for energy-containing beverages may facilitate weight management. Energy-containing beverages acutely increase energy intake, however long-term effects on body weight are uncertain. While there may be health benefits for some beverage categories, additional energy provided by beverages should be compensated for by reduced consumption of other foods in the diet.

Keywords

adult weight management; beverage; water; soft drinks; obesity; energy intake

1. Introduction

Caloric intake has increased over the past 20 years, with the majority of the increase derived from snacks foods (Nielsen, Siega-Riz, & Popkin, 2002) and beverages (Duffey & Popkin, 2007). Beverage consumption patterns in children and adolescents are an important target for promoting body weight management (Ludwig, Peterson, & Gortmaker, 2001; Sanigorski, Bell, & Swinburn, 2007), yet until recently, less attention has been directed at beverage consumption and adult weight management. The potential negative public health consequences of sweetened beverage consumption have led some to suggest a sugar-sweetened beverage tax (Brownell & Frieden, 2009), which is controversial due in part to a lack of direct evidence linking changes in sweetened beverage intake to weight outcomes (Allison & Mattes, 2009). Thus, the purpose

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of this article is to review literature addressing beverage consumption and adult weight management.

Though beverages of all types satisfy thirst (Almiron-Roig & Drewnowski, 2003), caloric (i.e., energy-containing) beverages do not effect food intake during acute meal settings (Almiron-Roig & Drewnowski, 2003; DellaValle, Roe, & Rolls, 2005; Harper, James, Flint, & Astrup, 2007; Tsuchiya, Almiron-Roig, Lluch, Guyonnet, & Drewnowski, 2006). However, when compared to water or energy-free, artificially-sweetened beverages, consumption of energy-containing beverages increases total meal energy intake (Almiron-Roig & Drewnowski, 2003; DellaValle et al., 2005). The low satiety value of beverages may be explained by the fact that for most of human evolutionary history, water was the only beverage consumed (Wolf, Bray, & Popkin, 2008); regulation of beverage energy was not of biological importance. Though the exact mechanism of this weak satiety response is unclear, there are several possibilities. First, relative to solid foods, beverages take less time to consume and are rapidly emptied from the stomach (Kissileff, 1985). This is supported by research demonstrating that consumption of an isocaloric liquid compared with solid food given prior to an ad libitum meal increases food intake (Stull, Apolzan, Thalacker-Mercer, Iglay, & Campbell, 2008). Second, food form (i.e. solid vs. liquid) influences appetite-related hormonal response (Tieken et al., 2007). Finally, energy-containing beverages are largely comprised of carbohydrates, which stimulate fewer satiety signals than fat or protein (Wolf et al., 2008).

Because energy from beverages is less satiating than consumption of solid foods (DiMeglio & Mattes, 2000; R. Mattes, 2006; R. D. Mattes, 1996; Stull et al., 2008), consumption of energy-containing beverages may produce weight gain (Ludwig et al., 2001). Trends in beverage consumption coinciding with increases in overweight and obesity support this possibility; energy intake from sweetened beverages (i.e., soft drinks and fruit drinks) has increased by 222 kcal in recent decades (Duffey & Popkin, 2007). Adults with a high energy-containing beverage intake consume less healthy diets (Duffey & Popkin, 2006; Popkin, Barclay, & Nielsen, 2005), while water consumers ingest less total energy (Duffey & Popkin, 2006; Popkin et al., 2005). Soft drinks are the single greatest energy source (i.e., 7% total energy) in the American diet (Block, 2004); average daily consumption of soft drinks is > 12.3 fl oz per person (Wolf et al., 2008). Therefore, beverage consumption patterns may be an important dietary factor influencing adult weight management.

This review was conducted using a PubMed (National Library of Medicine) online literature search to identify publications (within 15 years) investigating beverage consumption and either food/energy intake or body weight management. A small number of less recent publications were included if they were a key reference for later work on this topic. Articles were limited to those published in English, and in adults. Findings were categorized according to beverage type as follows: water, other energy-free beverages (artificially sweetened beverages, coffee and tea), and energy-containing beverages (soft drinks, juice and juice drinks, milk and soy beverages, alcohol). Details of studies reviewed are presented in the Table in alphabetical order by first author's name within each subsection. Research findings are summarized within the text in the following order: epidemiological research, test meal/short-term feeding studies, and randomized controlled trials (if available). Relevant meta-analyses and reviews are also presented.

2. Water

There is a common belief that water ingestion facilitates weight management. Epidemiological data indicate that energy intake among water drinkers is ~9% (194 kcal/d) lower than non-water drinkers (Popkin et al., 2005), yet few studies have directly addressed the effect of increased water consumption on weight management. Water consumed before or with a meal reduces sensations of hunger and increases satiety among nonobese adults (Lappalainen, Mennen, van Weert, & Mykkanen, 1993; Van Walleghen, Orr, Gentile, & Davy, 2007). However, young, normal weight men consume the same amount of energy at an ad libitum meal when given water (8 and 16 fl. oz) as compared to no beverage 30 minutes prior to the meal (Rolls et al., 1990). Pre-meal water consumption reduces meal energy intake in nonobese older adults (Van Walleghen et al., 2007), and also among middle-aged and older overweight/obese adults (Davy, Dennis, Dengo, Wilson, & Davy, 2008). Thus, it appears ingesting water (~16 fl oz) prior to a meal reduces meal energy intake among middle-aged and older adults by ~75-90 kcals, but may not impact meal energy intake among younger population segments (Davy, Dennis, Dengo et al., 2008; Van Walleghen et al., 2007).

Longer term studies have investigated changes in self-reported beverage intake to energy intake and weight during a weight loss intervention (see Table) (Stookey, Constant, Gardner, & Popkin, 2007). Over 12 months, drinking ≥1 L water (>33.8 fl oz) per day increased weight loss by ~ 2 kg as compared to drinking less water (Stookey, Constant, Popkin, & Gardner, 2008). However, these investigations relied on self-reported data and to date, no clinical intervention studies have assessed the influence of increased water consumption on weight loss in adults; the aforementioned intervention compared popular weight loss diets and water/beverage consumption was not the primary focus. Preliminary data suggests increasing daily water intake may facilitate long term weight loss among middle-aged and older adults (Davy, Dennis, Akers, Dengo, & Davy, 2008); a trend ($p=0.09$) was detected for greater weight loss after 6 months among individuals ($n=20$) following a hypocaloric diet along with three 500-ml bottled water per day (16.9 fl oz) as compared to those in a diet-only control condition. Additional long term studies with larger sample sizes are needed to confirm this possibility.

There may be other benefits of water consumption for weight management, such as increased metabolic rate (Boschmann et al., 2003; Brown, Dulloo, & Montani, 2006). Additional research is needed to confirm these findings, as well as to address issues of optimal volume and timing of water ingestion for managing hunger and reducing meal energy intake.

The Beverage Guidance Panel provided an overview of the nutritional benefits and risks of different beverage categories, and provided recommendations for beverage intake in relation to weight status and health (Popkin et al., 2006). These recommendations were controversial, in that not all were supported by scientific data (Kaplan, 2006; Weaver et al., 2006). Though there is not a Recommended Daily Allowance (RDA) for total water intake due to insufficient evidence and individual variability, the Institute of Medicine's Food and Nutrition Board suggested a Daily Recommended Intake (DRI) for adult males and nonpregnant, nonlactating females over 19 years of 3.7 L/day and 2.7 L/day, respectively. However, this includes total water from all beverages such as coffee, tea, juices, soda and water, as well as moisture from foods (Panel on Dietary Reference Intakes for Electrolytes and Water, 2004). An Adequate Intake (AI) of 3.0 L/day for men and 2.2 L/day for women (~104 fl oz and 72 fl oz) of total beverages, including water, was also recommended. These guidelines recommend that individuals be attentive to thirst cues and consume beverages with meals to maintain adequate hydration status, but do not make specific recommendations pertaining to beverage consumption and weight management. Thus, epidemiological and acute meal studies suggests a beneficial role for water consumption in reducing energy intake and promoting weight management, yet there is insufficient data from intervention studies to make conclusive evidence-based intake recommendations for water consumption.

3. Other Energy-Free Beverages

3.1. Energy-free, Artificially Sweetened Beverages

Approximately one fifth of US adults consume energy-free, artificially sweetened beverages, such as diet soft drinks and other artificially sweetened beverages (Duffey & Popkin, 2006). These beverages provide a source of water and sweetness in the diet without additional energy (Popkin et al., 2006). Concern about a negative effect of diet soft drink consumption on energy intake arose from animal studies reporting an increased food intake and weight gain following prolonged exposure to saccharin-sweetened yogurt (Swithers & Davidson, 2008). This suggested that artificial sweeteners may “uncouple” a relationship between sweet taste and energy content, which prompted rodents to consume more food and gain weight (Swithers & Davidson, 2008). Yet, in humans there are conflicting data on artificial sweetener intake and weight status and most available data are correlational; few intervention studies have investigated the influence of energy-free artificially-sweetened beverages on energy intake regulation and body weight. Specifically, habitual intake of artificially sweetened beverages is associated with self-reported BMI, and high consumers of artificially sweetened beverages (>28 fl oz/d) were more likely to report body weight concerns such as restrained eating and body dissatisfaction (Appleton & Conner, 2001). A dose-response relationship between artificially sweetened beverage consumption and BMI change over time has also been reported; odds of becoming overweight/obese for individuals consuming >22 artificially sweetened drinks per week was almost twice that of individuals consuming no artificially sweetened beverages (Fowler et al., 2008). However, those consuming artificially sweetened beverages were more likely to be female, dieting, and overweight/obese at baseline.

In contrast, epidemiological investigations have reported that women who increased diet soft drink consumption gained less weight over a four-year period than women who decreased diet soft drink consumption (Schulze et al., 2004). In addition, replacing energy-containing beverages with artificially sweetened beverages was associated with greater weight loss (~1.6 kg) over 12 months, which is slightly less than that reported with water (Stookey et al., 2008).

In ad libitum meal studies, artificially sweetened beverage preloads (i.e. prior to the ingestion of a meal) do not appear to stimulate appetite or affect subsequent food intake (Canty & Chan, 1991; Holt et al., 2000; Rodin, 1990), and short term intervention studies incorporating artificially sweetened beverages into the usual diet have demonstrated weight loss in both overweight (Raben, Vasilaras, Moller, & Astrup, 2002) and normal weight adults (Tordoff & Alleva, 1990). Thus, although epidemiological data in this area are conflicting, existing experimental/intervention trials do not suggest that energy-free artificially sweetened beverages increase food intake or body weight. These beverages could be used as an alternative to water as a substitution for energy-containing beverages, particularly for interventions targeting weight management.

3.2. Coffee and Tea

Coffee and tea in their unaltered form contribute fluid to the diet without contributing energy. Increased coffee and tea consumption is associated with less weight gain over time in men and women; this observation is not attributed to beverage caffeine content (Lopez-Garcia et al., 2006). Adults who routinely (i.e., ≥1 time per week) consumed green, oolong or black tea for >10 years have lower body fat percentages and smaller waist circumferences than nonconsumers (Wu et al., 2003), and research has suggested that green tea in particular may play a role in weight loss and weight maintenance. Green tea contains catechins, particularly epigallocatechin gallate (EGCG), which in concentrated supplement form has been shown to increase fat oxidation (Auvichayapat et al., 2008; Dulloo et al., 1999; Venables, Hulston, Cox,

& Jeukendrup, 2008), reduce body fat (Nagao, Hase, & Tokimitsu, 2007), and increase weight loss (Auvichayapat et al., 2008). However, several cups of tea must be consumed to achieve the benefits of the catechin levels found in concentrated forms. In contrast, daily energy intake among high consumers of popular energy-containing coffee and tea drinks (i.e. lattes, espressos, café mochas, cappuccinos) is 206 kcal higher than nonconsumers (Shields, Corrales, & Metallinos-Katsaras, 2004). Thus, while there may be some benefits to consuming coffee and tea in their energy-free form, consumption of energy-containing coffee and tea drinks may increase total energy intake.

4. Energy-containing Beverages

4.1. Soft Drinks

Regular (sweetened) soft drinks are the greatest contributor of energy in the American diet (Block, 2004). A recent meta-analysis (Vartanian, Schwartz, & Brownell, 2007) reported a clear association between soft drink consumption and increased energy intake, and previous reviews have concluded that a strong association exists between sweetened soft drink consumption and risk of overweight/obesity (Malik, Schulze, & Hu, 2006). However, others suggest that dietary behaviors (i.e., food choices, dietary restraint, energy intake, beverage type and usage) and economics (i.e., poverty, food and beverage costs) contribute to obesity more than sugar-sweetened beverages (Drewnowski & Bellisle, 2007). Increased intake of soft drinks is associated with BMI (Lin, Huang, & French, 2004), weight gain and the risk of type 2 diabetes (Schulze et al., 2004), and risk factors for the metabolic syndrome (Dhingra et al., 2007). Soft drink consumers (>4 servings/wk) have higher total energy intakes and engage in less physical activity than low soft drink consumers (≤3 servings/wk) (Kvaavik, Andersen, & Klepp, 2005; Schulze et al., 2004). Longitudinal studies report that women who decrease their intake of soft drinks over a four-year period gain less weight than those who maintain or increase their soft drink intake (Schulze et al., 2004). Intervention studies indicate that consuming soft drinks for 3-weeks increases usual energy intake and body weight (Tordoff & Alleva, 1990), and although data are conflicting, some acute meal studies suggest an increase in total meal energy intake (i.e., beverage + meal) when sugar-sweetened soft drinks are consumed (see Table). Methodological differences may explain conflicting study outcomes in this area.

High fructose corn syrup (HFCS) is a primary ingredient in soft drinks, mainly because of its sweet taste, low cost and wide availability. Its potential role in the obesity epidemic has been suggested (Bray, Nielsen, & Popkin, 2004), but an expert panel assembled by The Center for Food, Nutrition, and Agricultural Policy conducted a review and concluded that HFCS consumption is not "uniquely" responsible for increasing rates of obesity (Forshee et al., 2007). Individual sweeteners (i.e., sucrose, HFCS) appear to have similar effects on intake-related hormones and energy intake (Melanson et al., 2007). Although controversy remains (Allison & Mattes, 2009; Brownell & Frieden, 2009), most research in this area suggests that energy-containing soft drink intake should be limited, regardless of sweetener type.

4.2. Juice and Juice Drinks

Fruit juices (100% juice) contain important nutrients, and are a contributor to total fruit intake (USDA). However, fruit juices contain little or no fiber, and because beverages are less satiating than solid foods (Flood-Obbagy & Rolls, 2009; R. D. Mattes, 1996), whole fruit is preferable for weight management (Popkin et al., 2006; USDA). Increased consumption of fruit juice (juice or juice drinks) compared with decreased consumption over four years is associated with weight gain, as is fruit drink intake (i.e., fruit punch, sweetened fruit-flavored drinks)(Schulze et al., 2004). Due to their minimal nutritional value and energy content, juice drink intake should be minimized (Popkin et al., 2006), and whole fruit should be encouraged rather than fruit juice due to its greater satiating ability.

4.3. Milk and Soy Beverages

Fluid milk is a major source of energy and calcium in the US diet (Cotton, Subar, Friday, & Cook, 2004). In recent years, a great deal of attention has focused upon the role of dietary calcium in weight loss. Interest in calcium arose from its role in the regulation of energy metabolism, specifically related to hormones influencing lipolysis and fatty acid synthesis (Zemel & Miller, 2004). Studies have associated a higher milk intake with less weight gain over time (Rosell, Hakansson, & Wolk, 2006), which suggests that milk consumption may be beneficial for weight management. Research has demonstrated that consumption of calcium-containing beverages promotes weight loss (Lukaszuk, Luebbers, & Gordon, 2007; Zemel & Miller, 2004), however conflicting evidence also exists (Barr et al., 2000).

Milk is rich in nutrients, however high milk consumption could increase dietary fat, cholesterol, and energy intake, and contribute to weight gain (Barr et al., 2000; Cotton et al., 2004; Hollis & Mattes, 2007). Satiety and fullness are greater after consumption of a skim milk beverage as compared to a sugar-sweetened beverage, however meal energy intake with the two beverages is not different (Harper et al., 2007; Soenen & Westerterp-Plantenga, 2007). Intervention studies (Barr et al., 2000) have demonstrated that increasing skim or 1% milk consumption by three servings per day without other intentional dietary changes leads to weight gain among adults aged 55-85 yrs, although less than would be expected based upon the additional energy provided in the milk.

Most research in this area has focused on dairy products; however, soy milk may be comparable to skim milk at facilitating weight loss (see Table). Individuals on a hypocaloric diet supplemented either with soy or skim milk lost equal amounts of weight and had similar nutrient intakes (Lukaszuk et al., 2007). Thus, consumption of either dairy or soy milk may be beneficial as part of a hypocaloric diet. Due to their energy and fat content, low-fat or non-fat options may be recommended, and appropriate reductions in other sources of energy should be encouraged to compensate for the energy content of the dairy or soy beverages.

4.4. Alcohol

Beer is among the top ten sources of energy in the US diet (Block, 2004). Although possibly controversial, the Beverage Guidance Panel (Popkin et al., 2006) categorized alcohol as an energy-containing beverage with some nutrients. Alcohol drinkers experience health benefits not seen in abstainers including smaller waist circumference (Tolstrup et al., 2008) and a lower prevalence of metabolic syndrome (Freiberg, Cabral, Heeren, Vasan, & Curtis Ellison, 2004; Rosell, De Faire, & Hellenius, 2003). Others have associated a high alcohol intake (>81 g/wk) with abdominal obesity; however, after accounting for alcoholic beverage type (beer, wine, liquor), only liquor consumption was associated with abdominal obesity (Riserus & Ingelsson, 2007). Similarly, a linear relationship between intake of spirits and BMI has been reported (see Table) (Lukasiewicz et al., 2005). Associations have also been found between a heavy alcohol intake (>30 g/day; a glass of wine represented ~10g alcohol), weight gain and obesity, but not light-moderate alcohol intake (Wannamethee & Shaper, 2003). This appears consistent with studies reporting a J-shaped relationship between total alcohol consumption and waist-to-hip ratio and BMI (Lukasiewicz et al., 2005). Conflicting results may be due to confounding factors related to alcohol intake and weight status, such as smoking, physical activity, educational level, and economic status, as well as to alcoholic beverage type (Rosell et al., 2003).

Clinical studies investigating alcohol consumption and meal energy intake have found that ad libitum alcoholic beverage consumption increased total meal energy intake as compared to soft drink consumption (Buemann, Toubro, & Astrup, 2002), and that daily energy intake was greater after consuming a 5% alcohol beer as compared to a nonalcoholic beer or cola (R. D. Mattes, 1996). Overconsumption of alcoholic beverages at a meal may be related to increased thirst due to their diuretic effect (Buemann et al., 2002), although others report that moderate alcohol consumption does not exert a diuretic effect (McDonald & Margen, 1979). A high plasma alcohol concentration may reduce dietary cognitive restraint and promote energy overconsumption (Buemann et al., 2002).

Moderate alcohol consumption may have health benefits (Goldberg, Mosca, Piano, & Fisher, 2001), including less weight gain with time (Wannamethee & Shaper, 2003) and a lower risk of abdominal obesity (Freiberg et al., 2004; Rosell et al., 2003; Tolstrup et al., 2008). Some evidence suggests more benefits of wine and beer consumption (Freiberg et al., 2004) as opposed to consumption of liquor/spirits (Lukasiewicz et al., 2005). However, as with other energy-containing beverages that appear to be additive to meal/daily energy intake, energy intake may acutely increase with alcohol ingestion. Thus, as with other energy-containing beverages that appear to be additive to meal/daily energy intake, portion control and moderation should be encouraged.

5. Conclusions

In the US, energy intake from beverages has increased dramatically in recent decades (Nielsen & Popkin, 2004). Americans are consuming more energy from soft drinks (Block, 2004) which may be replacing water and nutrient-containing beverages such as milk. Because energy-containing beverages do not promote satiety (R. D. Mattes, 1996), intake of energy-containing beverages may be an important dietary factor contributing to weight gain. In contrast, water consumption may reduce hunger and energy intake (Davy, Dennis, Dengo et al., 2008; Stookey et al., 2007; Stookey et al., 2008; Van Walleghen et al., 2007). These benefits, as well as its low cost and wide availability, suggests that increased water consumption (>1 L/day; >33.8 fl oz) and a reduced intake of energy-containing beverages (Stookey et al., 2008) may facilitate weight management. However, this has not been directly addressed beyond the acute meal setting.

A limited amount of research suggests that other energy-free beverages (i.e., diet soft drinks, coffee/tea) may facilitate weight management, particularly if substituted for energy-containing beverages (Stookey et al., 2008). While there may be health benefits to consuming milk, 100% fruit juice, and in moderation, alcoholic beverages, additional energy provided by these beverages must be compensated for by reducing food intake. A summary of research investigating beverage consumption (by category), acute energy intake and body weight is provided in the Figure. Due to the lack of long-term intervention studies, further research is warranted to determine if specific patterns of beverage consumption improves health and weight status.

There are a number of limitations to existing research which should be acknowledged. First, a conflict of interest may exist between financial sponsors of beverage research and researchers. Industry-sponsored research may be less likely to report unfavorable results compared to studies with no industry support (Lesser, Ebbeling, Goozner, Wypij, & Ludwig, 2007). Differences in effect sizes between industry-funded and non-funded research studies have also been reported (Vartanian et al., 2007). Therefore, financial disclosures should be considered when evaluating this literature. A second limitation, as mentioned previously, is the lack of randomized controlled trials. Available literature largely consists of epidemiological studies, which provide evidence of associations of beverage intake and weight status but not causal relationships, and from short-term feeding studies. Other limitations include possible confounding lifestyle behaviors by categories of beverage consumers (Duffey & Popkin, 2006; Popkin et al., 2005), and aging, which may independently influence gastric emptying and energy intake regulation (Davy, Dennis, Dengo et al., 2008; Van Walleghen et al., 2007).

Weight management practitioners may consider the recently proposed beverage intake guidelines (Popkin et al., 2006), and existing fluid intake recommendations. To maintain hydration, an AI of 3.0 L/day for men and 2.2 L/day for women (~104 fl oz and 72 fl oz, respectively) of total beverages is recommended, but no specific recommendations for water intake and weight management exist. An increase in the total beverage volume consumed is associated with greater weight loss during a hypocaloric diet (Stookey et al., 2008); therefore, water (> 1 L/day; >33.8 fl oz) and other energy-free beverages should be consumed to satisfy thirst and promote optimal hydration status, without increasing total energy intake. Solid fruits should be emphasized to meet fruit intake recommendations, and low-fat/non-fat dairy or soy products may be recommended to provide micronutrients while minimizing saturated fat and energy intake. Alcoholic beverages should be consumed in moderation, for those who wish to consume alcohol. Other energy-containing beverages (i.e., soft drinks, fruit drinks and whole milk) are not recommended for frequent consumption due to their energy content and low satiating ability, as energy provided by beverages appears additive to total energy intake. As highlighted in a recent commentary (Allison & Mattes, 2009), additional research addressing the role of beverage consumption in adult weight management is clearly needed.

6. References

Allison DB, Mattes RD. Nutritively sweetened beverage consumption and obesity: the need for solid evidence on a fluid issue. Jama 2009;301(3):318–320. [PubMed: 19155459]

Almiron-Roig E, Drewnowski A. Hunger, thirst, and energy intakes following consumption of caloric beverages. Physiol Behav 2003;79(4-5):767–773. [PubMed: 12954421]

Appleton KM, Conner MT. Body weight, body-weight concerns and eating styles in habitual heavy users and non-users of artificially sweetened beverages. Appetite 2001;37(3):225–230. [PubMed: 11895323]

Auvichayapat P, Prapochanung M, Tunkamnerdthai O, Sripanidkulchai BO, Auvichayapat N, Thinkhamrop B, et al. Effectiveness of green tea on weight reduction in obese Thais: A randomized, controlled trial. Physiol Behav 2008;93(3):486–491. [PubMed: 18006026]

Barr SI, McCarron DA, Heaney RP, Dawson-Hughes B, Berga SL, Stern JS, et al. Effects of increased consumption of fluid milk on energy and nutrient intake, body weight, and cardiovascular risk factors in healthy older adults. J Am Diet Assoc 2000;100(7):810–817. [PubMed: 10916520]

Block G. Foods contributing to energy intake in the US: data from NHANES III and NHANES 1999-2000. Journal of Food Composition and Analysis 2004;17:439–447.

Boschmann M, Steiniger J, Hille U, Tank J, Adams F, Sharma AM, et al. Water-induced thermogenesis. J Clin Endocrinol Metab 2003;88(12):6015–6019. [PubMed: 14671205]

Bray GA, Nielsen SJ, Popkin BM. Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity. Am J Clin Nutr 2004;79(4):537–543. [PubMed: 15051594]

Brown CM, Dulloo AG, Montani JP. Water-induced thermogenesis reconsidered: the effects of osmolality and water temperature on energy expenditure after drinking. J Clin Endocrinol Metab 2006;91(9):3598–3602. [PubMed: 16822824]

Brownell KD, Frieden TR. Ounces of prevention--the public policy case for taxes on sugared beverages. N Engl J Med 2009;360(18):1805–1808. [PubMed: 19357400]

Buemann B, Toubro S, Astrup A. The effect of wine or beer versus a carbonated soft drink, served at a meal, on ad libitum energy intake. Int J Obes Relat Metab Disord 2002;26(10):1367–1372. [PubMed: 12355333]

Canty DJ, Chan MM. Effects of consumption of caloric vs noncaloric sweet drinks on indices of hunger and food consumption in normal adults. Am J Clin Nutr 1991;53(5):1159–1164. [PubMed: 2021127]

Cotton PA, Subar AF, Friday JE, Cook A. Dietary sources of nutrients among US adults, 1994 to 1996. J Am Diet Assoc 2004;104(6):921–930. [PubMed: 15175590]

Davy, BM.; Dennis, EA.; Akers, J.; Dengo, AL.; Davy, KP. Increased Premeal Water Consumption is Associated With Rapid Initial Weight Loss (Abstract). Accepted for presentation at the 2008 Obesity Society Meeting; 2008. Unpublished Abstract accepted for presentation at the 2008 Obesity Society Meeting

Davy BM, Dennis EA, Dengo AL, Wilson KL, Davy KP. Water consumption reduces energy intake at a breakfast meal in obese older adults. J Am Diet Assoc 2008;108(7):1236–1239. [PubMed: 18589036]

DellaValle DM, Roe LS, Rolls BJ. Does the consumption of caloric and non-caloric beverages with a meal affect energy intake? Appetite 2005;44(2):187–193. [PubMed: 15808893]

Dhingra R, Sullivan L, Jacques PF, Wang TJ, Fox CS, Meigs JB, et al. Soft drink consumption and risk of developing cardiometabolic risk factors and the metabolic syndrome in middle-aged adults in the community. Circulation 2007;116(5):480–488. [PubMed: 17646581]

DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. Int J Obes Relat Metab Disord 2000;24(6):794–800. [PubMed: 10878689]

Drewnowski A, Bellisle F. Liquid calories, sugar, and body weight. Am J Clin Nutr 2007;85(3):651–661. [PubMed: 17344485]

Duffey KJ, Popkin BM. Adults with healthier dietary patterns have healthier beverage patterns. J Nutr 2006;136(11):2901–2907. [PubMed: 17056820]

Duffey KJ, Popkin BM. Shifts in patterns and consumption of beverages between 1965 and 2002. Obesity (Silver Spring) 2007;15(11):2739–2747. [PubMed: 18070765]

Dulloo AG, Duret C, Rohrer D, Girardier L, Mensi N, Fathi M, et al. Efficacy of a green tea extract rich in catechin polyphenols and caffeine in increasing 24-h energy expenditure and fat oxidation in humans. Am J Clin Nutr 1999;70(6):1040–1045. [PubMed: 10584049]

Flood-Obbagy JE, Rolls BJ. The effect of fruit in different forms on energy intake and satiety at a meal. Appetite 2009;52(2):416–422. [PubMed: 19110020]

Forshee RA, Storey ML, Allison DB, Glinsmann WH, Hein GL, Lineback DR, et al. A critical examination of the evidence relating high fructose corn syrup and weight gain. Crit Rev Food Sci Nutr 2007;47(6):561–582. [PubMed: 17653981]

Fowler SP, Williams K, Resendez RG, Hunt KJ, Hazuda HP, Stern MP. Fueling the obesity epidemic? Artificially sweetened beverage use and long-term weight gain. Obesity (Silver Spring) 2008;16(8):1894–1900. [PubMed: 18535548]

Freiberg MS, Cabral HJ, Heeren TC, Vasan RS, Curtis Ellison R. Alcohol consumption and the prevalence of the Metabolic Syndrome in the US.: a cross-sectional analysis of data from the Third National Health and Nutrition Examination Survey. Diabetes Care 2004;27(12):2954–2959. [PubMed: 15562213]

Goldberg IJ, Mosca L, Piano MR, Fisher EA. AHA Science Advisory: Wine and your heart: a science advisory for healthcare professionals from the Nutrition Committee, Council on Epidemiology and Prevention, and Council on Cardiovascular Nursing of the American Heart Association. Circulation 2001;103(3):472–475. [PubMed: 11157703]

Harper A, James A, Flint A, Astrup A. Increased satiety after intake of a chocolate milk drink compared with a carbonated beverage, but no difference in subsequent ad libitum lunch intake. Br J Nutr 2007;97(3):579–583. [PubMed: 17313721]

Hollis JH, Mattes RD. Effect of increased dairy consumption on appetitive ratings and food intake. Obesity (Silver Spring) 2007;15(6):1520–1526. [PubMed: 17557989]

Holt SH, Sandona N, Brand-Miller JC. The effects of sugar-free vs sugar-rich beverages on feelings of fullness and subsequent food intake. Int J Food Sci Nutr 2000;51(1):59–71. [PubMed: 10746106]

Kaplan RJ. Beverage guidance system is not evidence-based. Am J Clin Nutr 2006;84(5):1248–1249. author reply 1249-1250. [PubMed: 17093184]

Kissileff HR. Effects of physical state (liquid-solid) of foods on food intake: procedural and substantive contributions. Am J Clin Nutr 1985;42(5 Suppl):956–965. [PubMed: 4061368]

Kvaavik E, Andersen LF, Klepp KI. The stability of soft drinks intake from adolescence to adult age and the association between long-term consumption of soft drinks and lifestyle factors and body weight. Public Health Nutr 2005;8(2):149–157. [PubMed: 15877908]

Lappalainen R, Mennen L, van Weert L, Mykkanen H. Drinking water with a meal: a simple method of coping with feelings of hunger, satiety and desire to eat. Eur J Clin Nutr 1993;47(11):815–819. [PubMed: 8287852]

Lesser LI, Ebbeling CB, Goozner M, Wypij D, Ludwig DS. Relationship between funding source and conclusion among nutrition-related scientific articles. PLoS Med 2007;4(1):e5. [PubMed: 17214504]

Lin BH, Huang CL, French SA. Factors associated with women's and children's body mass indices by income status. Int J Obes Relat Metab Disord 2004;28(4):536–542. [PubMed: 14770199]

Lopez-Garcia E, van Dam RM, Rajpathak S, Willett WC, Manson JE, Hu FB. Changes in caffeine intake and long-term weight change in men and women. Am J Clin Nutr 2006;83(3):674–680. [PubMed: 16522916]

Ludwig DS, Peterson KE, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. Lancet 2001;357(9255):505–508. [PubMed: 11229668]

Lukasiewicz E, Mennen LI, Bertrais S, Arnault N, Preziosi P, Galan P, et al. Alcohol intake in relation to body mass index and waist-to-hip ratio: the importance of type of alcoholic beverage. Public Health Nutr 2005;8(3):315–320. [PubMed: 15918929]

Lukaszuk JM, Luebbers P, Gordon BA. Preliminary study: soy milk as effective as skim milk in promoting weight loss. J Am Diet Assoc 2007;107(10):1811–1814. [PubMed: 17904943]

Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. Am J Clin Nutr 2006;84(2):274–288. [PubMed: 16895873]

Mattes R. Fluid calories and energy balance: the good, the bad, and the uncertain. Physiol Behav 2006;89 (1):66–70. [PubMed: 16516935]

Mattes RD. Dietary compensation by humans for supplemental energy provided as ethanol or carbohydrate in fluids. Physiol Behav 1996;59(1):179–187. [PubMed: 8848479]

McDonald JT, Margen S. Wine versus ethanol in human nutrition. II. Fluid, sodium, and potassium balance. Am J Clin Nutr 1979;32(4):817–822. [PubMed: 433813]

Melanson KJ, Zukley L, Lowndes J, Nguyen V, Angelopoulos TJ, Rippe JM. Effects of high-fructose corn syrup and sucrose consumption on circulating glucose, insulin, leptin, and ghrelin and on appetite in normal-weight women. Nutrition 2007;23(2):103–112. [PubMed: 17234503]

Nagao T, Hase T, Tokimitsu I. A green tea extract high in catechins reduces body fat and cardiovascular risks in humans. Obesity (Silver Spring) 2007;15(6):1473–1483. [PubMed: 17557985]

Nielsen SJ, Popkin BM. Changes in beverage intake between 1977 and 2001. Am J Prev Med 2004;27 (3):205–210. [PubMed: 15450632]

Nielsen SJ, Siega-Riz AM, Popkin BM. Trends in energy intake in U.S. between 1977 and 1996: similar shifts seen across age groups. Obes Res 2002;10(5):370–378. [PubMed: 12006636]

Panel on Dietary Reference Intakes for Electrolytes and Water, Institute of Medicine. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. National Academy Press; Washington, DC: 2004.

Popkin BM, Armstrong LE, Bray GM, Caballero B, Frei B, Willett WC. A new proposed guidance system for beverage consumption in the United States. Am J Clin Nutr 2006;83(3):529–542. [PubMed: 16522898]

Popkin BM, Barclay DV, Nielsen SJ. Water and food consumption patterns of U.S. adults from 1999 to 2001. Obes Res 2005;13(12):2146–2152. [PubMed: 16421349]

Raben A, Vasilaras TH, Moller AC, Astrup A. Sucrose compared with artificial sweeteners: different effects on ad libitum food intake and body weight after 10 wk of supplementation in overweight subjects. Am J Clin Nutr 2002;76(4):721–729. [PubMed: 12324283]

Riserus U, Ingelsson E. Alcohol intake, insulin resistance, and abdominal obesity in elderly men. Obesity (Silver Spring) 2007;15(7):1766–1773. [PubMed: 17636095]

Rodin J. Comparative effects of fructose, aspartame, glucose, and water preloads on calorie and macronutrient intake. Am J Clin Nutr 1990;51(3):428–435. [PubMed: 2178391]

Rolls BJ, Bell EA, Thorwart ML. Water incorporated into a food but not served with a food decreases energy intake in lean women. Am J Clin Nutr 1999;70(4):448–455. [PubMed: 10500012]

Rolls BJ, Kim S, Fedoroff IC. Effects of drinks sweetened with sucrose or aspartame on hunger, thirst and food intake in men. Physiol Behav 1990;48(1):19–26. [PubMed: 2236270]

Rosell M, De Faire U, Hellenius ML. Low prevalence of the metabolic syndrome in wine drinkers--is it the alcohol beverage or the lifestyle? Eur J Clin Nutr 2003;57(2):227–234. [PubMed: 12571653]

Rosell M, Hakansson NN, Wolk A. Association between dairy food consumption and weight change over 9 y in 19,352 perimenopausal women. Am J Clin Nutr 2006;84(6):1481–1488. [PubMed: 17158433]

Sanigorski AM, Bell AC, Swinburn BA. Association of key foods and beverages with obesity in Australian schoolchildren. Public Health Nutr 2007;10(2):152–157. [PubMed: 17261224]

Schulze MB, Manson JE, Ludwig DS, Colditz GA, Stampfer MJ, Willett WC, et al. Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women. Jama 2004;292(8):927–934. [PubMed: 15328324]

Shields DH, Corrales KM, Metallinos-Katsaras E. Gourmet coffee beverage consumption among college women. J Am Diet Assoc 2004;104(4):650–653. [PubMed: 15054352]

Soenen S, Westerterp-Plantenga MS. No differences in satiety or energy intake after high-fructose corn syrup, sucrose, or milk preloads. Am J Clin Nutr 2007;86(6):1586–1594. [PubMed: 18065574]

Stookey JD, Constant F, Gardner CD, Popkin BM. Replacing sweetened caloric beverages with drinking water is associated with lower energy intake. Obesity (Silver Spring) 2007;15(12):3013–3022. [PubMed: 18198310]

Stookey JD, Constant F, Popkin BM, Gardner CD. Drinking Water Is Associated With Weight Loss in Overweight Dieting Women Independent of Diet and Activity. Obesity (Silver Spring). 2008

Stull AJ, Apolzan JW, Thalacker-Mercer AE, Iglay HB, Campbell WW. Liquid and solid meal replacement products differentially affect postprandial appetite and food intake in older adults. J Am Diet Assoc 2008;108(7):1226–1230. [PubMed: 18589034]

Swithers SE, Davidson TL. A role for sweet taste: calorie predictive relations in energy regulation by rats. Behav Neurosci 2008;122(1):161–173. [PubMed: 18298259]

Tieken SM, Leidy HJ, Stull AJ, Mattes RD, Schuster RA, Campbell WW. Effects of solid versus liquid meal-replacement products of similar energy content on hunger, satiety, and appetite-regulating hormones in older adults. Horm Metab Res 2007;39(5):389–394. [PubMed: 17533583]

Tolstrup JS, Halkjaer J, Heitmann BL, Tjonneland AM, Overvad K, Sorensen TI, et al. Alcohol drinking frequency in relation to subsequent changes in waist circumference. Am J Clin Nutr 2008;87(4):957–963. [PubMed: 18400719]

Tordoff MG, Alleva AM. Effect of drinking soda sweetened with aspartame or high-fructose corn syrup on food intake and body weight. Am J Clin Nutr 1990;51(6):963–969. [PubMed: 2349932]

Tsuchiya A, Almiron-Roig E, Lluch A, Guyonnet D, Drewnowski A. Higher satiety ratings following yogurt consumption relative to fruit drink or dairy fruit drink. J Am Diet Assoc 2006;106(4):550–557. [PubMed: 16567151]

USDA. Why is it important to eat fruit?. (Writer)http://www.mypyramid.gov/pyramid/fruits_why.html.

Van Walleghen EL, Orr JS, Gentile CL, Davy BM. Pre-meal water consumption reduces meal energy intake in older but not younger subjects. Obesity (Silver Spring) 2007;15(1):93–99. [PubMed: 17228036]

Vartanian LR, Schwartz MB, Brownell KD. Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. Am J Public Health 2007;97(4):667–675. [PubMed: 17329656]

Venables MC, Hulston CJ, Cox HR, Jeukendrup AE. Green tea extract ingestion, fat oxidation, and glucose tolerance in healthy humans. Am J Clin Nutr 2008;87(3):778–784. [PubMed: 18326618]

Wannamethee SG, Shaper AG. Alcohol, body weight, and weight gain in middle-aged men. Am J Clin Nutr 2003;77(5):1312–1317. [PubMed: 12716687]

Weaver C, Lupton J, King J, Go VL, Nicklas T, Pi-Sunyer FX, et al. Dietary guidelines vs beverage guidance system. Am J Clin Nutr 2006;84(5):1245–1246. author reply 1246-1248. [PubMed: 17093182]

Wolf A, Bray GA, Popkin BM. A short history of beverages and how our body treats them. Obes Rev 2008;9(2):151–164. [PubMed: 18257753]

Wu CH, Lu FH, Chang CS, Chang TC, Wang RH, Chang CJ. Relationship among habitual tea consumption, percent body fat, and body fat distribution. Obes Res 2003;11(9):1088–1095. [PubMed: 12972679]

Zemel MB, Miller SL. Dietary calcium and dairy modulation of adiposity and obesity risk. Nutr Rev 2004;62(4):125–131. [PubMed: 15141427]

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Beverage Type	Acute Energy Intake (i.e., Meal, Day)	Body Weight
Water	↓[b] ↔[c]	?
Artificially-Sweetened Beverages (energy-free)	↔	?
Coffee, Tea	?	?
Soft Drinks (energy-containing)	↑	↑
Juices, Juice Drinks	↑	?
Milk, Soy Beverages	↑	↑[b]
Alcohol	↑	?

[a] ↓ Decrease; ↑ Increase; ↔ No change; ? Unknown.

[b] Among middle aged and older adults.

[c] Among young adults.

Figure.

Summary: Influence of beverage consumption on acute energy intake and body weight[a]

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Table

Studies Investigating Energy-free and Energy-containing Beverage Consumption: Weight, Energy Intake, and Weight-Related Outcomes

Energy-Free Beverages			
Reference	**Study Population**	**Design**	**Findings**
Water			
Canty and Chan, 1991 (Canty & Chan, 1991)	n= 2; M* n= 18; F* normal weight	Experimental study, within-subjects, repeated measures; 200 ml preload (water, ASP*, SUC*, or SAC* sweetened beverage), *ad libitum* test meal.	No difference between preloads on meal EI*. Rating of desire to eat was higher 45 minutes after water preload compared to SUC preload.
Davy et al., 2008 (Davy, Dennis, Dengo et al., 2008)	n = 7; M n= 17; F overweight	Experimental study, within-subjects, repeated measures; 500 ml water preload or no beverage, *ad libitum* test meal.	Test meal EI was 74 kcals less after the water preload compared to the no preload condition.
DellaValle et al., 2005 (DellaValle et al., 2005)	n= 44; F normal weight, overweight and obese	Experimental study, within-subjects, repeated measures; 360 ml beverages (regular cola, orange juice, 1% milk, ASP cola, tap water) or no beverage consumed with an *ad libitum* meal.	Meal EI was not different in water preload vs. no beverage conditions.
Duffey and Popkin, 2006 (Duffey & Popkin, 2006)	n= 9,491; M, F	Cross sectional analysis, NHANES* 1999-2002	Water consumers ingest less energy from energy-containing beverages than soft drink consumers (10.7% vs. 24.0%); those who avoid high fat, fast foods are more likely to consume water.
Holt et al., 2000 (Holt et al., 2000)	n= 11; M normal weight	Experimental study, within-subjects, repeated measures; 375 ml preload (sugar-rich cola, ASP cola, water) before *ad libitum* consumption of a snack (chips) and lunch.	Total EI was similar across conditions.
Lappalainen et al., 1993 (Lappalainen et al., 1993)	n= 8; F normal weight	Experimental study, within-subjects, repeated measures; 400 ml water given during fixed-intake meal	Drinking water increased feelings of satiety and diminished hunger; effect was not maintained after the meal.
Murakami et al., 2008 (Murakami et al., 2008)	n= 1,136; F	Cross-sectional survey; diet-history questionnaire (150 food and beverage items)	Water intake from foods (all foods except beverages), but not beverages (sum of energy-containing beverages and energy-free beverages) was associated with lower BMI and WC.
Popkin et al., 2005 (Popkin et al., 2005)	n= 4,755; M, F	Cross-sectional analysis; NHANES 1999-2001	Total daily EI was 194 kcals less for water consumers vs. nonconsumers; water consumers also ingest fewer energy-containing beverages.
Rodin, 1990 (Rodin, 1990)	n= 12; M n= 12; F overweight and normal weight	Experimental study, within-subjects, repeated measures; 500ml preload (fructose, glucose, ASP, or plain water), *ad libitum* meal.	The water preload yielded similar meal EI to that of ASP.
Rolls et al., 1990 (Rolls et al., 1990)	n= 42; M normal weight	Experimental study, within-subjects, repeated measures; 240 ml or 480 ml preloads (ASP, SUC or water), *ad libitum* test meal.	No difference in meal EI between preloads.
Stookey et al., 2007 (Stookey et al., 2007)	n= 311; F overweight and obese	Experimental study, 24 hr recalls; Fixed effect model used for analysis	During a 12-month hypocaloric diet intervention, replacing energy-containing beverages with water was associated with decreased self-reported EI (~200 kcal/d); impact on body weight was not reported.

Energy-Free Beverages			
Reference	**Study Population**	**Design**	**Findings**
Stookey et al., 2008 (Stookey et al., 2008)	n= 173; F overweight	Experimental study, 24 hr recalls; Mixed models used for analysis (secondary analysis of above study)	Drinking ≥1 L water/day (by self-report) was associated with greater weight loss (2 kg) vs. water intake of <1 L/d, over 12 months.
Van Walleghen et al., 2007 (Van Walleghen et al., 2007)	n= 25; M n= 25; F normal weight	Experimental study, within-subjects, repeated measures; 500 ml water preload or no beverage, *ad libitum* test meal.	Test meal EI was 60 kcals lower in the water preload vs. no preload condition among older adults (60-80 yrs). No differences in meal EI between conditions among younger adults (21-35 yrs).
Energy-free Artificially Sweetened Beverages			
Appleton and Blundell, 2007 (Appleton & Blundell, 2007)	n= 20; F normal weight	Experimental study, within-subjects, repeated measures; 330 ml preload (water, energy containing, or AS* beverages), *ad-libitum* test meal.	Low consumers of AS beverages (0 ml/d) had higher intakes following a sweetened preload compared to the high consumers (>825 ml/ day).
Binkley and Golub, 2007 (Binkley & Golub, 2007)	n= 1,574; M,F	Cross-sectional; comparison of grocery purchase patterns of regular vs. diet soft drink consumers.	Diet soda consumers spend more on items deemed “nutritious” than regular soda consumers; use of diet soft drinks is not associated with increased purchase of high energy-dense foods.
Canty and Chan, 1991 (Canty & Chan, 1991)	n= 2; M n= 18; F normal weight	Experimental study, within-subjects, repeated measures; 200ml preload (water, ASP, SUC, or SAC sweetened beverage), *ad libitum* test meal.	No effect of sweetener type on meal EI.
DellaValle et al., 2005 (DellaValle et al., 2005)	n= 44; F normal weight, overweight and obese	Experimental study, within-subjects, repeated measures; 360 ml beverages (regular cola, orange juice, 1% milk, ASP cola, tap water) or no beverage consumed with an *ad libitum* meal.	Meal EI was not different in noncaloric (water, ASP cola) vs. no beverage conditions.
Fowler et al., 2008 (Fowler et al., 2008)	n=3,682; M, F	Prospective cohort, 8-yr follow-up, ~65% Mexican American	Among San Antonio Heart Study participants, self-reported consumption of AS beverages (diet soft drinks, artificially sweetened coffee and tea) at baseline was associated with increased risk of weight gain at follow-up compared with non-consumers.
Holt et al., 2000 (Holt et al., 2000)	n= 11; M normal weight	Experimental study, within-subjects, repeated measures; 375 ml preload (sugar-rich cola, ASP cola, water) before *ad libitum* consumption of a snack (chips) and lunch.	The ASP drink did not stimulate a greater appetite when compared to plain water; total EI was similar across conditions.
Monsivais et al., 2007 (Monsivais, Perrigue, & Drewnowski, 2007)	n= 19; M n= 18; F normal and overweight	Experimental study, within-subjects, repeated measures; preloads (cola sweetened with SUC, HFCS*-42 (42% fructose), HFCS-55 (55% fructose), ASP, and 1% milk), *ad libitum* meal.	Meal EI not different in AS cola vs. no beverage condition.
Raben et al., 2002 (Raben et al., 2002)	n= 6; M n= 35; F overweight	Experimental study, parallel; given food and beverages sweetened with SUC (n=21) or AS (ASP, ACE-K*, cyclamate, SAC; n=20) for 10 weeks.	No changes in EI, BW*, or FM* observed among those receiving AS.
Rodin, 1990 (Rodin, 1990)	n= 12; M n= 12; F overweight and normal weight	Experimental study, within-subjects, repeated measures; 500ml preload (fructose, glucose, ASP, or plain water), *ad libitum* meal.	The ASP drink yielded similar meal EI to that of water.
Schulze et al., 2004 (Schulze et al., 2004)	n= 51,603; F	Prospective cohort, association of sweetened beverage consumption with weight gain over a four-year period	Less weight gain among F who increased AS soft drink consumption from ≤ 1 per week to 1 ≥ per

Energy-Free Beverages			
Reference	**Study Population**	**Design**	**Findings**
			day than those decreasing AS drink consumption.
Stookey et al., 2008 (Stookey et al., 2008)	n= 173; F overweight	Experimental study, 24 hr recalls; Mixed models used for analysis	Replacement of energy-containing beverages with nonwater energy-free beverages ("diet drinks") was associated with less weight loss than increasing water consumption, over 12 months (determined by self-report).
Tordoff and Alleva, 1990 (Tordoff & Alleva, 1990)	n= 21; M n= 9; F normal weight	Experimental study, within-subjects, repeated measures; supplemented usual diet covertly with 1150 g/day of soda sweetened with ASP, HFCS, or no drink for 3 weeks each.	Lower EI and BW in ASP condition in M.
Coffee/Tea			
Lopez-Garcia et al., 2006 (Lopez-Garcia et al., 2006)	n= 1,847; M n= 39,740; F	12-yr prospective study; participants were classified into quintiles based on levels of change in caffeine, coffee and tea consumption.	Increases in tea and coffee consumption were inversely associated with weight gain independent of caffeine intake.
Wu et al., 2003 (Wu et al., 2003)	n= 569; M n= 641; F	Cross sectional study on habitual tea consumption	Habitual tea drinkers (≥1 drink/wk regularly) for >10 yrs had lower BF%*, WHR* than nonhabitual tea drinkers.

Energy-containing Beverages			
Soft-drinks			
Buemann et al., 2002 (Buemann et al., 2002)	n= 22; M normal weight	Experimental study, within-subjects, repeated measures; red wine, lager beer, or carbonated SSB* were served with an *ad libitum* meal. Beverages were supplied *ad libitum* in first condition and fixed in second.	No significant difference across beverage conditions in total EI when beverage intake was fixed. Total meal EI was lower in the soft drink and beer condition in the *ad libitum* beverage condition.
Canty and Chan, 1991 (Canty & Chan, 1991)	n= 2; M n= 18; F normal weight	Experimental study, within-subjects, repeated measures; 200ml preload (water, ASP, SUC, or SAC sweetened beverage), *ad libitum* test meal.	No effect of sweetener type on meal EI.
DellaValle et al., 2005 (DellaValle et al., 2005)	n= 44; F normal weight, overweight and obese	Experimental study, within-subjects, repeated measures; 360 ml beverages (regular cola, orange juice, 1% milk, ASP cola, tap water) or no beverage consumed with an *ad libitum* meal.	Energy-containing beverages (cola, OJ, milk) add to total meal EI. No difference in total meal EI across energy-containing beverage conditions; total meal EI ~104 kcal higher in energy-containing vs. energy-free conditions due to added beverage kcals.
Dhingra et al., 2007 (Dhingra et al., 2007)	n= 2,569; M n= 3,470; F	Prospective, 4 yrs	In middle aged adults (mean age=53 yrs), consuming >1 soft drink (diet or regular) per day increased odds of developing obesity (OR 1.31, 95% CI) as compared to those consuming <1 drink/day. Not differentiated between regular and diet soft drinks for BMI*.
Harper et al., 2007 (Harper et al., 2007)	n= 22; M normal weight	Experimental study, within-subjects, repeated measures; 500 ml preload (cola or chocolate milk), *ad libitum* lunch.	No difference between beverages on meal EI.
Holt et al., 2000 (Holt et al., 2000)	n= 11; M normal weight	Experimental study, within-subjects, repeated measures; 375 ml preload (sugar-rich cola, ASP cola, water) mornings before *ad libitum* consumption of a snack (chips) and	Total EI from the snack and lunch did not differ between preloads; total daily EI was also similar across conditions.

		lunch.	
Kvaavik et al., 2005 (Kvaavik et al., 2005)	n= 207; M n= 215; F	Longitudinal, 18-20 yr follow-up	Long-term, high consumption (>3-4/wk) of sweetened soft drinks was associated with increased EI, smoking, and decreased PA*, but not self reported BW.
Lin et al., 2004 (Lin et al., 2004)	n= 2,914; F	Cross-sectional	Soft drinks correlated positively with BMI in high-income samples (>185% poverty guidelines).
Mattes, 1996 (R. D. Mattes, 1996)	n= 8; M n= 8; F normal weight	Experimental study, within-subjects, repeated measures; 1.08L beverage (5% ethanol beer, 2.9% ethanol light beer, 0.1% ethanol no-alcohol beer, cola, carbonated water) provided with crackers and cheese; daily EI assessed with 24-hr food records	EI was greater on days energy-containing beverage (cola) were consumed as compared to water.
Melanson et al., 2007 (Melanson et al., 2007)	n= 30; F normal weight	2 day experimental study, within-subjects, repeated measures; day 1 given HFCS-55 or SUC beverage, day 2 *ad libitum* EI assessed; compared effects of sweetener on EI and related hormones.	No differences in plasma glucose, insulin, leptin, and ghrelin between conditions; No differences in EI on day 2. No “control” comparison condition.
Monsivais et al., 2007 (Monsivais et al., 2007)	n= 19; M n=18; F normal and overweight	Experimental study, within-subjects, repeated measures; 215 kcal preloads (cola sweetened with SUC, HFCS-42 (42% fructose), HFCS-55 (55% fructose), ASP, and 1% milk), *ad libitum* meal.	No differences between SUC and HFCS sweetened colas on meal EI, hunger, or satiety; meal EI higher in all energy-containing beverage conditions than no beverage and ASP beverage.
Raben et al., 2002 (Raben et al., 2002)	n= 6; M n= 35; F overweight	Experimental study, parallel; given food and beverages sweetened with SUC (n=21) or AS (ASP, ACE-K, cyclamate, SAC; n=20) for 10 weeks.	SUC group had increases in EI, BW, and FM.
Rodin, 1990 (Rodin, 1990)	n= 12; M n= 12; F normal weight and overweight	Experimental study, within-subjects; 500ml preload (fructose, glucose, ASP, or plain water), *ad libitum* meal.	Lower meal EI after fructose preload vs. other preloads.
St. Onge et al., 2004 (St-Onge et al., 2004)	n= 11; M n= 8; F normal weight and overweight	Experimental study, within-subjects repeated measures; two isocaloric (600 kcal) isovolumetric conditions: SSB* or mixed nutrient (17% Protein, 67% Carbohydrate, 16% Fat) beverages followed by energy expenditure thermic response for 7 hrs measured via indirect calorimetry.	Reduced thermogenesis with the SSB beverage vs. mixed nutrient beverage; higher satiety/fullness ratings (AUC*) with the mixed nutrient beverage as compared to the SSB following consumption.
Tordoff and Alleva, 1990 (Tordoff & Alleva, 1990)	n= 21; M n= 9; F normal weight	Experimental study, within-subjects, repeated measures; supplemented usual diet covertly with 1150 g/day of soda sweetened with ASP, HFCS, or no drink for 3 weeks each.	Higher EI and BW in HFCS conditions among M & F.
Other energy-containing beverages			
DellaValle et al., 2005 (DellaValle et al., 2005)	n= 44; F normal weight, overweight and obese	Experimental study, within-subjects, repeated measures; 360 ml beverages (regular cola, orange juice, 1% milk, ASP cola, tap water) or no beverage consumed with an *ad libitum* meal.	Orange juice added to total meal EI. Beverage intake has no effect on satiety; no difference in total meal EI across energy-containing beverage conditions; total meal EI ~104 kcal higher in energy-containing vs. energy-free conditions due to added beverage kcals.
Lin et al., 2004 (Lin et al., 2004)	n= 2,914; F	Cross-sectional	Juice drinks correlated positively with BMI in high-income samples (>185% poverty guidelines).
Schulze et al., 2004 (Schulze et al., 2004)	n= 51,603; F	Prospective cohort, association of SSB consumption with weight gain	4-yr weight gain was highest in women who increased SSB consumption from <1 per week to 1≥ per day, and lowest in woman who decreased consumption. Increased fruit punch and fruit juice consumption was also associated with greater

			weight gain vs. decreased consumption.
Soenen and Westerterp-Plantenga, 2007 (Soenen & Westerterp-Plantenga, 2007)	n= 15; M n= 15; F normal weight	Experimental study, within subjects, repeated measures; 800 ml preloads (0 kcal or 358 kcal SUC, HFCS, 1.5% milk), *ad libitum* meal.	Total EI (preload + meal) was higher with all energy-containing preloads as compared to the 0 kcal beverage preload. No effect on satiety.
Sun and Empie, 2007 (Sun & Empie, 2007)	n= 38,409; M, F	Cross-sectional; association of SSB (energy-containing soft drinks, colas, sugar sweetened fruit beverages) with BMI.	No relationship was found between obesity and SSB consumption among SSB consumers and non-consumers.
Milk			
Barr et al., 2000 (Barr et al., 2000)	n= 71; M n= 129; F normal weight and overweight, aged 55-85 yrs	Randomized; 12 weeks, two groups: skim or 1% milk supplement (three 8 oz. servings/day) or control (no supplement). Both groups maintained usual diets.	Weight gain in the milk group was 0.6 kg more than the control group.
DellaValle et al., 2005 (DellaValle et al., 2005)	n= 44; F normal weight, overweight and obese	Experimental study, within-subjects, repeated measures; 360 ml beverages (regular cola, orange juice, 1% milk, ASP cola, tap water) or no beverage consumed with an *ad libitum* meal.	Milk added to total meal EI. Beverage intake has no effect on satiety; no difference in total meal EI across energy-containing beverage conditions; total meal EI ~104 kcal higher in energy-containing vs. energy-free conditions due to added beverage kcals.
Harper et al., 2007 (Harper et al., 2007)	n= 22; M normal weight	Experimental study, within-subjects, repeated measures; 500 ml preload (cola or skim chocolate milk), *ad libitum* lunch.	Satiety and fullness were greater with milk preload compared to cola; no difference between conditions on meal EI.
Hollis and Mattes, 2007 (Hollis & Mattes, 2007)	n= 28, M n=30, F overweight and obese	Experimental study, crossover; 7 day low dairy (1 portion 2% milk, 1% chocolate milk, yogurt or cheese), 7 day washout, 7 day high dairy (3 total; 1 portion each milk, yogurt and cheese)	EI was 209 kcal/day higher in high vs. low dairy period. Increased dairy consumption may lead to weight gain.
Lukaszuk et al., 2007 (Lukaszuk et al., 2007)	n= 14; F overweight and obese	Randomized control trial; 720 ml/day soy milk or skim milk on a hypocaloric diet for 8 weeks.	No differences in weight, %BF, WC*, and FFM* between soy and skim milk groups.
Monsivais et al., 2007 (Monsivais et al., 2007)	n= 19; M n=18; F normal and overweight	Experimental study, within-subjects, repeated measures; 215 kcal preloads (cola sweetened with SUC, HFCS-42 (42% fructose), HFCS-55 (55% fructose), ASP, and 1% milk), *ad libitum* meal.	Reduced meal EI following milk beverage as compared to SUC and HFCS beverage; total (meal + beverage) EI greater in milk condition than no beverage and ASP condition.
Rosell et al., 2006 (Rosell et al., 2006)	n=19,352; F	Longitudinal, weight change over 9 yrs, association with frequencies of dairy consumption	Consistent intake of <1 serving per day of whole milk, sour milk and cheese was inversely associated with weight gain.
Soenen and Westerterp-Plantenga, 2007 (Soenen & Westerterp-Plantenga, 2007)	n= 15; M n= 15; F normal weight	Experimental study, within subjects, repeated measures; 800 ml preloads (0 kcal or 358 kcal SUC, HFCS, 1.5% milk), *ad libitum* meal.	Total EI (preload + meal) was higher after the milk preload compared to the 0 kcal preload.
Alcohol			
Buemann et al., 2002 (Buemann et al., 2002)	n= 22; M normal weight	Experimental study, within-subjects, repeated measures; red wine, lager beer, or carbonated SSB were served with an *ad libitum* meal. Beverages were supplied *ad libitum* in first condition and fixed in second.	Total meal EI was higher with wine than with beer in the *ad libitum* beverage condition. No significant meal EI difference when beverage intakes were fixed.
Freiberg et al., 2004 (Freiberg et al., 2004)	n= 3,951; M n= 4,174; F	Cross-sectional; alcohol consumption and metabolic syndrome prevalence	Mild to moderate alcohol consumption (>20 beverages/month), particularly wine and beer, is associated with lower WC and metabolic syndrome prevalence compared with non-consumers;

			strongest association with beer and wine drinkers.
Lukasiewicz et al., 2005 (Lukasiewicz et al., 2005)	n= 1,481; F n= 1,210; M	Cross-sectional; alcohol intake was assessed with 24-hr dietary recalls; association of total alcohol and specific beverages (beer, wine, spirits) with BMI and WHR.	J-shaped relationship for WHR and total alcohol consumption; BMI was positively associated with total alcohol consumption and wine in M only. Positive linear association with spirits and BMI in M & F. No relationships found with beer.
Mattes, 1996 (R. D. Mattes, 1996)	n= 8; M n= 8; F normal weight	Experimental study, within-subjects, repeated measures; 1.08L beverage (5% ethanol beer, 2.9% ethanol light beer, 0.1% ethanol no-alcohol beer, cola, carbonated water) provided with crackers and cheese; daily EI assessed with 24-hr food records	Daily EI was greater on days energy-containing beverages (beer, light beer, no-alcohol beer) were consumed as compared to water. Daily EI was also higher when the 5% beer was consumed as compared to 0.1% beer or water.
Riserus and Ingelsson, 2007 (Riserus & Ingelsson, 2007)	n= 807; M	Cross-sectional; association of self reported alcohol intake with insulin sensitivity and abdominal obesity.	High alcohol intake (>81g/wk) was associated with abdominal obesity; alcohol intake associated with WC but not BMI.
Rossell et al., 2003 (Rosell et al., 2003)	n= 1,730; M n= 1,974; F	Cross-sectional; alcohol consumption and metabolic syndrome prevalence.	Nondrinkers had higher WHR than drinkers. In F, metabolic syndrome was more common in non-drinkers than drinkers. No relationship between alcohol intake and metabolic syndrome in M.
Tolstrup et al., 2008 (Tolstrup et al., 2008)	n= 20,472; M n= 23,071; F	Prospective cohort, 5 yrs; association of drinking frequency with changes in WC.	Drinking frequency was inversely associated with changes in WC in women but not men. Nondrinkers and rare drinkers had highest odds of major increases in WC.
Wannamethee and Shaper, 2003 (Wannamethee & Shaper, 2003)	n= 7,608; M	Prospective study, 5 yrs; self reported alcohol consumption and BMI.	BMI increased significantly from the light-moderate (≤30g/d) to very heavy alcohol (>30g/d) intake group in a dose-response manner. Heavy drinking was associated with weight gain over time, but not light-moderate drinking.

*Acesulfame K, ACE-k; Area under the curve, AUC; Artificially sweetened, AS; Aspartame, ASP; Body Fat, BF; Body mass index, BMI; Body weight, BW; Energy Intake, EI; Fat-free mass, FFM; Female, F; High Fructose corn syrup, HFCS; Male, M; National Health and Nutrition Examination Survey, NHANES; Physical Activity, PA; Saccharin, SAC; Sucrose, SUC; Sugar sweetened beverages, SSB; Waist circumference, WC; Waist-to-Hip Ratio; WHR.