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To what extent have sweetened beverages contributed to the obesity epidemic?

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Abstract

Objective: A systematic literature review was conducted to determine whether sweetened beverage intake increases the risk for obesity, and the extent to which it has contributed to recent increases in energy intake and adiposity in the USA.
Design: The search included studies published between 1970 and 2010 that examined secular trends, mechanisms, observational associations and intervention outcomes. Observational and intervention studies were abstracted and systematically evaluated for quality.
Setting: Trends in obesity prevalence in the USA and studies from industrialized (developed) countries were included.
Subjects: Studies were included for all ages, genders, ethnic and socio-economic groups for which data were available.
Results: Obesity rates and sweetened beverage intake have increased in tandem in the USA. Studies consistently show that higher intake of sweetened beverages is associated with higher energy intake. Energy in liquid form is not well compensated for by reductions in the intake of other sources of energy. Well-designed observational studies consistently show a significant positive relationship between sweetened beverage intake and adiposity. More importantly, several well-conducted randomized controlled trials have shown statistically significant changes in adiposity as a result of corresponding changes in sweetened beverage intake.
Conclusions: All lines of evidence consistently support the conclusion that the consumption of sweetened beverages has contributed to the obesity epidemic. It is estimated that sweetened beverages account for at least one-fifth of the weight gained between 1977 and 2007 in the US population. Actions that are successful in reducing sweetened beverage consumption are likely to have a measurable impact on obesity.

Keywords
Sweetened beverages
Obesity
Dietary intake
Body weight

During the past 30 years, there has been a substantial increase in the prevalence of overweight and obesity† in both adults and children and among all ethnic and socio-economic groups in the USA. During this same 30-year period, studies of immigrant populations have found that subsequent generations of Americans tend to be heavier, pointing to the US environment as a likely contributing factor[1].

Findings suggest that increases in energy availability and intake have played a critical role in the increased prevalence of obesity. Between the late 1970s and 2000, the amount of energy available for human consumption in the USA increased by more than 2092 kJ (500 kcal)/d per capita, even after adjusting for estimated spoilage, cooking, plate waste and other losses[2]. Data from two national surveys of food intake over the same time period suggest a more modest, but nevertheless substantial, increase of nearly 1255 kJ (300 kcal)/d per capita (all ages combined)[3–5].

Compared to dietary data, relatively few data are available on changes over time in physical activity levels. No single survey or data set has examined activity levels over the entire time period in the USA, and therefore data must be compared from several studies using varied methodologies that examined various shorter time periods, different subsets of the population and different types of physical activity. The limited available data suggest that there have not been substantive changes in physical activity levels in the USA in recent decades[6–9]. A recent report found that adults (aged 18–50 years) in the USA and Europe currently burn about the same amount of energy on physical activity as they did 20 years ago[10]. This meta-analysis of thirteen studies involving nearly 400 subjects included only investigations that used doubly labelled water to measure energy expenditure.

† Overweight in adults is defined as having BMI ≥ 25 and $<30\,kg/m^2$; obesity in adults is defined as BMI of $\geq 30\,kg/m^2$.

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However, subjects' activity habits or weight changes may not have been representative of the general population.

Inadequate physical activity levels during this period, however, are well documented[11–13], and when combined with dramatic increases in energy supply, have likely left the US population susceptible to obesity. This susceptibility is due, in part, to the fact that an individual's energy homeostasis relies upon physiological signals both for hunger – which are very efficient – and for satiety – which, by comparison, are relatively inefficient[14].

The impact of energy intake on satiation and satiety varies with the characteristics of the food[15]. This suggests that obesity is not the result of just eating too much of everything, and that identifying which food choices are contributing most to the current obesity epidemic is imperative.

Neither children nor adults in the USA come close to meeting the guidelines for balanced dietary intake[16,17]. Only 1 % of children meet the 1995 Dietary Guidelines with regard to core, healthful food groups[16]. Sugar in liquid form accounts for almost half the total added-sugar intake in the US population[18,19] and sweetened beverages displace healthier and/or more nutrient-dense beverages like milk, 100 % fruit juice and water[20–23]. Given the correspondence between the rapid rise in obesity and a similarly rapid increase in sweetened beverage intake by all age and ethnic groups in the USA[2,20,24–27], sweetened beverages have been identified as a likely risk factor for obesity and a target for intervention. Of particular concern is the higher intake of sweetened beverages by those at most risk for obesity: African Americans, Mexican Americans and lower education and income populations[25].

The present paper examines the literature regarding the relationship between sweetened beverages* and obesity and seeks to evaluate the contribution of this factor to the obesity epidemic in the USA.

Methods

A systematic search of the PubMed Database identified studies examining the association between sweetened beverages and adiposity. The following inclusion criteria were used.

- Search limits: publication dates from January 1970 to March 2010; English; human.
- Search terms: soda; soft drinks; sweetened beverages; fruit drinks, obesity, overweight, body weight.

Abstracts identified through the search process were reviewed by the authors and trained academic research staff. Training studies, weight loss studies and studies of populations with chronic diseases were excluded. Studies had to have been conducted in a developed country and had to fall into one of the following categories.

- Secular trends: reports on the intake of sweetened beverages in the USA, to determine the extent to which changes correspond to recent increases in the prevalence of obesity.
- Mechanisms: studies that examine mechanisms that explain the relationship between sweetened beverage intake and obesity.
- Observational studies: studies that examine the relationship between adiposity† and sweetened beverage intake in free-living populations.
- Intervention trials: studies that examine the impact on adiposity of programmes designed to improve health or prevent weight gain by reducing the consumption of sweetened beverages, or that study the impact on weight of prescribed increases in sweetened beverage intake.

Meta-analyses of observational studies and intervention trials relating sweetened beverage intake to adiposity were included if they estimated effect size.

Papers that met the criteria were abstracted by the authors and/or trained research staff onto a standardized form that included information on sample size and demographics, study design and methodology, sampling strategy, statistical analyses, control variables, dependent and independent variables, design/methodological strengths and weaknesses and study results.

Each published observational study was given a quality score of plus, neutral (0) or minus using the American Dietetic Association's (ADA) Quality Criteria Checklist, based on the Agency for Healthcare Research and Quality domains for research studies[28]. The checklist includes four questions about the relevance of the results to the central question of the review and ten questions about the validity of the results using information about study design, methods of data collection and analysis. The answers to the relevance and validity questions are the basis for assigning the quality score‡.

The authors then examined the proportion of studies with a given result and quality rating to determine whether the preponderance of higher-quality studies supported an association between beverage intake and adiposity. The experimental studies were not rated, but because

* For the purposes of the present paper, when speaking in general terms, 'sweetened beverages' refers to any combination of beverages that contains added caloric sweetener. However, individual studies and data sets referred to in the present paper used variable definitions, most commonly as follows: 'sweetened beverages' – any beverage with added caloric sweetener, most commonly includes fruit-flavoured drinks and sodas and sometimes includes low-calorie drinks, sweetened teas and coffees; 'soft drinks or sodas' – caloric-sweetened carbonated beverages (sometimes includes diet drinks); 'fruit drinks' – non-carbonated fruit-flavoured drinks with added caloric sweetener including 'ades' and punches. In many cases, no definition was provided.

† For the purposes of the present paper, adiposity refers to any measure of body fat, including BMI, as well as more direct measures such as skinfold measures, bioelectrical impedance (BIA) and dual-energy X-ray absorptiometry (DXA).

‡ Specific questions within the validity categories may be found at the ADA Evidence Analysis Library website (http://www.adaevidencelibrary.com/topic.cfm?cat=1234).

they were more limited in number, their relative merits were analysed and are described in more detail. The authors' conclusions are based on both the relative number and quality of studies with a given result.

Secular trends in sweetened beverage consumption

Sweetened beverage intake and the prevalence of obesity have risen over the same time period

Although parallel trends cannot establish causation, the correspondence between the rapid rise in obesity and a simultaneous rapid increase in sweetened beverage intake and overall energy intake points to sweetened beverages as a likely contributor to the obesity epidemic in the USA[2,20,24–26]. Between 1977 and 2002, Americans on average increased their energy intake from soft drinks by 228 % and their energy intake from fruit drinks by 171 %[29] (Fig. 1).

All ethnic and age groups, including the very young, have increased their sweetened beverage consumption[20,24,25,27,29–33]; the percentage of total energy coming from sweetened beverages has more than doubled for all age groups (Fig. 2).

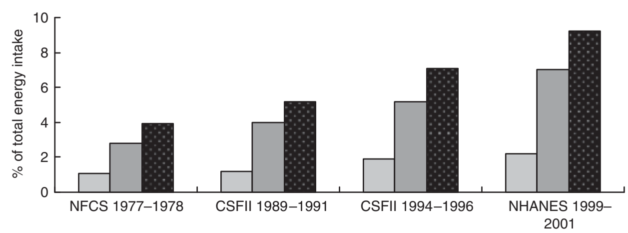

Fig. 1 Trends in US beverage consumption (▢, fruit drinks; ▢, soft drinks; ■, sweetened beverages) as a percentage of total daily energy intake (Nationwide Food Consumption Survey, 1977–1978; Continuing Survey of Food Intakes by Individuals, 1989–1991, 1994–1996; National Health and Nutrition Examination Survey, 1999–2001)[24]

Sweetened beverages contribute a substantial amount of energy to the diet of Americans

Soft drinks contribute more energy to the diet than any other single type of food or beverage; they are also the top source of liquid energy in the USA[4,34,35]. By 1999–2004, adults (aged 20–44 years) consumed 12 % of their total daily intake from sweetened beverages, while children aged 2–18 years obtained 10 % and teenagers 13 % of their energy from these drinks[25,26]. Lytle *et al.*[36] reported that as students moved from elementary to middle school, the proportion of beverages consumed as soft drinks more than tripled, while milk and 100 % fruit juice consumption declined substantially. Data collected between 1999 and 2004 revealed that boys aged 13–18 years consume the most sweetened beverages of all age and gender groups: an average of 1494 kJ (357 kcal)/d[30]. Those at most risk for obesity, including African Americans, Mexican Americans and lower education and income populations, have the highest intake of sweetened beverages[25].

Increasing portion sizes, low prices and increased availability and marketing contribute to the increased consumption of sweetened beverages

Soda and sweetened fruit drinks are among the least expensive sources of energy[37,38]. Although the consumer price index for food rose from 100 in the early 1980s to 180 by 2002, the price index for fruit and vegetables increased to 258, whereas that for soda only increased to 126[38]. Several studies have shown that price reductions and subsidies influence consumer food and

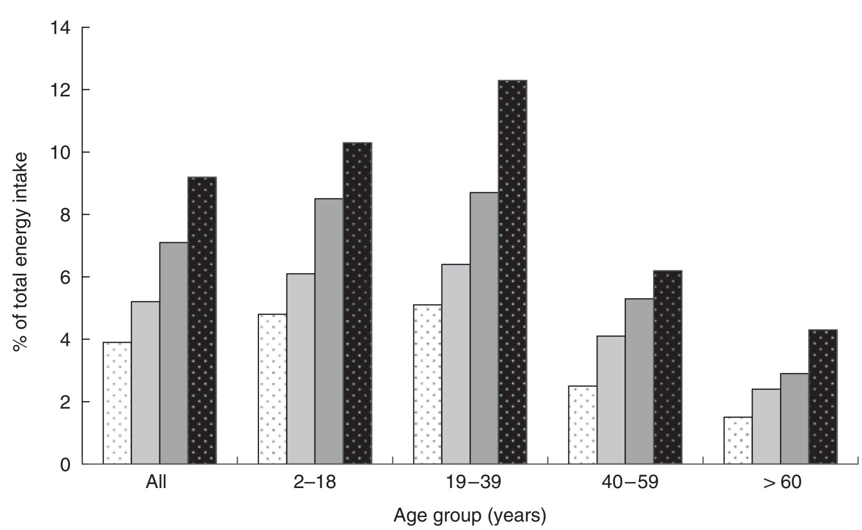

Fig. 2 Trends in US sweetened beverage consumption by age as a percentage of total daily energy intake (▢ Nationwide Food Consumption Survey, 1977–1978; Continuing Survey of Food Intakes by Individuals, ▢ 1989–1991, ▢ 1994–1996; ■ National Health and Nutrition Examination Survey 1999–2001)[24]

beverage purchases[39–44]. The lower-cost beverages are also most consistently associated with weight gain[37].

Sweetened beverage portion sizes have grown from an average serving size of 192 ml/368 kJ (6·5 fl oz/88 kcal) in the 1950s, to 355 ml/669 kJ (12 fl oz/160 kcal) and 591 ml/1113 kJ (20 fl oz/266 kcal) today[26,45]. Between 1977 and 1996, the average soda portion size nearly doubled, from 384 ml (13 fl oz) to nearly 591 ml (20 fl oz)[45].

Sweetened beverages are heavily promoted on television, websites, games and product placement agreements. In 2000, for example, the soft drink industry spent over $US700 million on advertising alone, up from $US381 million in 1986[26,46,47]. The industry's continued willingness to invest heavily in marketing suggests its efficacy in encouraging consumer purchases.

Mechanisms explaining the relationship between sweetened beverage intake and excess weight gain

Energy in liquid form is not well regulated and therefore may lead to weight gain

Research suggests that individuals do not self-regulate energy from beverages as well as energy from solid foods. Mattes[48] estimated from a meta-analysis of over forty studies that, on average, 64 % of food energy from solid foods is offset by subsequent downward adjustment in energy consumed, while only 9 % of liquid energy is compensated for by changes in energy intake. Poor compensation for energy provided in liquid form has been documented by testing a variety of beverages with carbohydrate, fat, protein or energy density of the solids and liquids matched. Clear liquid sources of energy appear to have a lower satiety value than more viscous fluids[49]. In addition, adding sweetened drinks to adults' diets has been shown to result in increased self-selected daily energy consumption[47–54]. In both short-term and longer-term trials, individuals appear to adjust their intakes of other foods only modestly to compensate for energy consumed in liquid form.

Several mechanisms responsible for this incomplete compensation for liquid sources of energy have been proposed[48,51]. As they are typically quickly consumed and rapidly absorbed by the gastrointestinal tract, beverages may not stimulate satiety signals to the same extent as solids. Furthermore, fluids may not be as effective in stimulating insulin release, one of the physiological signals for energy balance[55].

Sweetened beverage intake is consistently associated with higher energy intake

Higher consumption of sweetened beverages is consistently associated with higher total energy consumption[21,23,56,57]. Adolescents drinking an average of 236 ml (8 fl oz) or more of soda (non-diet) consumed almost 837 kJ (200 kcal) more total energy every day than those drinking other types of beverages[21]. Children who consumed the largest amounts of sweetened drinks took in 1381 kJ (330 kcal) more daily energy than did children with the lowest intake[57]. In a comparison of intakes measured on two non-consecutive days, children and adolescents' total energy intake was 444 kJ (106 kcal) higher for each additional serving (236 ml (8 fl oz)) of sugar-sweetened beverage consumed. Wang *et al.*[58] estimated that total energy intake would be reduced on average by 984 kJ (235 kcal)/d if all sugar-sweetened beverages consumed by 2–19-year-olds were replaced with water. Finally, a recent meta-analysis found that all but two of twenty-one studies (cross-sectional, longitudinal and experimental) showed increased daily energy consumption associated with increased sweetened beverage intake[23]. These increases in energy intake without an increase in energy expenditure will inevitably result in weight gain.

Observational studies examining the relationship between sweetened beverage intake and adiposity

Numerous well-designed observational studies have found positive associations between sweetened beverage intake and obesity or adiposity

Fifty-six observational studies were identified that examined the association between sweetened beverage intake and adiposity[2,31,59–109]*. Twenty-four were longitudinal[59–82] (i.e. following the same group of people over time to see whether those with higher sweetened beverage intake gained more weight). Sixteen[59,61,62,64,66–68,70–72,74–76,78,81,82] of the longitudinal studies reported a statistically significant positive association and eight reported no significant association between one or more categories of sweetened beverage intake and a measure of adiposity. Twelve of the sixteen longitudinal studies[59,62,64,66–68,70–72,75,76,81,82] that found a positive association received the highest quality 'plus' rating, compared to only three of the eight studies that did not detect a significant association. Therefore, 67 % of the total and 75 % of the highest-quality studies reported a significantly positive association between sweetened beverage intake and adiposity.

Thirty-two cross-sectional analyses examined the association between sweetened beverage intake and adiposity at one point in time[2,31,59,67,75,83–109]. Eight were cross-sectional studies that included subjects from nationally representative US samples[2,83–89]. Three of the six nationally representative studies of children found statistically significant positive associations between sweetened beverage

* Adiposity outcome variables were defined in different ways in these studies. Some studies conducted several analyses using different outcome variables. BMI was most commonly used as either a continuous or categorical variable. DXA, BIA or skinfold measures were used in some studies.

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intake and adiposity[2,83,86]. All three received the highest quality rating, whereas only one of the three that did not find a significant association received the highest quality rating. Two of the studies that did not detect a significant association were conducted by the same author and were funded by the beverage industry[84,85]. Therefore, half of the total and 75 % of the highest-quality nationally representative cross-sectional studies in children found a statistically significant positive association between sweetened beverage intake and adiposity.

Only two of the nationally representative studies included adults[88,89]. Both received a neutral quality rating; one found a significant positive association between sweetened beverage intake and adiposity[88].

Seventeen of the other (not US nationally representative) observational studies examined the cross-sectional relationship between some type of sweetened beverage intake and adiposity among children[31,59,67,75,90–102]. Twelve reported a statistically significant positive association between sweetened beverage intake and some measure of adiposity[31,59,67,75,91–93,95,97–100,102]; four found no significant association[90,94,96,101]; and one found a significant negative association[99]. Seven of the studies that reported a significant positive association and two of those that reported no significant association received the highest (plus) quality rating. The study that reported a negative association received a neutral quality rating. Thus, 63 % of the total studies and 83 % of the highest-quality studies with cross-sectional analyses of children found a significant positive association between sweetened beverage consumption and adiposity.

Seven (not US nationally representative) studies with cross-sectional analyses included adults[103–109]. Six reported positive associations[103–107,109] and one reported no statistically significant association[108] between sweetened beverage intake and adiposity. Four of the six studies that found a positive association and the one study that reported no significant association received the highest quality rating[104,105,107,109]. Therefore, 86 % of the total and 80 % of the highest-quality studies with cross-sectional analyses of adults reported a statistically significant positive association between sweetened beverage intake and adiposity.

In sum, the majority of longitudinal studies, half of the US nationally representative cross-sectional studies and the majority of other studies with cross-sectional analyses reported a statistically significant association between some type of sweetened beverage intake and adiposity. Of those studies that received the highest quality 'plus' rating, from 75 % to 80 % (depending on the type of study) reported such an association. Only one of the observational studies found a significant *negative* association between adiposity and any type of sweetened beverage intake and most of the non-significant associations trended in the positive direction.

Intervention trials examining the impact of changes in sweetened beverage intake on body weight

Findings from studies of interventions to reduce sweetened beverage intake suggest a causal association between sweetened beverage intake and weight gain

Five intervention trials were identified that evaluated the relationship between sweetened beverage consumption and body weight in children aged 6–18 years[110–114]. All were successful in reducing sweetened beverage intake compared with control groups. The two studies with stronger designs[111,112] found statistically significant reductions in adiposity or BMI among subjects compared with controls, whereas two studies of weaker (non-randomized) design found that the observed trends towards lower adiposity were not significant[110,114]. A third study of weaker design found that BMI *Z*-scores increased significantly in the comparison group, but not in the intervention group[113].

Two multi-component studies, the Zuni Diabetes Prevention Program[114] and the Girls' Health Enrichment Multi-site Study (GEMS)[110], included beverage consumption as just one of several intervention components. Neither found a statistically significant relationship between their intervention and BMI change, but neither examined the independent effect of change in sweetened beverage consumption. Furthermore, the Zuni study lacked a true control group and limitations in the sample size and length of the GEMS intervention may have contributed to its lack of significant findings. The absence of significant findings from these two studies is thus neither surprising nor definitive.

Two of the three studies that found significant decreases in body weight from reductions in sweetened beverage consumption were stronger in design. Both were randomized controlled trials examining the independent effect of reducing sweetened beverage intake and were powered to detect changes in physical measures. One, a home-based intervention of 13–18-year-olds, involved counselling and weekly deliveries of non-caloric beverages[111]. Subjects experienced lower increases in BMI relative to controls, but this difference was not significant. There was, however, a statistically significant reduction in BMI among the heaviest subjects (upper tertile of baseline BMI), who reduced their BMI by 0·63 points, while the control group increased their BMI by 0·12 points.

The Christchurch Obesity Prevention Project in Schools focused exclusively on discouraging the consumption of carbonated beverages[112]. Four educational sessions were delivered over a 1-year period to students aged 7–11 years. Findings showed a statistically significant reduction in the percentage of children who stayed overweight in the intervention group as compared to an increase in the percentage of children who became overweight in the control group.

The third study, an evaluation of a naturalistic experiment, that reported a significant impact on BMI was weaker in design[113]. It compared students at elementary schools that had *v.* had not adopted policies providing nutritious food choices and physical activity. The schools were not randomly assigned to these groups. Although this was a multi-component study, the only dietary variable that changed significantly in the intervention group was sweetened beverage intake; physical activity did not appear to change.

Findings from experimental studies designed to increase sweetened beverage intake also suggest a causal relationship between sweetened beverage intake and weight gain

In one cross-over study, thirty normal-weight adults were given artificially sweetened soda, soda sweetened with high-fructose corn syrup or no soda supplementation over successive 3-week periods[50]. The regular soda provided the equivalent of four to five 330 ml (3–4 12 fl oz) cans each day. Participants were not told which type of soda they were given. When consuming regular soda, participants increased their energy intake by 13 % and gained an average of 0·7 kg (1·04 lbs), gains that were significant compared with the other conditions. Another cross-over trial tested the adjustments in intake over 4-week periods of supplementation with 1879 kJ (450 kcal)/d in either a solid (jelly beans) or liquid (soda) form[51]. Weight significantly increased when energy was provided in liquid compared with solid form. Compensation for the additional energy provided as a liquid averaged only 17 %.

A randomized controlled trial of forty-one overweight adults followed for 10 weeks provided either sucrose (3347 kJ (800 kcal)/d) or artificial sweeteners primarily in the form of soft drinks and fruit drinks[52]. The sucrose group increased its total energy intake by 1615 kJ (386 kcal)/d and gained 1·6 kg (3·5 lbs), whereas those given diet beverages decreased their total energy intake by 439 kJ (105 kcal)/d and lost 1 kg (2·2 lbs) – a significant difference between the groups of over 0·2 kg (0·5 lb)/week. In a 4-week trial of 133 women involving sucrose *v.* artificially sweetened beverages, those provided 1799 kJ (430 kcal)/d in the form of sucrose-sweetened drinks consumed an extra 795 kJ (190 kcal) total daily[54]. In both of these studies, the subjects decreased their usual intake by an amount equal to only half of the liquid energy they were given.

In summary, all four experimental studies found that increases in sweetened beverage intake resulted in significant increases in both energy intake and weight.

Meta-analyses that determined effect size

Two meta-analyses were identified that examine the magnitude of the effect of sweetened beverages on body weight. Combining thirty-three cross-sectional, longitudinal observational and intervention studies of adults and children, Vartanian *et al.*[115] used a standardized measure to calculate a statistically significant effect size equivalent to a 0·08 SD change in BMI for each SD change in energy from sweetened beverages. Larger effect sizes were observed for intervention trials, studies involving adults, studies focusing on soft drinks and studies not funded by the beverage industry. Based on the calculated associations of sweetened beverage intake with increased energy intake, decreased intake of milk, calcium and other nutrients, increased body weight and health problems such as type 2 diabetes, the authors concluded that recommendations to reduce soft drink consumption were clearly supported by science.

Forshee *et al.*[116] analysed ten longitudinal and intervention studies of children and adolescents. The maximum estimated effect size of 0·02 units of BMI change for each daily serving change in sweetened beverage consumption was not significantly different from zero. Given the variable length of the studies, it is not possible to translate this effect size into anticipated weight gain. The authors conclude that reducing the consumption of sweetened beverages would not have a measurable impact on BMI among youth. Of note, this meta-analysis was conducted by authors who received funding from the American Beverage Association.

A letter to the editor written by Malik *et al.*[117] criticized this meta-analysis for failing to weight studies appropriately and failing to exclude studies of weaker design. Both authors conducted the analysis again; Forshee *et al.*[118] only corrected the weighting error, whereas Malik *et al.* corrected for all the weaknesses they had identified. Forshee's revised analysis produced an effect size of 0·03 unit change in BMI per 355 ml (12 fl oz) of soda/d over the study time period (which varied); Malik *et al.*[119] reported a statistically significant effect size of 0·08 unit change in BMI per 355 ml (12 fl oz) of soda.

Contribution of sweetened beverages to increases in energy consumption in the USA

According to data from national surveys of dietary intake among individuals 2 years old and above, per capita energy intake increased from 7489 kJ (1790 kcal)/d in 1977–1978 to 11 213 kJ (2068 kcal)/d in 1999–2001[24], an increase of 1163 kJ (278 kcal)/d (Table 1). Over the same time period, per capita energy from sweetened beverages increased from 293 to 795 kJ (70–190 kcal)/d, an increase of 502 kJ (120 kcal)/d. Therefore, the increase in these sweetened beverages is equivalent to 43 % of the increase in energy consumption.

Given that physical activity levels have not increased substantially in recent decades[6–10], the increase in per capita energy intake during this period was likely to have been in excess of average energy needs and therefore to have contributed to excess weight gain in the US population. Although some of the increase in energy from sweetened

Table 1 Proportion of increase in total energy intake from sweetened beverages, 1977–2001

	1977–1978	1999–2001	Unadjusted difference	Difference adjusted for compensatory intake
Total kJ (kcal)/d per capita	7489 (1790)	8653 (2068)	1164 (278)	N/A
kJ (kcal)/d per capita from sweetened beverages	293 (70)	795 (190)	501 (120)	251 (60)
Percentage of increase in total energy intake from sweetened beverages			43	22

N/A, not applicable.
Sources: Nationwide Food Consumption Survey, 1977–1978; National Health and Nutrition Examination Survey, 1999–2001[24].

beverages may have been compensated for by a decrease in other foods or beverages, the available evidence suggests that this compensation is incomplete and is unlikely to be higher than 50 %[48,50–52,54]. Even if compensation as high as 50 % did occur, sweetened beverages would still have accounted for close to one-fifth of the net weight gained in the USA between 1977–1978 and 1999–2001, when obesity rates were increasing most rapidly.

Discussion and conclusion

All five categories of evidence examined (secular trends, mechanisms, observational studies, intervention trials and meta-analyses) provide support for the hypothesis that the intake of sweetened beverages increases the risk of overweight. The population-wide increase in the intake of sweetened beverages in the USA corresponds with increases in energy intake and obesity. Studies show that energy intake from sugar in liquid form is not well compensated for by reductions in subsequent intake and that sweetened beverage intake is consistently associated with higher energy intake.

The majority of observational studies, including the more conclusive longitudinal studies, and those of more rigorous design and higher quality in every category (cross-sectional, longitudinal, nationally representative, adults and children) show that sweetened beverage intake is significantly associated with greater adiposity. Only one study reported a significant negative association between any type of sweetened beverage intake and adiposity among any age or ethnic group.

Most importantly, two randomized controlled trials showed that successful reduction of sweetened beverage intake resulted in reductions in adiposity among children. Similarly, four trials to increase intake of sweetened beverages consistently showed weight gain among free-living adults. Two additional trials that failed to detect a significant impact on adiposity were less appropriately designed to address this hypothesis.

Although the two meta-analyses examined initially arrived at different conclusions, the more comprehensive and rigorous analysis did report a significant effect size. A re-analysis by another group of the second study (which initially yielded insignificant results) addressed several methodological issues and produced significant results similar in magnitude to the first. Furthermore, a simple analysis of national (US) dietary intake data found that the increase in sweetened beverage intake accounted for 43 % of the per capita increase in total energy intake and therefore most likely contributed to at least one-fifth of the weight gained over the time period when obesity rates were increasing most rapidly.

While more studies are warranted – particularly long-term, randomized controlled trials – the currently available evidence is extensive and consistently supports the hypothesis that sweetened beverage intake is a risk factor for the development of obesity and has made a substantive contribution to the obesity epidemic experienced in the USA in recent decades.

Sweetened beverages are an especially promising focus for efforts to prevent and reduce obesity for two reasons: (i) the evidence supporting the association between sweetened beverage intake and excess weight is stronger than for any other single type of food or beverage[20]; and (ii) sweetened beverages provide no nutritional benefit other than energy and water. One simple dietary change – reducing the consumption of sweetened sodas – could have a measurable impact on obesity without any negative dietary consequences.

Although educational efforts to reduce sweetened beverage intake are an important element of any strategy to reduce intake[111,112], it is well recognized that the increases in obesity in recent decades are most likely the result of environmental and policy influences[120,121]. Given that increasing portion sizes, low prices and increased availability and marketing have most likely contributed to the increased consumption of sweetened beverages[26,37–47], efforts to reduce sweetened beverage intake would be well advised to focus on these factors.

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