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REVIEW OF RESEARCH

EFFECTS OF SOFT DRINK CONSUMPTION ON NUTRITION AND HEALTH

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ABSTRACT

Soft drink consumption has become a highly visible and controversial public health and public policy issue. Soft drinks are viewed by many as a major contributor to obesity and related health problems and have consequently been targeted as a means to help curtail the rising prevalence of obesity, particularly among children.In a meta-analysis of 88 studies, we examined the association between soft drink consumption and nutrition and health outcomes.

KEYWORD : *Nutrition Meta-Analysis & Soft Drink*

INTRODUCTION

Soft drinks have been banned from schools in Britain and France, and in the United States, school systems as large as those in Los Angeles, Philadelphia, and Miami have banned or severely limited soft drink sales. Many US states have considered statewide bans or limits on soft drink sales in schools, with California passing such legislation in 2005. A key question is whether actions taken to decrease soft drink consumption are warranted given the available science and whether decreasing population consumption of soft drinks would benefit public health.

The issue is not new. In 1942 the American Medical Association mentioned soft drinks specifically in a strong recommendation to limit intake of added sugar.1 At that time, annual US production of carbonated soft drinks was 90 8-oz (240-mL) servings per person; by 2000 this number had risen to more than 600 servings.2 In the intervening years, controversy arose over several fundamental concerns: whether these beverages lead to energy overconsumption; whether they displace other foods and beverages and, hence, nutrients; whether they contribute to diseases such as obesity and diabetes; and whether soft drink marketing practices represent commercial exploitation of children.3–5

METHODS

We focused on research investigating the effects of sugar-sweetened beverages; diet and artificially sweetened beverages are noted only in certain cases for comparison purposes. We conducted a computer search through MEDLINE and PsycINFO using the key terms “soft drink,” “soda,” and “sweetened beverage.” We identified articles that assessed the association of soft drink consumption with 4 primary outcomes (energy intake, body weight, milk intake, and calcium intake) and 2 secondary outcomes (nutrition and health). We identified additional articles by searching each article's reference section and the Web of Science database. Finally, we contacted the authors of each included article with a request for unpublished or in-press work, and we asked each author to forward our request to other researchers who might have relevant work. Our searches yielded a total of 88 articles that were included in the present analysis.

There is a great deal of variability in research methods in this literature. Studies vary in their design (i.e., cross-sectional, longitudinal, or experimental studies), sample characteristics (e.g., male vs female, adults vs children), and operational definitions of independent and dependent variables. Because such heterogeneity of research methods is likely to produce heterogeneity of effect sizes across studies (an effect size represents the magnitude of the relationship between 2 variables), we took 2 steps to assess the impact of research method on outcome.

Initially, for each primary outcome (energy intake, body weight, milk intake, and calcium intake), we assessed the degree of heterogeneity of effect sizes by testing the significance of the Q statistic, which is the sum of the squared deviations of each effect size from the overall weighted mean effect size. We did not assess the degree of heterogeneity for secondary outcomes (nutrition and health) because there were relatively few studies in these domains. Our analysis of primary outcomes revealed a significant degree of heterogeneity of effect sizes in each case, and thus we separated the studies according to research design. This procedure reduces the likelihood of aggregating effect-size estimates across heterogeneous studies. Moreover, some research designs are viewed as more powerful than others. Cross-sectional studies represent the weakest design, because such studies cannot determine causality. Longitudinal designs are considered stronger, but experimental designs are the strongest test of causal relationships. Thus, separating studies according to type of design allowed us to examine effect magnitudes as a function of strength of research design.

We further explored variability in effect sizes by examining a number of potential moderator variables, including (1) population studied (children and adolescents vs adults), (2) gender of participants (only male, only female, or male and female combined), (3) type of beverage (sugar-sweetened carbonated soft drinks vs a mix of sugar-sweetened and diet beverages), (4) whether the reported results were adjusted for covariates (e.g., age, gender, ethnicity, activity level), (5) assessment method (self-reports vs observations or measurements), and (6) presence or absence of food industry funding. A study was coded as "industry funded" if the authors acknowledged support from food companies, beverage companies, or trade associations. Articles that did not report a funding source or cited support from other sources (e.g., pharmaceutical industry, university, foundation, or government grants) were coded as "non–industry funded."

We calculated average effect sizes (*r* values) using Comprehensive Meta-Analysis version x2 (Biostat, Englewood, NJ). In most cases, we entered data in the form in which they appeared in each individual study, including group means and standard deviations, correlation coefficients, *t* values, *P* values, and odds ratios and confidence intervals. In certain cases, it was necessary to manually calculate effect sizes. For example, when means for more than 2 groups were presented (e.g., low, moderate, and high soft drink consumption), we used the formulas for 1-way contrasts described by Rosenthal et al.[6] In other cases, odds ratios were reported with uneven confidence intervals (as a result of rounding), and effect sizes were calculated directly from the odds ratio according to the method described by Chinn.[7]

When data from different subgroups were presented separately (e.g., data for male and female participants were presented independently), we calculated effect sizes separately for each subgroup. In the case of studies that reported multiple measures of a particular construct (e.g., both body weight and body mass index [BMI]), we computed the average effect size of the reported measures. When there was extraordinary variability in sample sizes across studies, we employed the conservative approach of limiting the sample size of the largest study in a particular domain (e.g., cross-sectional studies of energy intake) to the maximum sample size of the other studies in that domain. This approach ensured that the calculated average effect size would not be dominated by a single study. We considered an effect size of 0.10 or less as small, an effect size of 0.25 as medium, and an effect size of 0.40 or above as large.[8]

To assess the presence of publication bias, we computed a "fail-safe N" for each of the main outcomes; this value is an estimate of the number of unretrieved or unpublished studies with null results that would be required to render the observed effect non-significant. Rosenthal9 suggested that a fail-safe N greater than $5k + 10$ (with k being the number of studies included in the analysis) indicates a robust effect; in the present analyses, each fail-safe N far exceeded Rosenthal's recommendation, suggesting a low probability of publication bias.

RESULTS

Soft Drink Consumption and Energy Intake

The overall effect size (*r*) across all studies for the relation between soft drink consumption and energy intake was 0.16 ($P < .001$, $Q_{46} = 715.46$, fail-safe N = 9726). Because there was a significant degree of heterogeneity among the effect sizes, we separated studies according to type of research design. Effect sizes for soft drink consumption and energy intake are shown in Table 1 ⊫.

Of the 12 cross-sectional studies examining the relation between soft drink consumption and energy intake, 10 reported a significant positive association, 1 reported mixed results, and 1 reported no statistically significant effect. Two studies showed that the increase in energy intake associated with soft drink consumption was greater than what could be explained by consumption of the beverages alone, suggesting that such beverages might stimulate appetite or suppress satiety, perhaps because of a high glycemic index (foods with a high glycemic index produce a rapid rise in blood sugar). The average effect size of the association between soft drink consumption and energy intake across all cross-sectional studies was 0.13 ($P < .001$; $Q_{15} = 433.67$, $P < .001$).

The 5 longitudinal studies that we identified all reported positive associations between soft drink consumption and overall energy intake. The average effect size for these studies was 0.24 ($P < .001$; $Q_6 = 109.11$, $P < .001$).

Four long-term experimental studies in which participants consumed soft drinks for between 3 and 10 weeks showed that individuals failed to compensate for the extra energy consumed in the form of sugar-sweetened beverages in that they did not reduce the rest of their food energy intake, resulting in a greater total daily energy intake. One study revealed that participants consumed 17% more energy than in their typical diet even after the energy from the soft drinks they consumed had been taken into account, suggesting again that soft drinks may influence other aspects of dietary intake. The average effect size was 0.30 ($P < .001$; $Q_4 = 2.37$, $P = .667$). Because the Q statistic was not statistically significant, we did not investigate moderators for long-term experimental studies.

Findings from short-term experimental studies (i.e., those examining energy intake over the course of a subsequent meal or a single day) were mixed. Of 12 studies, 5 reported that individuals who consumed soft drinks consequently took in a greater amount of total energy (food energy plus beverage energy) than did those who consumed water. One study also revealed higher-than-expected energy intakes among participants given the energy they consumed from soft drinks. By contrast, 5 other studies reported that participants compensated at a subsequent meal for energy consumed from beverages. Still others reported mixed results, depending, for example, on how long before lunch participants consumed soft drinks. The average effect size for short-term experimental studies was 0.21 ($P < .001$; $Q_{18} = 37.92$, $P = .004$).

These results, taken together, provide clear and consistent evidence that people do not compensate for the added energy they consume in soft drinks by reducing their intake of other foods, resulting in increased total energy intakes. Not only do people fail to compensate for the energy consumed in soft drinks, but there is also some evidence that the increase in energy intake associated with soft drink consumption is even greater than what can be accounted for by the beverages alone, suggesting that food energy intake is also higher. The largest effect sizes were observed in long-term experimental studies, followed by short-term experimental and longitudinal studies. The smallest effects were found in cross-sectional studies. Further testing of moderators revealed significantly larger effect sizes among (1) women,

(2) adults, (3) studies focusing on sugar-sweetened soft drinks, and (4) studies not funded by the food industry (Table 1).

Soft Drink Consumption and Body Weight

Research evaluating the relationship between soft drink consumption and body weight is complicated by the fact that researchers operationalize body weight in a number of different ways, even within the same study. When multiple measures of weight were provided in a single study, we calculated the average effect size across those measures. The overall effect size for studies examining the link between soft drink consumption and body weight was 0.08 ($P < .001$; $Q_{47} = 337.73$, $P < .001$, fail-safe N = 3173). Because there was a significant degree of effect size heterogeneity,

Soft Drink Consumption and Milk and Calcium Intake

The overall effect size for milk intake was −0.12 ($P < .001$, $Q_{33} = 300.43$, $P < .001$, fail-safe N = 4048). The overall effect size for calcium intake was −0.04 ($P < .001$; $Q_{28} = 368.65$, $P < .001$, fail-safe N = 418). Effect sizes for soft drink consumption and milk and calcium intake are shown in Tables 3 and 4, respectively.

Soft Drink Consumption and Nutrient Intake

Soft drink consumption also has been examined in relation to a variety of other foods, macronutrients, and micronutrients. In the case of many of these outcomes, there were only a small number of studies (and sometimes only a single study). We therefore aggregated effect sizes across all studies without examining the impact of research design or any other potential moderator variables. Thus, these aggregated effects should be interpreted with caution. A complete list of the nutritional variables investigated is available from the authors.

Soft Drink Consumption and Health Outcomes

A number of studies examined links between soft drink consumption and various health outcomes. We report average effect sizes only when there was more than a single study for a particular outcome.

Perhaps the most striking link between soft drink consumption and health outcomes was the prospective evidence obtained for type 2 diabetes. In a study of 91249 women followed for 8 years, those who consumed 1 or more servings of soft drink per day were twice as likely as those who consumed less than 1 serving per month to develop diabetes over the course of the study.17 These effects were only slightly attenuated when various potential confounds, including BMI and energy intake, were controlled. When diet soft drinks replaced sugar-sweetened soft drinks in the analysis, the increased risk was no longer present, suggesting that the risk was specific to sugar-sweetened soft drinks.

DISCUSSION

Intake of soft drinks and added sugars, particularly high fructose corn syrup, has increased coincident with rising body weights and energy intakes in the population of the United States. Yearly US per capita consumption of nondiet soft drinks rose 86% between 1970 and 1997 alone (22 gal [83.6 L] vs 41 gal). The prevalence of obesity increased 112% during that approximate time. US per capita energy consumption from added sugar rose from 984 kJ (235 kcal) per day in 1977 through 1978 to 1331 kJ (318 kcal) in 1994 through 1996, with soft drinks contributing far more to the total (440 kJ [105 kcal]) than foods such as fruit drinks (130 kJ [31 kcal]) and desserts (251 kJ [60 kcal]).

Although informative, the data just described represent only broad correlations. A true test of links between an environmental agent such as soft drinks and various health outcomes requires a robust literature with studies involving different methods, populations, and outcomes, but most important is a critical mass of studies with strong methods and sufficient sample sizes. These conditions now exist, and several clear conclusions are apparent.

One of the most consistent and powerful findings is the link between soft drink intake and increased energy consumption. Fully 10 of 12 cross-sectional studies, 5 of 5 longitudinal studies, and all 4 of the long-term experimental studies examined showed that energy intake rises when soft drink consumption increases. The effect sizes for these studies, respectively, were 0.13, 0.24, and 0.30.

The available literature also supports the observation that people do not adequately compensate for the added energy they consume in soft drinks with their intake of other foods and consequently increase their intake of sugar and total energy. Noteworthy are findings from several studies that soft drink intake is associated with a higher level of energy consumption than can be accounted for by the soft drinks themselves. These findings raise the possibility that soft drinks increase hunger, decrease satiety, or simply calibrate people to a high level of sweetness that generalizes to preferences in other foods.

CONCLUSIONS

Available data indicate a clear and consistent association between soft drink consumption and increased energy intake. Given the multiple sources of energy in a typical diet, it is noteworthy that a single source of energy can have such a substantial impact on total energy intake. This finding alone suggests that it would be prudent to recommend population decreases in soft drink consumption. The fact that soft drinks offer energy with little accompanying nutrition, displace other nutrient sources, and are linked to several key health conditions such as diabetes is further impetus to recommend a reduction in soft drink consumption.

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