Editorial

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Are sugar-sweetened beverages the whole story?[1,2]

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For a time, dietary fat was implicated in the epidemic of obesity. Now, added sugars and their main proxy, sugar-sweetened beverages (SSBs), have taken its place and are increasingly being regarded as a serious threat to public health. Some have ordained sugars as the "new tobacco" (1), with calls to regulate sugars like tobacco or alcohol (2). In this regard, New York City has proposed a ban on all SSBs >16 oz (473 mL) sold in restaurants. The Ontario Medical Association has also proposed using tobacco-like warning labels on SSBs to help prevent obesity and type 2 diabetes and their complications (**Figure 1**). The implied corollary is that SSBs are to obesity and cardiometabolic diseases as tobacco smoke is to lung disease and cardiovascular disease.

Evidence from randomized trials, however, has yet to support this strong position. A WHO-commissioned systematic review and meta-analysis published earlier this year found that added sugars (including those from SSBs) in isocaloric exchange for other sources of carbohydrate do not lead to weight gain in randomized feeding trials, suggesting that added sugars are a determinant of weight only insofar as they provide excess energy in the diet (3). Another systematic review and meta-analysis reached a similar conclusion for the purported main culprit, fructose (4). Despite the prominent role of energy in these analyses, interventions to reduce energy from SSBs have not been shown to be as effective as one would hope. An updated meta-analysis of randomized trials failed to show the expected body weight benefit from reducing energy from SSBs, except in a secondary analysis restricted to overweight or obese participants (5). In the absence of convincing evidence from randomized trials that added sugars and SSBs behave differently than other forms of excess energy in the diet or that strategies to reduce the energy from SSBs have particular benefit over strategies to reduce other sources of excess energy (as implied by proposed policies), observational studies have been relied on to carry the debate. Because of their long longitudinal follow-up and the ability to relate exposure to clinical events, prospective cohort studies provide some of the strongest evidence that SSBs are associated with obesity, diabetes, hypertension, ischemic heart disease (IHD), and stroke (3, 6–9). But whether the associations seen only when comparing extreme quantiles of intake in these studies will translate into meaningful public health consequences in the context of actual intake patterns needs careful inspection.

In this issue of the Journal, 2 articles provide some important data to address this question. In the first article, Ambrosini et al (10) conducted a prospective analysis of adolescent offspring in the Western Australian Pregnancy Cohort (Raine) Study. An increase from the lowest (0–0.5 servings/d) to the highest (>1.3 servings/d) tertile of SSBs from 14 to 17 y of age was associated with an increase in the risk of overweight/obesity and a high cardiometabolic risk cluster in girls (ORs: 3.8 and 2.7, respectively, in most adjusted models) but not in boys (ORs: 1.0 and 0.8, respectively, in most adjusted models). None of the associations were significant for boys using the most adjusted models with one exception: boys had a negligible increase in waist circumference (1.4%) when comparing the highest with the lowest tertile of SSBs. Although the effect sizes were quite large for overweight/obesity and the high cardiometabolic risk cluster in girls, the lack of association in boys creates some uncertainty in the generalizability of the estimates.

The second article by Wang and Vine (11) puts these data in the context of actual intake patterns in the United States by exploring the effect of the New York City ban on portion sizes of SSBs >16 oz on calorie reduction in an analysis of the NHANES. The analysis showed that adolescents (12–19 y of age) consume 75.3% of SSBs sold in America and are the largest consumers of portion sizes of SSBs >16 oz (11.8%). The authors estimate that a policy to ban portion sizes of SSBs >16 oz would result in a modest decrease in energy from SSBs of −57.6 kcal/d in children and adolescents and −62.6 kcal/d in adults. These projected reductions assume that 80% of people would downsize their SSBs without purchasing additional servings to compensate for the ban. It is questionable whether so few people (20%) would not compensate by purchasing additional servings, although the analysis suggests that the people most affected by the ban would have the lowest income and so would be least able to afford any additional servings. It can be argued that some may also compensate for this reduction in energy by increasing their consumption of energy from other sources,

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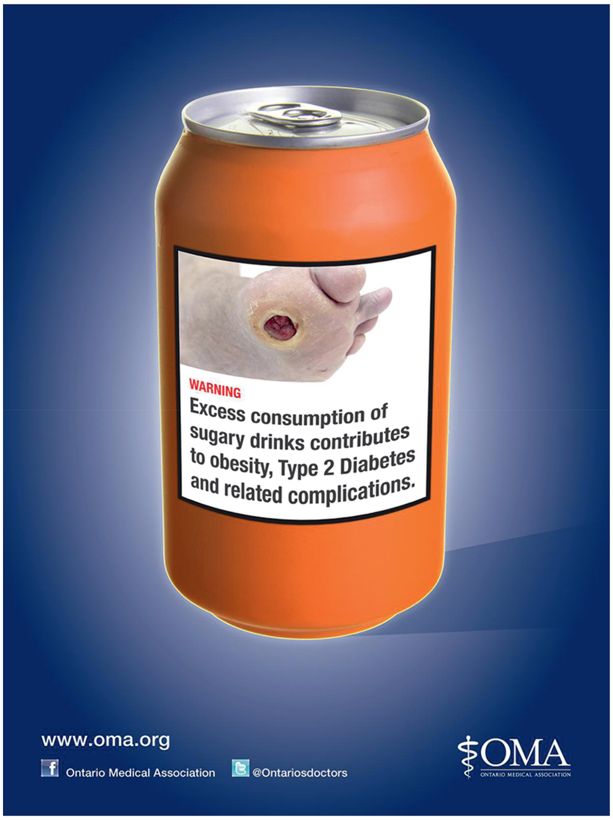

FIGURE 1. Warning label for soda proposed by the Ontario Medical Association. Reproduced with permission from the Ontario Medical Association. The image is available at https://www.oma.org/Resources/Documents/Pop%20Obesity%20Warning.pdf. Additional information is available at https://www.oma.org/HealthPromotion/Obesity/Pages/default.aspx.

especially other highly palatable sources of energy that tend to be coingested with SSBs as part of a Western dietary pattern. There is some evidence that this may already be happening. Another analysis of NHANES showed that the decrease in the intake of added sugars mainly from SSBs from 1999 to 2009 in the United States has been compensated for by reciprocal increases in the intake of other carbohydrates, protein, and fat, such that overall energy intake has remained high (12). Compensation may also explain why interventions designed to displace energy from SSBs have failed to show sustained benefits in meta-analyses of randomized trials (5).

Putting aside these limitations, whether such a small reduction in energy will be enough to have a detectable benefit is unclear. In the Raine cohort (10), as in other cohorts (3, 6–9), the association of SSBs with obesity and cardiometabolic outcomes was seen only when comparing extreme quantiles of intake. Whereas the difference in calories from SSBs resulting from the ban would be <65 kcal/d (11), the difference in calories from SSBs required to see an association in the Raine cohort and other cohorts is typically >140 kcal/d when comparing extreme quantiles (3, 6–10). Accurately capturing changes in energy from SSB intakes in large cohorts and relating these changes to risk estimates have proven difficult. Although the caloric differences achieved may well prove meaningful, it is unclear whether the effect sizes among the cohort studies are sufficiently strong so as to translate into public health significance. Meta-analyses of cohort studies show evidence of significant heterogeneity (6). Adjusted RR estimates for the downstream cardiometabolic complications including metabolic syndrome, diabetes, hypertension, IHD, and stroke are also ≤1.26 (6–9), estimates that are smaller than those for other established risk factors with high population-attributable risk for cardiovascular disease (13). These include other dietary risk factors such as high dietary salt, low n–3 fatty acids, and high *trans* fatty acids.

The small RRs associated with SSBs suggest the involvement of multiple other factors. Numerous dietary factors other than SSBs have been associated with cardiometabolic risk. For example, an increase in one serving of French fries (+1.52 kg), potato chips (+0.77 kg), unprocessed meat (+0.43 kg), processed meat (+0.42 kg), *trans* fat (+0.29 kg), or boiled, baked, or mashed potatoes (+0.26 kg) resulted in greater or similar weight gain than did SSBs (+0.45 kg) for every 4 y of follow-up in a pooled analysis of 3 Harvard cohorts (14). The contribution to the diet of these other foods is not trivial: the servings per day provided by unprocessed meats (0.6), potatoes (0.4), processed meats (0.2–0.4), and potato chips (0.1–0.2) were similar to those provided by SSBs (0.2–0.3) in the Harvard cohorts. These relative contributions, however, may not be representative for all groups. Low-income adults consume disproportionately higher servings per day of SSBs (2.6) than unprocessed meats (0.6), processed meats (0.4), and potatoes (0.4) (15). Children and adolescents also consume, on average, ~50% more SSBs than adults as a percentage of total energy (12).

Important collinearity among different dietary factors must also be considered. Food and lifestyle choices do not exist in isolation. An approach that looks only at a single food or lifestyle behavior may be inadequate for disentangling complicated interactions among different foods and the dietary and lifestyle patterns they comprise under free-living conditions. In this regard, high consumers of SSBs in the Raine cohort as well as in other cohorts tend to consume more calories, exercise less, smoke more, and have a poorer dietary pattern (7, 8, 10), all of which can be difficult to measure and adjust for completely in observational studies. Dietary pattern analyses, which take advantage of this collinearity, have identified 2 distinct dietary patterns among the Harvard cohorts: a Western dietary pattern (characterized by high intakes of processed meat, red meat, refined grains, French fries, sweets and desserts, and SSBs) and a prudent dietary pattern (characterized by high intakes of vegetables, fruit, legumes, fish, poultry, and whole grains) in which the relative contributions of different foods varies depending on the cohort. The Western dietary pattern was associated with SSB intake in the Raine cohort (10) and has been associated with cardiometabolic disease outcomes including weight gain and increased risk of diabetes, IHD, and IHD mortality (16–18). The effect sizes for weight gain (+7.03 kg over 8 y) (16), diabetes (RR: 2.56–2.93) (17), and IHD (RR: 1.46) (18) are larger than those reported for SSBs alone (3), and these associations remained unchanged even after adjustment for SSBs [in the 2 analyses in which this adjustment was performed (16, 17)]. Taken together, a high intake of SSBs may be a marker of an overall unhealthy lifestyle characterized by high energy intake, inactivity, and a poor dietary pattern, in which the components in aggregate contribute to a high risk of obesity and cardiometabolic disease.

In conclusion, excessive intakes of SSBs remain an important public health target. Because SSBs offer no nutritive value, there is certainly no harm in policies to reduce their intake. It is difficult, however, to separate the contribution of SSBs from that of other factors in the epidemic of obesity and cardiometabolic disease. Because of the small effect sizes and lack of demonstrated harm over other sources of excess energy in the diet, public health interventions that solely target SSBs are unlikely to be sufficient. A broader focus is needed. SSBs are one of many pathways to overconsumption. Other highly palatable foods such as refined grains, potato products, salty snack foods, and processed meats also contribute to overconsumption leading to weight gain and cardiometabolic complications. Dietary patterns that bring these factors together have the greatest influence on weight gain and cardiometabolic risk and represent the best opportunity for successful interventions. Attention needs to remain focused on reducing overconsumption of all caloric foods associated with obesity and cardiometabolic disease, including SSBs, as well as promoting greater physical activity.

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REFERENCES

1. Ravichandran R. Sugar is the new tobacco. Available from: http://blogs.bmj.com/bmj/2013/03/15/balaji-ravichandran-sugar-is-the-new-tobacco/ (cited 13 June 2013).
2. Lustig RH, Schmidt LA, Brindis CD. Public health: the toxic truth about sugar. Nature 2012;482:27–9.
3. Te Morenga L, Mallard S, Mann J. Dietary sugars and body weight: systematic review and meta-analyses of randomised controlled trials and cohort studies. BMJ 2013;346:e7492.
4. Sievenpiper JL, de Souza RJ, Mirrahimi A, Yu ME, Carleton AJ, Chiavaroli L, DiBuono M, Jenkins AL, Leiter LA, Wolever TWS, et al. Effect of fructose feeding on body weight: systematic review and meta-analyses of controlled feeding trials. Ann Intern Med 2012;156: 291–304.
5. Kaiser KA, Shikany JM, Keating KD, Allison DB. Will reducing sugar-sweetened beverage consumption reduce obesity? Evidence supporting conjecture is strong, but evidence when testing effect is weak. Obes Rev 2013; Jun 7 (Epub ahead of print; DOI:10.1111/obr.12048).
6. Malik VS, Popkin BM, Bray GA, Després JP, Willett WC, Hu FB. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis. Diabetes Care 2010;33:2477–83.
7. Cohen L, Curhan G, Forman J. Association of sweetened beverage intake with incident hypertension. J Gen Intern Med 2012;27:1127–34.
8. de Koning L, Malik VS, Kellogg MD, Rimm EB, Willett WC, Hu FB. Sweetened beverage consumption, incident coronary heart disease, and biomarkers of risk in men. Circulation 2012;125:1735–41.
9. Bernstein AM, de Koning L, Flint AJ, Rexrode KM, Willett WC. Soda consumption and the risk of stroke in men and women. Am J Clin Nutr 2012;95:1190–9.
10. Ambrosini GL, Oddy WH, Huang RC, Mori TA, Beilin LJ, Jebb SA. Prospective associations between sugar-sweetened beverage intakes and cardiometabolic risk factors in adolescents. Am J Clin Nutr 2013: 98:327–34.
11. Wang YC, Vine SM. Caloric effect of a 16-ounce (473-mL) portion-size cap on sugar-sweetened beverages served in restaurants. Am J Clin Nutr 2013:98:430–5.
12. Welsh JA, Sharma AJ, Grellinger L, Vos MB. Consumption of added sugars is decreasing in the United States. Am J Clin Nutr 2011;94:726–34.
13. Danaei G, Ding EL, Mozaffarian D, Taylor B, Rehm J, Murray CJ, Ezzati M. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. PLoS Med 2009;6:e1000058.
14. Mozaffarian D, Hao T, Rimm EB, Willett WC, Hu FB. Changes in diet and lifestyle and long-term weight gain in women and men. N Engl J Med 2011;364:2392–404.
15. Leung CW, Ding EL, Catalano PJ, Villamor E, Rimm EB, Willett WC. Dietary intake and dietary quality of low-income adults in the Supplemental Nutrition Assistance Program. Am J Clin Nutr 2012;96: 977–88.
16. Schulze MB, Fung TT, Manson JE, Willett WC, Hu FB. Dietary patterns and changes in body weight in women. Obesity (Silver Spring) 2006; 14:1444–53.
17. Schulze MB, Hoffmann K, Manson JE, Willett WC, Meigs JB, Weikert C, Heidemann C, Colditz GA, Hu FB. Dietary pattern, inflammation, and incidence of type 2 diabetes in women. Am J Clin Nutr 2005; 82:675–84.
18. Fung TT, Willett WC, Stampfer MJ, Manson JE, Hu FB. Dietary patterns and the risk of coronary heart disease in women. Arch Intern Med 2001;161:1857–62.