The Journal of Nutrition
**Community and International Nutrition**

# Warning Labels Reduce Sugar-Sweetened Beverage Intake among College Students

Cindy W Leung,[1] Julia A Wolfson,[1,2] Robert Hsu,[2] Keith Soster,[3] Steve Mangan,[3] and Jennifer Falbe[4]

[1]Department of Nutritional Sciences, School of Public Health, University of Michigan, Ann Arbor, MI, USA; [2]Department of Health Management and Policy, School of Public Health, University of Michigan, Ann Arbor, MI, USA; [3]Michigan Dining, University of Michigan, Ann Arbor, MI, USA; and [4]Human Development and Family Studies Program, Department of Human Ecology, University of California, Davis, Davis, CA, USA

## ABSTRACT

**Background:** Health-related warning labels may reduce the intake of sugar-sweetened beverages (SSBs), but the effectiveness of such labels in real-world settings is not well established.

**Objectives:** We investigated the influence of warning labels on SSB intake among college students at a large public Midwestern university.

**Methods:** We conducted a quasi-experimental intervention study among 840 undergraduate students recruited from 3 dining halls on 1 university campus. One dining hall was selected as the intervention (I) site, whereas the other dining halls served as control (C) sites. In January 2019, warning labels were posted on SSB dispensers at the I site. All students reported their beverage intake using a modified beverage frequency questionnaire 2 mo before and 2 mo after the warning label implementation. Generalized linear models examined the influence of the warning labels on SSB consumption at the I site compared with the C sites, adjusting for students' sociodemographic characteristics.

**Results:** In the sample, 68% were aged 17–18 y old at baseline, and 51% identified as female. From baseline to follow-up, there was a 19% decrease in SSB intake at the I site, compared with a 5% decrease at the C sites ($P = 0.049$ comparing I with C). This difference was driven by significant decreases in the intakes of fruit-flavored drinks, sweetened teas, and flavored milk at the I site compared with the C sites. Although not an SSB, 100% fruit juce consumption decreased 21% at the I site, compared with a 1% increase at the C sites ($P = 0.01$ comparing I with C). No significant differences were observed in the intakes of soda, energy drinks, sweetened coffees, and nonsugary drinks at the I site compared with the C sites.

**Conclusions:** Warning labels were effective in reducing SSB intake among college students, particularly for fruit-flavored drinks, sweetened teas, and flavored milk. This trial was registered at clinicaltrials.gov as NCT04435145. *J Nutr* 2021;151:179–185.

**Keywords:** sugar-sweetened beverages, warning label, college students, intervention, quasi-experimental

## Introduction

Added sugars contribute ~14% of Americans' daily caloric intake, exceeding the 10% limit recommended by the WHO and the 2015–2020 Dietary Guidelines for Americans (1). Nearly half of Americans' added sugar intake is consumed in the form of sugar-sweetened beverages (SSBs) (2). SSB consumption contributes to weight gain and obesity (3), and risks of dental caries (4), type 2 diabetes (5), and cardiovascular disease (6). Hence, reduction of SSB intake is a major public health priority.

Borrowing from successful tobacco control efforts, warning labels are an emerging approach to reduce SSB consumption (7, 8). Studies simulating the population-level impact of warning labels and other public health approaches to SSB reduction have estimated significant reductions in obesity prevalence, ranging from 1.5% to 6.0%, and in type 2 diabetes incidence of ≤2.6% (9–13). Although experts agree that a combination of policies will be necessary to reduce SSB consumption, warning labels are a promising approach that has garnered high bipartisan support (14–19).

To date, only 2 studies have tested warning labels in field settings. In 1 study, graphic warning labels were displayed in a hospital cafeteria, which decreased SSB calories and proportion of SSBs purchased (18). In another study, text warning labels in the shape of an octagon were placed on the front of beverages in a simulated convenience store, which also had similar effects on calories and beverages purchased (20). Although most of the current research has been conducted in online and laboratory settings (16, 17, 21–24), these results suggest that SSB warning labels can be effectively translated into, and scaled in, actual dining and food purchasing settings. Despite promising results, current research has key

© The Author(s) 2020. Published by Oxford University Press on behalf of the American Society for Nutrition. All rights reserved. For permissions, please e-mail: journals.permissions@oup.com
Manuscript received July 7, 2020. Initial review completed August 24, 2020. Revision accepted September 15, 2020.
First published online November 26, 2020; doi: https://doi.org/10.1093/jn/nxaa305.

limitations to address. First, most studies have focused on SSB selection or purchase; to our knowledge, no study has examined the impact of warning labels on SSB consumption. Second, studies should examine if compensatory effects occur with caloric non-SSBs (e.g., 100% juice). Third, existing studies have been limited to short-term changes, so longer-term studies are needed. And finally, studies have typically recruited adults of all ages, and only 3 have focused on young adults (17, 23, 25).

Understanding the effectiveness of warning labels among young adults, particularly college students, is important because this demographic is among the highest consumers of SSBs (26), and the start of college marks a key developmental transition that can set the stage for lifelong eating behaviors (27). To address some of the limitations of prior research, we used a quasi-experimental approach to examine the influence of SSB warning labels on college students' SSB and other beverage intake.

## Methods

### Overview

We conducted a quasi-experimental intervention study (NCT04435145) among undergraduate students at the University of Michigan. One of 3 large dining halls was selected as the intervention (I) site, and 2 other dining halls were the control (C) sites. At the I site, warning labels were placed on SSB dispensers. At the C sites, no changes to any food or beverage dispensers were made. To assess beverage consumption and student characteristics, online (Qualtrics) surveys were administered 2 mo before (i.e., baseline) and 2 mo after the intervention began (i.e., follow-up). Students provided informed consent at the beginning of both surveys. The study was approved by the University of Michigan Institutional Review Board.

### Participants and recruitment

Students were eligible to participate if they were frequent diners at 1 of the 3 dining halls during the Fall 2018 academic term (i.e., visited the dining hall ≥100 times within the first 2 mo of the semester). Student samples for each of the dining halls were provided by Michigan Dining, the campus unit that manages all on-campus dining halls and eateries. No exclusion criteria based on students' prior health conditions or dietary preferences were applied.

In November 2018, all eligible students were contacted through their university e-mail address to take part in the research project. We aimed to recruit 1000 total students, which we estimated a priori from pilot data would provide 80% power to detect a 10% decline in SSB consumption in the I group relative to the C group, assuming a retention rate of ≥60%. The sample included 400 students from the I site and 300 students from each C site. From the initial eligible pool of 3032 students, we achieved our target sample size within 2 d, and the baseline survey was subsequently closed to new responses. In March 2019, students who completed the baseline survey were recontacted by e-mail to complete a follow-up survey. Of the 1084 students in the baseline sample, 934 students completed the follow-up survey, yielding an 86% retention rate. Students received a $10 Amazon.com gift card for completing each survey. To avoid deterring or attracting participants based on their beverage preferences, the purpose of the survey was described as being to better understand "students' health behaviors among new/incoming University of Michigan students," and no specific mention of SSBs was made in the descriptions of the baseline and follow-up surveys.

### Intervention

The Michigan dining halls are open to the entire university community, although primarily they cater to students in residence halls with dining plans. Students in residence halls have unlimited meal plans, allowing them unrestricted access to all campus dining halls during the academic year. All dining halls provide food through an all-you-care-to-eat style buffet, i.e., students swipe their cards upon entering but are not charged for individual foods and drinks chosen, and these items are not tracked at the student level. The I dining hall was selected because it was on North Campus and geographically separated from the C sites, which would minimize students at the C sites being exposed to the intervention, and vice versa. The C dining halls were selected because they were both located on Central Campus, ∼1 mile away from each other. Campus administrative data showed that 94% of students who ate at the I dining hall lived on North Campus, whereas 91% of students who ate at the C sites lived on Central Campus. All dining halls had the same assortments of beverages, dispensed from self-serve fountain stations, with the same selections of regular sodas, fruit drinks, diet sodas, 100% fruit juice, plain milk, chocolate milk, chai tea, hot chocolate, and plain water.

The development of the SSB warning label was informed by the results of a formative study led by a member of this research team, which used 10 focus groups at 3 universities to generate warning label design mock-ups, which were tested in an online experiment (under review) (28). The final label was 10 inches × 2 inches (25.4 cm × 5.1 cm), displayed an icon with an exclamation mark, used a bright yellow background with black text and a black border, and displayed a loss-frame message (**Figure 1**). The warning label message was based on phrasing that was efficacious in prior studies and the proposed label message in a California legislative bill [Assembly Bill (AB)-347]. The key difference was the replacement of the health outcome "obesity" with "heart disease," at the request of our dining partners. The warning labels were affixed to all SSB stations at the I site (**Supplemental Figure 1**). Because most self-serve beverage stations had a variety of both SSBs and non-SSBs, a 1-inch × 1-inch (2.54-cm × 2.54-cm) sticker of the exclamation mark icon was applied next to the beverage label to indicate which beverages contained added sugar. All SSB warning labels were applied in January 2019, before the beginning of the academic term, and remained posted for the duration of the semester. To our knowledge, there were no changes in food offerings at the I dining hall to accommodate the presence of the warning labels. There were also no additional messages or materials provided to students by the researchers or dining staff related to the warning labels.

### Measures

The primary outcomes of interest were daily intakes of individual SSB and non-SSB beverages and overall SSB consumption. Beverage consumption was assessed over the past month using a modified beverage frequency questionnaire: the BEVQ-15. The BEVQ-15 is a validated instrument that measures the frequency and amount consumed across 15 types of beverages (29). We modified the original

Supported by a grant from Poverty Solutions at the University of Michigan and the McNerney Award from the Department of Health Management and Policy at the University of Michigan School of Public Health. CWL was supported by Eunice Kennedy Shriver National Institute of Child Health and Human Development grant 4R00HD084758, JAW was supported by National Institute of Diabetes and Digestive and Kidney Diseases grant K01DK119166, and JF was supported by National Institute of Diabetes and Digestive and Kidney Diseases grant K01DK113068.
Author disclosures: RH was previously an employee at PepsiCo and reports no past or current stock ownership. He was a student at the University of Michigan during the time of his contribution to this article. All other authors report no conflicts of interest.
The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH. The sponsors had no role in the design or conduct of the study; in the collection, analysis, or interpretation of the data; or in the preparation, review, or approval of the manuscript.
Supplemental Figure 1 is available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/jn/.
Address correspondence to CWL (e-mail: cindyleung@post.harvard.edu).
Abbreviations used: AB, Assembly Bill; BEVQ, beverage intake questionnaire; BIB, bag-in-box; C, control; HB, House Bill; I, intervention; SB, Senate Bill; SSB, sugar-sweetened beverage; UCSF, University of California San Francisco.

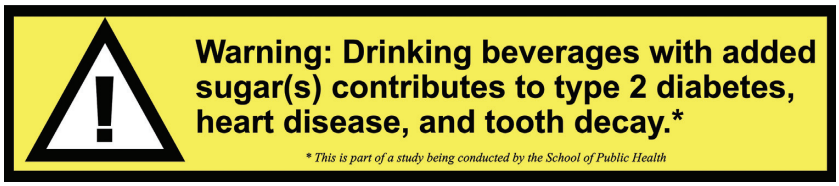


**FIGURE 1** Sugar-sweetened beverage warning label.

instrument by combining whole milk, reduced-fat milk, and low-fat/skim milk into 1 "plain/unflavored milk" category, and separating "flavored milk" into another category. The beverages assessed in the current study included regular soda, energy or sports drinks, fruit-flavored drinks, sweetened tea, sweetened coffee, flavored milk, diet soda, 100% fruit juice, plain/unflavored milk, artificially sweetened or unsweetened tea and coffee, and water. With the exception of energy or sports drinks and sweetened coffee, all beverages assessed by the modified BEVQ-15 were available in the dining halls. In the survey, examples of each kind of beverage were provided to help students understand the different beverage categories using beverages that were available within the dining halls. For example, pink lemonade and fruit punch were provided as examples for fruit-flavored drinks, chai tea was provided as an example of sweetened tea, and chocolate milk and hot chocolate were provided as examples of flavored milk. Students reported their responses as frequencies ranging from "never" to "6 or more times per day," and the usual amount consumed for each beverage that was consumed at least once per month, ranging from "less than 6 fluid ounces" to "more than 20 fluid ounces." We estimated daily intakes (in ounces) by multiplying the frequency of intake and the usual amount for each beverage type. Regular soda (i.e., sugar-sweetened carbonated soft drinks), energy or sports drinks, fruit-flavored drinks, sweetened tea, sweetened coffee, and flavored milk were counted as SSBs. Diet soda (i.e., artificially sweetened carbonated soft drinks), 100% fruit juice, plain/unflavored milk, artificially sweetened or unsweetened tea and coffee, and water were counted as non-SSBs.

Surveys also assessed students' demographic characteristics, including age, sex, race/ethnicity, year in school, degree type, highest educational attainment of both parents, and Pell grant status. First-generation students were defined as students who had both parents attaining less than a Bachelor's degree for their highest educational attainment. Federal Pell grants are awarded to low-income students and students with significant financial need, and were included as an indicator of family socioeconomic status. Students also reported their frequency of dining at campus dining hall locations, which allowed us to assess their exposure to the intervention. In the follow-up survey at the I site, 1 additional question assessed students' perceptions of the labels: "Over the past couple of months, labels were posted on all sugar-sweetened beverage (SSB) dispensers at Bursley Dining. These labels were part of a study from the School of Public Health on beverage consumption among college students. How do you feel about these labels?" Responses were provided using a 5-point Likert scale, ranging from very negative to very positive.

### Statistical analysis

We removed 78 students from the C sites who reported frequently dining at the I site during follow-up because they were exposed to the SSB intervention. We also removed 2 students from the I site who reported never dining at the I site during follow-up because they were not exposed to the SSB intervention. Students who had missing data for any of the key sociodemographic characteristics or BEVQ questions were also removed ($n = 14$). From the 934 students with follow-up data, this yielded an analytic sample of 840 students.

All statistical analyses were performed with SAS version 9.3 (SAS Institute, Cary, NC). To examine the effect of the SSB warning labels on students' beverage intake, we used a difference-in-differences approach to estimate changes in beverage consumption from preintervention to postintervention in the I site relative to concurrent changes in the C sites. For each beverage, we modeled the ounces consumed using generalized linear mixed models with a $\gamma$ distribution and a log link to account for the skewed distribution of beverage variables, using the PROC GLIMMIX. Modeling assumptions were verified through examination of the skewness of outcome variables, residual plots, and Pearson's chi-square statistic divided by the model's df. Models included an indicator for the I group, an indicator for the time period (e.g., preintervention compared with postintervention), and an interaction term for the I group and time period. The exponentiated coefficient for the interaction term represents the percentage change (i.e., difference) in beverage consumption from preintervention to postintervention among students at the I site relative to students at the C sites. All models were also adjusted for students' age, sex, race/ethnicity, first-generation student status, and Pell grant status. Finally, we tested for potential effect modification by sex (males compared with females) and by first-generation student status.

All statistical tests were 2-sided, and statistical significance was considered at $P < 0.05$.

## Results

In the analytic population of 840 students, 77% of study participants were freshmen, 16% were sophomores, and 7% were juniors, seniors, or super seniors (i.e., fifth-year students or higher). Table 1 shows demographic characteristics of the students in the I and C sites. In the total sample, 68% were 17–18 y old at baseline, 51% identified as female, 56% were non-Hispanic white, 17% were first-generation students, and 25% were Pell grant recipients. Compared with students in the C sites, students in the I site were slightly older and more likely to be male. There were no significant differences in race/ethnicity, first-generation student status, or Pell grant status between the I and C sites.

Table 2 shows beverage consumption preintervention and postintervention by intervention site and differences in change by intervention site. At baseline, mean SSB consumption was 10.9 ± 0.9 oz/d at the I site and 9.0 ± 0.7 oz/d at the C sites. After the initiation of the intervention, adjusted SSB consumption declined significantly more at the I site (−18.5%) than at the C sites (−4.7%) [adjusted percentage change at the I site relative to the C sites (I compared with C): −14.5%, $P = 0.049$]. From the preintervention to the postintervention period, significant reductions at the I site compared to the C sites were observed in the consumption of fruit drinks [I: −37.2%; C: −17.8%, adjusted percentage change (I compared with C): −23.6%, $P = 0.02$], sweetened tea [I: −16.3%, C: +15.3%, adjusted percentage change (I compared with C): −27.5%, $P = 0.01$], and flavored milk [I: −24.6%, C: +2.3%, adjusted percentage change (I compared with C): −26.3%, $P = 0.02$]. Although not an SSB, 100% fruit juice consumption also significantly declined at the I site relative to the C sites [I: −21.1%, C: +1.4%, adjusted percentage change (I compared with C): −22.2%, $P = 0.01$]. There were no other significant differences between I and C sites for changes in regular soda, energy or sports drinks, sweetened coffee, plain/unflavored milk, diet soda, plain coffee/tea, and water consumption. There was also no evidence of effect modification in the overall

**TABLE 1** Demographic characteristics of 840 undergraduate college students in the sugar-sweetened beverage warning label study by I and C sites[1]

| | Total ($n = 840$) | | I site ($n = 374$) | | C sites ($n = 466$) | | |
|---|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | *n* | % | $P^2$ |
| Age, y | | | | | | | 0.01 |
| 17–18 | 568 | 67.6 | 239 | 63.9 | 329 | 70.6 | |
| 19 | 190 | 22.6 | 86 | 23.0 | 104 | 22.3 | |
| ≥20 | 82 | 9.8 | 49 | 13.1 | 33 | 7.1 | |
| Sex | | | | | | | <0.0001 |
| Male | 411 | 48.9 | 219 | 58.6 | 192 | 41.2 | |
| Female | 424 | 50.5 | 152 | 40.6 | 272 | 58.4 | |
| Transgender, gender nonconforming, other | 5 | 0.6 | 3 | 0.8 | 2 | 0.4 | |
| Race/ethnicity | | | | | | | 0.75 |
| White | 472 | 56.2 | 213 | 57.0 | 259 | 55.6 | |
| Black | 35 | 4.2 | 17 | 4.6 | 18 | 3.9 | |
| Hispanic | 44 | 5.2 | 22 | 5.9 | 22 | 4.7 | |
| Asian or Pacific Islander | 235 | 28.0 | 97 | 25.9 | 138 | 29.6 | |
| Other or multiracial | 54 | 6.4 | 25 | 6.7 | 29 | 6.2 | |
| First-generation student | 144 | 17.1 | 67 | 17.9 | 77 | 16.5 | 0.60 |
| Pell grant recipient | 207 | 24.6 | 93 | 24.9 | 114 | 24.5 | 0.89 |

[1]C, control; I, intervention.
[2]*P* values for difference between I and C sites based on $\chi^2$ tests.

impact of the SSB warning label on SSB consumption by sex (*P*-interaction = 0.70), by first-generation student status (*P*-interaction = 0.17), or by baseline SSB consumption (*P*-interaction = 0.85).

When asked about their general perceptions of the SSB warning labels, 45% of students at the I site indicated feeling "very positive" or "positive," 40% indicated feeling "neutral," and 14.4% indicated feeling "somewhat negative" or "very negative." There were no differences in the SSB warning label perceptions by sex ($P = 0.16$).

## Discussion

Results of this intervention demonstrate that SSB warning labels led to a 14.5% reduction in consumption of SSBs among college students, which was driven by significant declines in consumption of fruit drinks, sweetened teas, and flavored milk. The vast majority of students at the I site also reported positive or neutral attitudes toward the SSB warning labels. Together, these findings suggest that the warning labels are an acceptable and appropriate way to curb the consumption of SSBs, particularly consumption of SSBs where added sugars are less obvious, unlike regular sodas which have been the target of public health programs and policies for years. These results are consistent with an online study which found that warning label exposure increased risk perceptions for all SSBs except regular soda (30). There were no significant differences in the intakes of energy or sports drinks or sweetened coffees, which was expected because these drinks were not available in the dining halls. There was also no significant difference in the intake of diet soda, which remained low at both time points of the study, suggesting that students did not shift their consumption from SSBs to artificially sweetened beverages. Our results did not differ by sex or first-generation student status, similar to prior studies showing the effectiveness of SSB warning labels across broad demographic groups.

One unexpected finding was that there were no increases in the consumption of water or other non-SSBs. This might be attributed to a ceiling effect of the BEVQ-15, where a substantial proportion of students already reported high frequencies for water intake, making it unlikely that the instrument would be able to detect differences at even higher consumption amounts. Water was also the only beverage measured for which consumption did not change among students in the I group from baseline to follow-up. Had the BEVQ-15 included responses of higher frequency for water intake, it is possible that water intake would have significantly increased in response to decreasing SSBs.

This study makes an important contribution to the evidence base demonstrating the effectiveness of SSB warning labels. In a hospital cafeteria, graphic warning labels decreased the SSB share of bottled purchases by 14.8%, combined with increases in bottled water purchases (18). Unlike that study, which tested calorie, text, and graphic warning labels, our study found that yellow text-based, icon-containing warning labels were effective in a cafeteria setting. In a simulated convenience store, a red text warning label in the shape of an octagon decreased the likelihood of SSB purchases by 14% and SSB calories purchased by 21.9% (20). Although our study measured intake rather than beverage selection, our results are of similar magnitude to those of these field-based studies.

Institutions such as universities and workplaces have wide latitude to use warning labels for health promotion. Many institutions are going even further. Numerous health sector institutions have implemented sales bans on SSBs [e.g., Cleveland Clinic, University of Michigan Health System, University of California San Francisco (UCSF)], but UCSF—a university, workplace, and health care provider—was among the first to evaluate a sales ban. Ten months after implementation, SSB consumption had dropped by almost 50%, and this resulted in metabolic improvements among heavy SSB consumers (31). Meanwhile, universities like Cornell, Stanford, and University of California Los Angeles have replaced SSBs in some or all of their dining halls with healthier drinks. Replacing SSBs with appealing alternatives in dining halls may be especially impactful for college students.

**TABLE 2** Differences in beverage consumption at preintervention and postintervention by I and C sites among 840 undergraduate college students[1]

| | I site ($n = 374$) | | | | | C sites ($n = 466$) | | | | | Impact of warning label | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Preintervention[2] | Postintervention[2] | Unadjusted absolute change[2] | Adjusted percentage change[3] | $P$[4] | Preintervention[2] | Postintervention[2] | Unadjusted absolute change[2] | Adjusted percentage change[3] | $P$[4] | Unadjusted absolute change at the I site relative to that at the C sites[2] | Adjusted percentage change at the I site relative to that at the C sites[3] | $P$[5] |
| SSBs | | | | | | | | | | | | | |
| Regular soda | 2.5 ± 0.3 | 2.4 ± 0.4 | −0.1 ± 0.4 | −12.5 | 0.07 | 1.8 ± 0.3 | 1.4 ± 0.2 | −0.4 ± 0.2 | −4.7 | 0.47 | 0.3 ± 0.5 | −8.1 | 0.39 |
| Energy drinks | 0.6 ± 0.2 | 0.5 ± 0.1 | −0.1 ± 0.2 | −3.0 | 0.78 | 0.7 ± 0.2 | 0.7 ± 0.2 | −0.1 ± 0.1 | −0.7 | 0.94 | 0.0 ± 0.2 | −2.3 | 0.87 |
| Fruit drinks | 1.8 ± 0.3 | 1.0 ± 0.1 | −0.8 ± 0.3 | −37.2 | <0.0001 | 2.0 ± 0.3 | 1.5 ± 0.2 | −0.5 ± 0.2 | −17.8 | 0.01 | −0.3 ± 0.4 | −23.6 | 0.02 |
| Sweetened coffee | 2.2 ± 0.4 | 1.8 ± 0.3 | −0.4 ± 0.4 | −5.3 | 0.59 | 1.7 ± 0.2 | 1.5 ± 0.2 | −0.1 ± 0.2 | 2.3 | 0.78 | −0.3 ± 0.5 | −7.4 | 0.55 |
| Sweetened tea | 1.3 ± 0.3 | 1.0 ± 0.1 | −0.4 ± 0.3 | −16.3 | 0.07 | 1.1 ± 0.1 | 1.3 ± 0.2 | 0.2 ± 0.2 | 15.3 | 0.06 | −0.6 ± 0.3 | −27.5 | 0.01 |
| Flavored milk | 2.3 ± 0.3 | 2.0 ± 0.4 | −0.3 ± 0.4 | −24.6 | 0.004 | 1.7 ± 0.3 | 1.6 ± 0.3 | −0.1 ± 0.3 | 2.3 | 0.79 | −0.2 ± 0.5 | −26.3 | 0.02 |
| Total SSBs | 10.9 ± 0.9 | 8.6 ± 0.8 | −2.3 ± 0.9 | −18.5 | 0.001 | 9.0 ± 0.7 | 8.0 ± 0.6 | −1.0 ± 0.6 | −4.7 | 0.35 | −1.2 ± 1.1 | −14.5 | 0.049 |
| Artificially sweetened or unsweetened beverages | | | | | | | | | | | | | |
| Plain milk | 4.8 ± 0.4 | 4.5 ± 0.4 | −0.3 ± 0.4 | −7.0 | 0.75 | 3.6 ± 0.3 | 3.9 ± 0.3 | 0.3 ± 0.3 | −1.9 | 0.24 | −0.6 ± 0.5 | −8.4 | 0.31 |
| Diet soda | 1.2 ± 0.3 | 1.0 ± 0.2 | −0.2 ± 0.2 | −5.6 | 0.620.9 | 0.9 ± 0.2 | 0.7 ± 0.1 | −0.1 ± 0.1 | 3.8 | 0.73 | 0.0 ± 0.2 | −9.0 | 0.55 |
| 100% fruit juice | 3.1 ± 0.4 | 2.4 ± 0.2 | −0.7 ± 0.3 | −21.1 | 0.001 | 2.3 ± 0.2 | 2.2 ± 0.2 | −0.1 ± 0.2 | 1.4 | 0.82 | −0.6 ± 0.4 | −22.2 | 0.01 |
| Plain coffee/tea | 2.8 ± 0.4 | 2.7 ± 0.4 | −0.1 ± 0.5 | −12.6 | 0.24 | 3.0 ± 0.4 | 3.0 ± 0.3 | 0.0 ± 0.4 | 8.7 | 0.34 | −0.1 ± 0.6 | −19.6 | 0.13 |
| Water | 56.2 ± 1.7 | 54.7 ± 1.7 | −1.5 ± 1.6 | 0.0 | 0.99 | 55.9 ± 1.6 | 52.2 ± 1.5 | −3.7 ± 1.4 | −7.6 | 0.03 | 2.2 ± 2.2 | 8.2 | 0.15 |

[1]C, control; I, intervention; SSB, sugar-sweetened beverage.
[2]Values are means ± SEs in ounces per day.
[3]Values in percentages comparing post- with preconsumption within sites. Adjusted for age, sex, race/ethnicity, first-generation student status, and Pell grant recipient.
[4]$P$ values were estimated from generalized linear mixed models with a $\gamma$ distribution and log link. $P$ values reflect the adjusted percentage change from preintervention to postintervention within the I or C sites.
[5]$P$ values were estimated from generalized linear mixed models with a $\gamma$ distribution and log link. $P$ values reflect the adjusted percentage change from preintervention to postintervention at the I site relative to that at the C sites.

Currently, 8 US cities and states have proposed warning labels for SSBs. In 2015, San Francisco, California was the first to propose and pass an ordinance requiring health warnings on SSB physical advertisements. Before the ordinance could take effect, a lawsuit was brought forth by the American Beverage Association, the California Retailers Association, and the California State Outdoor Advertising Association. The Ninth Circuit Court of Appeals found that the ordinance as written likely violated the First Amendment. San Francisco's Board of Supervisors are moving forward with amending the ordinance to address issues raised by the Court's opinion (e.g., warning size). Since then, Baltimore (Council Bill 16-0617), Washington [House Bill (HB)-2798], New York State [AB-5239, Senate Bill (SB)-162], Vermont (HB-433), Massachusetts (HB-3329, SB-1562), Hawaii (HB-1209, SB-307), and California (SB-300) have all proposed similar legislation for SSB warning labels; as of yet, none have moved forward in the legislative process. Thus, creating a robust evidence base on the effectiveness of SSB warning labels in field settings is important for informing future proposals.

The warning labels that have been tested and legislatively proposed in the United States have focused on health outcomes. Other countries, however, have adopted "high in" warning labels focused on nutrients. In 2016, Chile required marketing restrictions and "high in" front-of-package labels in the shape of an octagon for products exceeding sugar, sodium, saturated fat, or calorie thresholds. After implementation, household purchases of "high in" beverages decreased 24% (32). SSB warning labels are one of many approaches being considered to curb SSB consumption. It has been conservatively estimated that the impact of SSB warning labels will result in modest reductions in obesity with greater improvements in Black, Hispanic, lower-income, and lower-education populations, making warning labels a promising strategy to reduce health disparities (9, 10). Although any policy alone is unlikely to reverse the current epidemics in diet-sensitive chronic disease, SSB warning labels could work synergistically with other public health programs and policies to promote healthier beverage consumption. For example, SSB excise taxes have been passed in multiple jurisdictions in the United States and around the world, resulting in sizeable reductions in SSB purchasing or consumption. In Mexico, a 1-peso/L SSB tax led to a 10% drop in SSB purchasing (33). After Berkeley, California implemented a 1-cent/oz SSB tax, supermarket SSB sales declined 10% within a year (34), and SSB consumption in low-income neighborhoods dropped 52% during the 3 y after the tax (35). Philadelphia's sweetened beverage tax (which also applies to artificially sweetened beverages) resulted in a 38% net decrease in sales of taxed beverages (36). Other regions (e.g., Seattle, Catalonia) with SSB taxes have also experienced similar effects (37, 38).

This study has some limitations. First, the intervention was not randomized, and students who primarily dined at the I site were slightly different than the students who primarily dined at the C sites. The choice to not randomize was purposeful. The geographic separation of the I site from the C sites allowed us to limit potential exposure of the SSB warning labels among students in the C group, and to prevent students from the I site from dining at a C site to avoid the intervention. The analysis was further adjusted to account for observed differences in students' demographic characteristics across sites, and this adjustment did not alter the main findings. However, the survey did not capture students' school, intended major, or other characteristics about their family socioeconomic status aside from parental education, which may have led to residual differences between students in the I and C sites. Because this study was conducted at 1 university, the findings may also not be generalizable to students at other universities or other young adults.

Finally, overall beverage intake was self-reported using the BEVQ-15. Because this instrument did not ask specifically about beverage intake in the dining halls, we cannot determine whether the warning labels led to changes in beverage intake only within the dining halls or had carryover effects to meals and snacks consumed elsewhere. We considered other assessments of beverage consumption in the context of self-serve beverage stations at all-you-care-to-eat dining halls, but these did not prove to be feasible. For example, Michigan Dining maintains records on beverage bag-in-box (BIB) purchases, but does not routinely track BIB usage, waste (from expiration), or transfers between dining halls. Thus, we were unable to examine the amounts of various beverages dispensed as a secondary outcome. Audits of students' behaviors were also considered, but each of the 3 dining halls has multiple beverage stations and serves hundreds of students at each meal occasion, creating substantial logistical challenges in having trained observers accurately record students' beverage choices and their consumption amounts. Although self-reported beverage data are subject to measurement error, the BEVQ-15 has been shown to have high reliability, and high correlations with SSB intake and total beverage energy measured with 24-h dietary recalls (29). Beverage frequency questionnaires have also been used in evaluations of the impact of SSB excise taxes on SSB consumption (39, 40). We further attempted to minimize bias from social desirability or through exposure to the intervention by specifically avoiding any mentions of SSBs in the initial descriptions of the baseline and follow-up surveys, administering the follow-up survey 2 mo after the SSB warning labels were first implemented, assessing multiple constructs unrelated to SSBs, and not referring to the intervention until after the BEVQ-15 had been completed, at the end of the follow-up survey. For these reasons, we believe that the BEVQ-15 as used here can provide reliable and valid data. Despite these limitations, our study is strengthened by the implementation of warning labels in a real-world setting, the large sample size of college students, and the collection of beverage data at 2 control dining halls to help control for any seasonality effect.

This is, as far as we know, the first follow-up study of warning labels that was conducted in a real-world setting and measured their impact on beverage intake. Our results demonstrate that warning labels are effective in reducing SSB intake among college students, particularly SSBs in which the presence of added sugars is less obvious, and could be used as an educational tool for consumers. These results provide evidence to inform future institutional strategies (e.g., at workplaces and universities) and legislative efforts to use warning labels as a promising approach to curb SSB consumption.

## Acknowledgments

The authors are grateful to Jeannie Mei, Mary McIntyre, and Juliette Farmer for their assistance in data collection. The authors' responsibilities were as follows—CWL, JAW, KS, SM, and JF: designed the research; CWL: oversaw data collection and had primary responsibility for the final content; CWL, JAW, and JF: performed the statistical analysis; RH and JF: conducted the literature review; CWL, JAW, RH, and JF: wrote the paper; and all authors: read and approved the final manuscript.

## References


1. Rehm CD, Drewnowski A. Trends in consumption of solid fats, added sugars, sodium, sugar-sweetened beverages, and fruit from fast food restaurants and by fast food restaurant type among US children, 2003–2010. Nutrients 2016;8(12):804.
2. US Department of Health and Human Services (US DHHS) and US Department of Agriculture. 2015–2020 Dietary Guidelines for Americans. 8th ed. Washington (DC): US DHHS and USDA; 2015.
3. Malik VS, Pan A, Willett WC, Hu FB. Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. Am J Clin Nutr 2013;98(4):1084–102.
4. Sohn W, Burt BA, Sowers MR. Carbonated soft drinks and dental caries in the primary dentition. J Dent Res 2006;85(3):262–6.
5. Hu FB. Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. Obes Rev 2013;14(8): 606–19.
6. Narain A, Kwok CS, Mamas MA. Soft drinks and sweetened beverages and the risk of cardiovascular disease and mortality: a systematic review and meta-analysis. Int J Clin Pract 2016;70(10):791–805.
7. Hammond D. Health warning messages on tobacco products: a review. Tob Control 2011;20(5):327–37.
8. Noar SM, Francis DB, Bridges C, Sontag JM, Ribisl KM, Brewer NT. The impact of strengthening cigarette pack warnings: systematic review of longitudinal observational studies. Soc Sci Med 2016;164: 118–29.
9. Grummon AH, Smith NR, Golden SD, Frerichs L, Taillie LS, Brewer NT. Health warnings on sugar-sweetened beverages: simulation of impacts on diet and obesity among U.S. adults. Am J Prev Med 2019;57(6): 765–74.
10. Lee BY, Ferguson MC, Hertenstein DL, Adam A, Zenkov E, Wang PI, Wong MS, Gittelsohn J, Mui Y, Brown ST. Simulating the impact of sugar-sweetened beverage warning labels in three cities. Am J Prev Med 2018;54(2):197–204.
11. Long MW, Gortmaker SL, Ward ZJ, Resch SC, Moodie ML, Sacks G, Swinburn BA, Carter RC, Wang YC. Cost effectiveness of a sugar-sweetened beverage excise tax in the U.S. Am J Prev Med 2015;49(1):112–23.
12. Basu S, Seligman HK, Gardner C, Bhattacharya J. Ending SNAP subsidies for sugar-sweetened beverages could reduce obesity and type 2 diabetes. Health Aff 2014;33(6):1032–9.
13. Wang YC, Coxson P, Shen Y-M, Goldman L, Bibbins-Domingo K. A penny-per-ounce tax on sugar-sweetened beverages would cut health and cost burdens of diabetes. Health Aff 2012;31(1):199–207.
14. Roberto CA, Wong D, Musicus A, Hammond D. The influence of sugar-sweetened beverage health warning labels on parents' choices. Pediatrics 2016;137(2):e20153185.
15. VanEpps EM, Roberto CA. The influence of sugar-sweetened beverage warnings: a randomized trial of adolescents' choices and beliefs. Am J Prev Med 2016;51(5):664–72.
16. Mantzari E, Vasiljevic M, Turney I, Pilling M, Marteau T. Impact of warning labels on sugar-sweetened beverages on parental selection: an online experimental study. Prev Med Rep 2018;12:259–67.
17. Bollard T, Maubach N, Walker N, Ni Mhurchu C. Effects of plain packaging, warning labels, and taxes on young people's predicted sugar-sweetened beverage preferences: an experimental study. Int J Behav Nutr Phys Act 2016;13(1):95.
18. Donnelly GE, Zatz LY, Svirsky D, John LK. The effect of graphic warnings on sugary-drink purchasing. Psychol Sci 2018;29(8): 1321–33.
19. Miller CL, Dono J, Wakefield MA, Pettigrew S, Coveney J, Roder D, Durkin SJ, Wittert G, Martin J, Ettridge KA. Are Australians ready for warning labels, marketing bans and sugary drink taxes? Two cross-sectional surveys measuring support for policy responses to sugar-sweetened beverages. BMJ Open 2019;9(6):e027962.
20. Grummon AH, Taillie LS, Golden SD, Hall MG, Ranney LM, Brewer NT. Sugar-sweetened beverage health warnings and purchases: a randomized controlled trial. Am J Prev Med 2019;57(5):601–10.
21. Grummon AH, Hall MG, Taillie LS, Brewer NT. How should sugar-sweetened beverage health warnings be designed? A randomized experiment. Prev Med 2019;121:158–66.
22. Mantzari E, Pechey R, Codling S, Sexton O, Hollands GJ, Marteau TM. The impact of 'on-pack' pictorial health warning labels and calorie information labels on drink choice: a laboratory experiment. Appetite 2020;145:104484.
23. Popova L, Nonnemaker J, Taylor N, Bradfield B, Kim A. Warning labels on sugar-sweetened beverages: an eye tracking approach. Am J Health Behav 2019;43(2):406–19.
24. Machin L, Aschemann-Witzel J, Curutchet MR, Gimenez A, Ares G. Does front-of-pack nutrition information improve consumer ability to make healthful choices? Performance of warnings and the traffic light system in a simulated shopping experiment. Appetite 2018;121:55–62.
25. Billich N, Blake MR, Backholer K, Cobcroft M, Li V, Peeters A. The effect of sugar-sweetened beverage front-of-pack labels on drink selection, health knowledge and awareness: an online randomised controlled trial. Appetite 2018;128:233–41.
26. Ogden CL, Kit BK, Carroll MD, Park S. Consumption of sugar drinks in the United States, 2005–2008. NCHS Data Brief, no 71. Hyattsville, (MD): National Center for Health Statistics; 2011.
27. Nelson MC, Story M, Larson NI, Neumark-Sztainer D, Lytle LA. Emerging adulthood and college-aged youth: an overlooked age for weight-related behavior change. Obesity (Silver Spring) 2008;16(10):2205–11.
28. Falbe J, Solar SE, Engelman A, Montuclard AL. Developing a salient warning label for sugar-sweetened beverages (T-OR-2009). The Obesity Society. Las Vegas (NV): Nov 5, 2019.
29. Hedrick VE, Savla J, Comber DL, Flack KD, Estabrooks PA, Nsiah-Kumi PA, Ortmeier S, Davy BM. Development of a brief questionnaire to assess habitual beverage intake (BEVQ-15): sugar-sweetened beverages and total beverage energy intake. J Acad Nutr Diet 2012;112(6):840–9.
30. Moran AJ, Roberto CA. Health warning labels correct parents' misperceptions about sugary drink options. Am J Prev Med 2018;55:e19.
31. Epel ES, Hartman A, Jacobs LM, Leung C, Cohn MA, Jensen L, Ishkanian L, Wojcicki J, Mason AE, Lustig RH, et al. Association of a workplace sales ban on sugar-sweetened beverages with employee consumption of sugar-sweetened beverages and health. JAMA Intern Med 2020;180(1):9–16.
32. Taillie LS, Reyes M, Colchero MA, Popkin B, Corvalan C. An evaluation of Chile's Law of Food Labeling and Advertising on sugar-sweetened beverage purchases from 2015 to 2017: a before-and-after study. PLoS Med 2020;17(2):e1003015.
33. Colchero MA, Rivera-Dommarco J, Popkin BM, Ng SW. In Mexico, evidence of sustained consumer response two years after implementing a sugar-sweetened beverage tax. Health Aff 2017;36(3):564–71.
34. Silver LD, Ng SW, Ryan-Ibarra S, Taillie LS, Induni M, Miles DR, Poti JM, Popkin BM. Changes in prices, sales, consumer spending, and beverage consumption one year after a tax on sugar-sweetened beverages in Berkeley, California, US: a before-and-after study. PLoS Med 2017;14(4):e1002283.
35. Lee MM, Falbe J, Schillinger D, Basu S, McCulloch CE, Madsen KA. Sugar-sweetened beverage consumption 3 years after the Berkeley, California, sugar-sweetened beverage tax. Am J Public Health 2019;109(4):637–9.
36. Roberto CA, Lawman HG, LeVasseur MT, Mitra N, Peterhans A, Herring B, Bleich SN. Association of a beverage tax on sugar-sweetened and artificially sweetened beverages with changes in beverage prices and sales at chain retailers in a large urban setting. JAMA 2019;321(18):1799–810.
37. Powell LM, Leider J. The impact of Seattle's Sweetened Beverage Tax on beverage prices and volume sold. Econ Hum Biol 2020;37:100856.
38. Royo-Bordonada MÁ, Fernández-Escobar C, Simón L, Sanz-Barbero B, Padilla J. Impact of an excise tax on the consumption of sugar-sweetened beverages in young people living in poorer neighbourhoods of Catalonia, Spain: a difference in differences study. BMC Public Health 2019;19(1):1553.
39. Falbe J, Thompson HR, Becker CM, Rojas N, McCulloch CE, Madsen KA. Impact of the Berkeley excise tax on sugar-sweetened beverage consumption. Am J Public Health 2016;106(10):1865–71.
40. Zhong Y, Auchincloss AH, Lee BK, Kanter GP. The short-term impacts of the Philadelphia beverage tax on beverage consumption. Am J Prev Med 2018;55(1):26–34.