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# A Cross-Sectional Examination of Diabetes Screening in US Adults by Sugar Sweetened Beverage Consumption Levels

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**Abstract:** Background: To examine diabetes screening by sugar sweetened beverage (SSB) consumption levels among US adults who fall under the American Diabetes Association's (ADA) recommended screening guidelines. Methods: Using 2017 Behavioral Risk Factor Surveillance System survey data, we determined screening estimates by SSB consumption levels for US adults who belong to the ADA's two recommended screening groups: (1) <45 years with body mass index ≥25 kg/m$^2$ and (2) ≥45 years. Unadjusted and adjusted screening estimates by SSB consumption levels for each recommended screening group were obtained from logistic regressions. Results: Differences in screening by SSB consumption were primarily observed in the younger screening group (0 drinks/day: 64.5%, between 0 and 1 drink/day: 57.1%, ≥1 drink/day: 57.8%). Unadjusted (between 0 and 1 drink/day OR: 0.73 (95% CI: 0.56–0.96), ≥1 drink/day OR: 0.75 (95% CI: 0.56–1.01)) and adjusted (between 0 and 1 drink/day OR: 0.76 (95% CI: 0.57–1.00), ≥1 drink/day OR: 0.87 (95% CI: 0.64–1.18)) estimates show an association between SSB consumption and lower screening in younger individuals. Conclusions: SSB consumption was associated with lower diabetes screening receipt in the younger screening group. Additional research examining factors contributing to low screening among SSB drinkers in the younger screening group are needed to develop screening interventions for these individuals.

**Keywords:** diabetes; screening; sugar sweetened beverage; epidemiology; prevention



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## 1. Introduction

Approximately 7.3 million Americans are currently living with undiagnosed diabetes, the majority of which is type 2 [1–3]. Once diagnosed, the condition can be managed with insulin or medication, as well as with changes in diet and physical activity regimens [4]. However, if diabetes is left undetected and untreated this can result in complications, such as kidney disease and nerve damage [1,5]. There is also evidence suggesting that individuals with undiagnosed diabetes (relative risk (RR): 2.7) had a greater risk of mortality than those with diagnosed diabetes (RR: 2.5) when both groups were compared to individuals without diabetes [6].

For the 50% of US adults who drink sugar sweetened beverages (SSBs) every day, undiagnosed diabetes may be a particular concern as those who have around one SSB each day have a 24% increased risk of type 2 diabetes compared to those who never drink SSBs [7–9]. Despite the American Diabetes Association (ADA) recommending diabetes screening as a way to ensure individuals receive timely diabetes care, there is limited information on nationwide screening patterns among US adults who regularly drink SSBs [10]. Thus, we conducted a study to assess diabetes screening by SSB consumption levels in US adults who fall under the ADA's recommended screening guidelines. We also compared estimates of screening prior to and following adjustment for diabetes and SSB related factors.

## 2. Materials and Methods

### *2.1. Data*

We identified individuals with SSB consumption and diabetes screening information who were screening eligible under the ADA guidelines from the 2017 Behavioral Risk Factor Surveillance System (BRFSS) survey. The BRFSS is an annual US survey administered to non-institutionalized individuals ≥18 years via landline and cell phone by the Centers for Disease Control and Prevention (CDC) [11]. BRFSS study participants are asked a number of questions on their demographic background, health care use, health behaviors, and existing conditions [11]. Survey administrators oversample underrepresented groups (i.e., racial/ethnic minorities, rural residents) in certain areas of the country in addition to using complex survey weighting to ensure estimates from BRFSS analyses are representative of the general US population [11]. Most BRFSS questions are administered in all 50 states, Washington D.C., Puerto Rico, and Guam [11]. However, our study is limited to nine states as SSB consumption was an optional module that in the 2017 survey was only administered in Alaska, Arizona, Arkansas, Delaware, Washington D.C., Hawaii, North Carolina, Vermont, West Virginia, and Wisconsin [12].

BRFSS survey responses are completely deidentified before being released for public use [11]. When using BRFSS data for research, investigators do not need to complete institutional review board approval or informed consent as these have already been obtained by the CDC [11]. Additional details about BRFSS methodology and data access can be found on the CDC's website [11].

### *2.2. Study Population*

We included individuals eligible for diabetes screening under the ADA guidelines: (1) people <45 years with body mass index ≥25 kg/m$^2$ and one or more other diabetes risk factors (i.e., hypertension, high cholesterol, physical inactivity) and (2) people ≥45 years [10]. Although ADA guidelines state that people <45 years with BMI ≥ 25 need an additional diabetes risk factor to be screening eligible, we included all BRFSS study participants <45 years with BMI ≥ 25 as there is evidence from prior literature that the majority of those <45 years with BMI ≥ 25 have an additional diabetes risk factor [13,14]. People with diabetes were automatically excluded from the study since these individuals are not asked about diabetes screening when completing the BRFSS [15].

### *2.3. Outcome, Exposure, and Covariates*

We determined the outcome, diabetes screening receipt, through the BRFSS question, "Have you had a test for high blood sugar or diabetes within the past three years?" with "Yes" responses classified as having diabetes screening and "No" responses as not having been screened [15]. The categorization of SSB consumption we used comes directly from CDC conducted BRFSS studies on SSBs [16–18]. Our exposure, total daily SSB consumption, was calculated by adding together responses to two BRFSS questions, "About how often do you drink regular soda or pop that contains sugar? Do not include diet soda or diet pop." and "During the past 30 days, how often did you drink sugar-sweetened fruit drinks (such as Kool-aid and lemonade), sweet tea, and sports or energy drinks (such as Gatorade and Red Bull)? Do not include 100 percent fruit juice, diet drinks, or artificially sweetened drinks." [16]. An individual's total daily SSB consumption was then categorized as "0 drinks/day", "between 0–1 drink/day", and "≥1 drink/day" [16]. Information on covariates known to be associated with diabetes and SSBs from the literature was also obtained from the BRFSS [7,8,10,15,19,20]. As is typically done in CDC analyses of the BRFSS, only "Don't know/Not Sure", "Refused", or "Not asked or Missing" responses to the questions used to assess the outcome and exposure resulted in an individual's exclusion from the study [21,22].

### *2.4. Statistical Analyses*

We found the distribution of study participants' characteristics by SSB consumption level. The percentage of people who had received diabetes screening in each ADA screening group by SSB consumption level was also determined. We used logistic regression models to estimate diabetes screening odds ratios (ORs) screening for the two ADA screening groups. For both screening groups, the unadjusted OR models contained SSB consumption. The adjusted OR model for the older screening group included SSB consumption, sex, race, household income, education, health care coverage, high blood pressure, high cholesterol, BMI, and history of cardiovascular disease, while the model for the younger screening group included these same variables except for BMI. We do not adjust for BMI in the younger screening group since limiting screening to those with BMI $\geq$ 25 essentially acts as a restriction [10,23]. Testing for statistical significance was conducted at $\alpha = 0.05$. All analyses had survey weighting applied to them and were carried out in R Version 4.0.

## 3. Results

### *3.1. Participant Characteristics*

Our study included 31,838 individuals of which 43.6% reported having between 0 and 1 drink/day and 23.1% $\geq$1 drink/day (Table 1). Compared to individuals who do not drink SSBs, those who had between 0 and 1 drink/day and $\geq$1 drink/day were more likely to be younger, male, have a lower household income, completed fewer years of education, and not have health insurance coverage. Overall, the distribution of clinical characteristics, such as high blood pressure, high cholesterol, BMI, and history of cardiovascular disease was comparable between SSB consumption levels.

**Table 1.** Characteristics of study participants in 2017 Behavioral Risk Factor Surveillance System survey by sugar sweetened beverage consumption levels ($n$ = 31,838).

| Covariates | 0 Drinks/Day [1] ($n$ = 10,605) | | Between 0–1 Drink/Day ($n$ = 13,883) | | ≥1 Drink/Day ($n$ = 7350) | |
|---|---|---|---|---|---|---|
| | $n$ | Weighted % (95% Confidence Interval) | $n$ | Weighted % (95% Confidence Interval) | $n$ | Weighted % (95% Confidence Interval) |
| Age | | | | | | |
| <45 | 1499 | 24.9 (24.0, 25.7) | 4144 | 45.6 (44.7, 46.4) | 2476 | 49.1 (48.0, 50.3) |
| >45 | 9106 | 75.1 (74.3, 76.0) | 9739 | 54.4 (53.6, 55.3) | 4874 | 50.9 (49.7, 52.0) |
| Sex | | | | | | |
| Male | 3852 | 39.1 (38.1, 40.0) | 6590 | 49.9 (49.1, 50.7) | 3938 | 58.4 (57.3, 59.6) |
| Female | 6753 | 60.9 (60.0, 61.9) | 7293 | 50.1 (49.3, 50.9) | 3412 | 41.6 (40.4, 42.7) |
| Race | | | | | | |
| White | 8604 | 81.4 (80.6, 82.1) | 9672 | 70.2 (69.4, 71.0) | 4902 | 69.2 (68.1, 70.2) |
| Black | 404 | 5.3 (4.9, 5.7) | 1186 | 10.7 (10.2, 11.3) | 874 | 13.4 (12.6, 14.2) |
| Multiracial/Other | 1153 | 8.0 (7.5, 8.5) | 2071 | 9.2 (8.7, 9.7) | 969 | 7.1 (6.5, 7.6) |
| Hispanic | 444 | 5.4 (4.9, 5.8) | 954 | 9.9 (9.4, 10.4) | 605 | 10.5 (9.8 11.2) |
| Household income | | | | | | |
| <$15,000 | 598 | 5.7 (5.2, 6.1) | 1032 | 6.7 (6.3, 7.1) | 958 | 11.8 (11.1, 12.5) |
| $15,000–<$25,000 | 1227 | 12.2 (11.5, 12.8) | 1855 | 14.5 (13.9, 15.1) | 1528 | 21.0 (20.1, 21.9) |
| $25,000–<$35,000 | 992 | 9.4 (8.8, 9.9) | 1367 | 9.9 (9.4, 10.4) | 922 | 13.3 (12.5, 14.0) |

**Table 1.** *Cont.*

| Covariates | 0 Drinks/Day [1] (*n* = 10,605) | | Between 0–1 Drink/Day (*n* = 13,883) | | ≥1 Drink/Day (*n* = 7350) | |
|---|---|---|---|---|---|---|
| | ***n*** | **Weighted % (95% Confidence Interval)** | ***n*** | **Weighted % (95% Confidence Interval)** | ***n*** | **Weighted % (95% Confidence Interval)** |
| $35,000–<$50,000 | 1435 | 12.1 (11.5, 12.8) | 2051 | 14.8 (14.2, 15.4) | 1108 | 16.4 (15.5, 17.2) |
| >$50,000 | 6353 | 60.7 (59.8, 61.6) | 7578 | 54.1 (53.2, 54.9) | 2834 | 37.6 (36.5, 38.7) |
| Education | | | | | | |
| Did not graduate High School | 281 | 5.5 (5.1, 6.0) | 553 | 7.9 (7.5, 8.4) | 668 | 16.3 (15.4, 17.1) |
| High school graduate | 1962 | 21.4 (20.6, 222) | 3290 | 23.8 (23.1, 24.5) | 2559 | 34.4 (33.3, 35.5) |
| Some college or technical school | 2723 | 33.1 (322, 34.0) | 3826 | 34.3 (33.5, 35.1) | 2198 | 33.7 (32.6, 34.7) |
| College graduate | 5639 | 40.0 (39.1, 40.9) | 6214 | 34.0 (33.2, 34.8) | 1925 | 15.7 (14.9, 16.5) |
| Health care coverage | | | | | | |
| Yes | 10,242 | 95.3 (94.9, 95.7) | 13,104 | 91.7 (91.3, 92.2) | 6665 | 86.2 (85.4, 87.0) |
| No | 363 | 4.7 (4.3, 5.1) | 779 | 8.3 (7.8, 8.7) | 685 | 13.8 (13.0, 14.6) |
| High blood pressure | | | | | | |
| Yes (systolic blood pressure >140 mm of mercury (mmHg) and diastolic blood pressure >90 mmHg) | 3977 | 33.6 (32.7, 34.5) | 5012 | 31.0 (30.2, 31.7) | 2902 | 33.4 (32.4, 34.5) |
| No (systolic blood pressure <140 mmHg and diastolic blood pressure <90 mmHg) | 6628 | 66.4 (65.5, 67.3) | 8871 | 69.0 (68.3, 69.8) | 4448 | 66.6 (65.5, 67.6) |

**Table 1.** *Cont.*

| Covariates | 0 Drinks/Day [1] (*n* = 10,605) | | Between 0–1 Drink/Day (*n* = 13,883) | | ≥1 Drink/Day (*n* = 7350) | |
|---|---|---|---|---|---|---|
| | ***n*** | **Weighted % (95% Confidence Interval)** | ***n*** | **Weighted % (95% Confidence Interval)** | ***n*** | **Weighted % (95% Confidence Interval)** |
| High cholesterol | | | | | | |
| Yes (total cholesterol >240 milligrams (mg)/deciliter (dL)) | 3915 | 34.4 (33.5, 35.3) | 4802 | 29.9 (29.1, 30.6) | 2446 | 27.9 (26.8, 28.9) |
| No (total cholesterol <240 mg/dL) | 6690 | 65.6 (64.7, 66.5) | 9081 | 70.1 (69.4, 70.9) | 4904 | 72.1 (71.1, 73.2) |
| Body Mass Index (BMI) | | | | | | |
| Underweight (BMI < 18.5) | 184 | 1.4 (1.1, 1.6) | 200 | 1.5 (1.3, 1.7) | 152 | 2.2 (1.8, 2.5) |
| Normal Weight (18.5 < BMI < 25.0) | 4182 | 37.1 (36.1, 38.0) | 4300 | 29.9 (29.1, 30.7) | 2010 | 28.0 (26.9, 29.0) |
| Overweight (25.0 < BMI < 30.0) | 3834 | 35.8 (34.9, 36.7) | 5304 | 38.0 (37.2, 38.8) | 2672 | 35.8 (34.7, 36.9) |
| Obese (BMI > 30.0) | 2405 | 25.8 (25.0, 26.6) | 4079 | 30.6 (29.8, 31.4) | 2516 | 34.1 (33.0, 35.2) |
| History of cardiovascular disease | | | | | | |
| Yes | 780 | 6.2 (5.8, 6.7) | 842 | 4.6 (4.3, 5.0) | 685 | 7.0 (6.4, 7.6) |
| No | 9825 | 93.8 (93.3, 94.2) | 13,041 | 95.4 (95.0, 95.7) | 6665 | 93.0 (92.4, 93.6) |

[1] Survey weights in the BRFSS have been used to obtain the weighted percentages.

### *3.2. Diabetes Screening Estimates*

In the younger screening group, individuals who had between 0 and 1 drink/day were 7.4% and those who had ≥1 drink/day were 6.7% less likely to receive screening than people who do not drink SSBs (Table 2). Only those who had ≥1 drink/day were less likely (2.8%) to receive screening compared to non-SSB drinkers in the older screening group. Screening was higher in the older screening group across all SSB consumption levels.

**Table 2.** Estimates of diabetes screening in American Diabetes Association recommended screening groups by sugar sweetened beverage consumption levels.

| Sugar Sweetened Beverage Consumption | Received Diabetes Screening within Past 3 Years | |
|---|---|---|
| | Age < 45 Years and Body Mass Index > 25 | Age ≥ 45 Years |
| | Survey Weighted % [1] (95% Confidence Interval) | Survey Weighted % (95% Confidence Interval) |
| 0 drinks/day | 64.5 (61.3, 67.8) | 71.9 (71.0, 72.9) |
| between 0–1 drink/day | 57.1 (55.2, 59.0) | 72.8 (71.9, 73.7) |
| ≥1 drink/day | 57.8 (55.5, 60.2) | 69.1 (67.8, 70.4) |

[1] Survey weighting from the Behavioral Risk Factor Surveillance System survey was used to calculate the weighted percentages.

Both individuals who had between 0 and 1 drink/day (OR: 0.73, 95% CI: 0.56–0.96) and those who had ≥1 drink/day (OR: 0.75, 95% CI: 0.56–1.01) had lower odds of screening compared to people who do not drink SSBs in the younger screening group (Table 3). Although slightly attenuated, these associations persisted after adjustment (between 0 and 1 drink/day OR: 0.76 (95% CI: 0.57–1.00), ≥1 drink/day OR: 0.87 (95% CI: 0.64–1.18)). In contrast, little association was seen between SSB consumption and diabetes in the older screening group with the slightly lower odds of screening among people who had ≥1 drink/day (OR: 0.87, 95% CI: 0.75–1.01) essentially no longer remaining after adjustment (OR: 0.97, 95% CI: 0.82–1.13).

**Table 3.** Unadjusted and adjusted odds ratios of diabetes screening receipt by sugar sweetened beverage consumption levels.

| Sugar Sweetened Beverage Consumption (Reference: 0 Drinks/Day) | Received Diabetes Screening within Past 3 Years | | | |
|---|---|---|---|---|
| | Age < 45 Years and Body Mass Index > 25 | | Age ≥ 45 Years | |
| | Unadjusted OR [1] (95% Confidence Interval) | Adjusted OR [2] (95% Confidence Interval) | Unadjusted OR (95% Confidence Interval) | Adjusted OR [3] (95% Confidence Interval) |
| between 0–1 drink/day | 0.73 (0.56, 0.96) | 0.76 (0.57, 1.00) | 1.04 (0.92, 1.18) | 1.02 (0.89, 1.17)) |
| ≥1 drink/day | 0.75 (0.56, 1.01) | 0.87 (0.64, 1.18) | 0.87 (0.75, 1.01) | 0.97 (0.82, 1.13) |

[1] All logistic models had Behavioral Risk Factor Surveillance System survey weighting applied to them. [2] Model for individuals age < 45 years and body mass index ≥ 25 adjusted for sex, race, household income, education, health care coverage, high blood pressure, high cholesterol, and history of cardiovascular disease. [3] Model for individuals age ≥ 45 years adjusted for sex, race, household income, education, health care coverage, high blood pressure, high cholesterol, and body mass index, and history of cardiovascular disease.

## 4. Discussion

In this study, we examined whether diabetes screening varied by SSB consumption levels in US adults who fall under the ADA's screening guidelines. Differences in screening by SSB consumption were mainly seen in the younger screening group. Unadjusted and adjusted screening estimates show an association between SSB consumption and lower screening receipt in younger individuals.

There have been several studies using national survey data such as the BRFSS and National Health Interview Survey (NHIS) to describe SSB consumption patterns in the general US population [16–18]. The SSB consumption levels observed in our study for ADA screening eligible individuals (between 0 and 1 drink/day: 43.6%, ≥1 drink/day: 23.1%) were comparable to those found for the general US population by Lundeen et al.

(between 0 and 1 drink/day: 41.5%, ≥1 drink/day: 32.1%) and Imoisili et al. (between 0 and 1 drink/day: 44.8%, ≥1 drink/day: 26.0%) using 2016 and 2017 BRFSS surveys, respectively [16,17]. In contrast, Chevinsky et al. found that 63.0% of adults who participated in the 2010–2015 NHIS surveys had SSBs ≥1 time/day [18]. The higher SSB consumption levels found by Chevinsky et al. compared to ours and the two other studies using the BRFSS may stem from different SSB consumption patterns during the early 2010s, the NHIS categorizing SSB consumption using frequency rather than number of drinks, and the NHIS including sweetened coffee as a SSB, while the BRFSS does not [16–18]. Our study expands on prior literature examining SSB consumption in US adults by presenting SSB consumption estimates in ADA screening eligible individuals, a group at risk for type 2 diabetes, as well as evidence that suggests SSB consumption is linked to lower diabetes screening in younger adults.

Low screening receipt and the greater influence of SSB consumption on screening in younger individuals may be attributed to differences in health attitudes by age and screening requirements for those <45. There is evidence that younger adults have lower risk perception regarding health behaviors, such as screening compared to older individuals [24,25]. Thus, people in the younger screening group could have forgone screening because they feel their diabetes risk is low since the average age of diabetes onset is 45 years [24–26]. Unlike people ≥45 years, people <45 years may encounter medical stigma or feel a sense of shame since they must possess an additional diabetes risk factor, as well as being overweight in order to qualify for screening [27]. Knowing that SSB consumption is viewed as an unhealthy behavior, younger individuals who drink SSBs may feel additional stigma or shame compared to those who do not drink SSBs [27]. Consequently, this additional stigma or shame could deter SSB drinkers <45 years from undergoing screening [27]. To determine if these reasons actually explain screening differences by SSB consumption in those <45 years, further qualitative type studies involving screening eligible individuals in this age group are needed.

Existing US literature on SSB consumption in people with diabetes offers encouraging signs that screening and diagnosis can lead to reductions in SSB consumption in this population [28,29]. In a study of 1090 National Health and Nutrition Examination Survey participants, 60% of individuals with undiagnosed diabetes had SSBs daily compared to 38% of individuals with diagnosed diabetes [28]. Additionally, a qualitative study on SSB consumption changes in households where one or more adults was diagnosed with diabetes found that not only did a majority of adults decrease their SSB consumption, but they also eliminated SSBs from the home resulting in lower SSB consumption for their children as well [29]. Findings from these two studies suggest that diabetes screening and subsequent diagnosis can have an impact on reducing SSB consumption beyond the diagnosed individual, making it even more critical to improve screening receipt among screening eligible individuals who regularly consume SSBs.

There are study limitations that need to be considered. Some degree of misclassification is to be expected when using self-reported data such as the BRFSS. Nonetheless, validations studies comparing BRFSS and electronic health record (EHR) prevalence of clinical conditions such as obesity (BRFSS: 23.8%, EHR: 22.8%), hypertension (BRFSS: 29.6%, EHR: 26.3%), and diabetes (BRFSS: 9.7%, EHR: 9.4%) have found estimates from the two data sources to be similar [30]. Some residual confounding may remain in our study. However, we tried to maintain a balance between confounding and statistical power by controlling for a number of diabetes and SSB related covariates frequently mentioned in diabetes and SSB literature [7,8,10,15,19,20]. Despite some limitations, our study provides contemporary information about how SSB consumption influences diabetes screening among US adults.

## 5. Conclusions

An association between SSB consumption and lower diabetes screening was observed in younger adults eligible for diabetes screening. Diabetes screening is a key part of primary

prevention that allows for timely diagnosis and appropriate treatment or lifestyle changes. As such, younger screening eligible adults who regularly consume SSBs would benefit from additional research that explores what factors influence their decision not to undergo screening.

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**Informed Consent Statement:** This article is exempt from needing informed consent as no human participants were involved in the study and the data used has been completely anonymized and approved for public use by the United States Centers for Disease Control and Prevention (CDC).

**Data Availability Statement:** All BRFSS datasets and corresponding codebooks can be found at the CDC's website (https://www.cdc.gov/brfss/data_documentation/index.htm, accessed on 30 September 2021).

**Conflicts of Interest:** The authors declare no conflict of interest.

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