Epidemiologic studies have suggested that higher intake of added sugar is associated with cardiovascular disease (CVD) risk factors. Few prospective studies have examined the association of added sugar intake with CVD mortality.

OBJECTIVE To examine time trends of added sugar consumption as percentage of daily calories in the United States and investigate the association of this consumption with CVD mortality.


MAIN OUTCOMES AND MEASURES Cardiovascular disease mortality.

RESULTS Among US adults, the adjusted mean percentage of daily calories from added sugar increased from 15.7% (95% CI, 15.0%-16.4%) in 1988-1994 to 16.8% (16.0%-17.7%): P = .02 in 1999-2004 and decreased to 14.9% (14.2%-15.5%; P < .001) in 2005-2010. Most adults consumed 10% or more of calories from added sugar (71.4%) and approximately 10% consumed 25% or more in 2005-2010. During a median follow-up period of 14.6 years, we documented 831 CVD deaths during 163 039 person-years. Age-, sex-, and race/ethnicity–adjusted hazard ratios (HRs) of CVD mortality across quintiles of the percentage of daily calories consumed from added sugar were 1.00 (reference), 1.09 (95% CI, 1.05-1.13), 1.23 (1.12-1.34), 1.49 (1.24-1.78), and 2.43 (1.63-3.62; P < .001), respectively. After additional adjustment for sociodemographic, behavioral, and clinical characteristics, HRs were 1.00 (reference), 1.07 (1.02-1.12), 1.18 (1.06-1.31), 1.38 (1.11-1.70), and 2.03 (1.26-3.27; P = .004), respectively. Adjusted HRs were 1.30 (95% CI, 1.09-1.55) and 2.75 (1.40-5.42; P = .004), respectively, comparing participants who consumed 10.0% to 24.9% or 25.0% or more calories from added sugar with those who consumed less than 10.0% of calories from added sugar. These findings were largely consistent across age group, sex, race/ethnicity (except among non-Hispanic blacks), educational attainment, physical activity, health eating index, and body mass index.

CONCLUSIONS AND RELEVANCE Most US adults consume more added sugar than is recommended for a healthy diet. We observed a significant relationship between added sugar consumption and increased risk for CVD mortality.
Consumption of added sugar, including all sugars added in processing or preparing foods, among Americans aged 2 years or older increased from an average of 235 calories per day in 1977-1978 to 318 calories per day in 1994-1996. This change was mainly attributed to the increased consumption of sugar-sweetened beverages. Although the absolute and percentage of daily calories derived from added sugars declined between 1999-2000 and 2007-2008, consumption of added sugars remained high in US diets, especially among children. Recommendations for added sugar consumption vary substantially. The Institute of Medicine recommends that added sugar make up less than 25% of total calories, whereas the World Health Organization recommends less than 10%. The American Heart Association recommends limiting added sugars to less than 100 calories daily for women and 150 calories daily for men. The 2010 Dietary Guidelines for Americans recommend limiting total intake of discretionary calories, which include added sugars and solid fats, to 5% to 15% of daily caloric intake. Randomized clinical trials and epidemiologic studies have shown that individuals who consume higher amounts of added sugar, especially sugar-sweetened beverages, tend to gain more weight and have a higher risk of obesity, type 2 diabetes mellitus, dyslipidemias, hypertension, and cardiovascular disease (CVD). Most previous studies have focused on sugar-sweetened beverages but not total added sugar, and none of these studies has used nationally representative samples to examine the relationship between added sugar intake and CVD mortality.

In the present study, we examined time trends of consumption of added sugar as percentage of total daily calories using a series of national representative samples. In addition, we investigated the association of this consumption with CVD mortality using a prospective cohort of a nationally representative sample of US adults.

Methods

National Health and Nutrition Examination Survey

The National Health and Nutrition Examination Survey (NHANES) comprises a series of cross-sectional, stratified, multistage probability surveys of the civilian, noninstitutionalized US population. The NHANES was conducted periodically before 1994; beginning in 1999, it became a continuous program, with every 2 years representing 1 cycle. Each survey participant completed a household interview and underwent a physical examination at a mobile examination center. Detailed descriptions of NHANES methods are published elsewhere.

NHANES III and NHANES 1999-2002 used a probabilistic matching algorithm to the National Death Index to determine the mortality status. Follow-up of participants continued until death attributable to CVD, with censoring at the time of death for those who died from causes other than CVD. Participants not matched with a death record were considered to be alive through the entire follow-up period. A detailed description of this methodology has been published elsewhere. The International Statistical Classification of Diseases, 10th Revision was used to identify participants for whom CVD (codes I00-I78) was listed as the underlying cause of death.

Estimating Usual Percentage of Calories From Added Sugar

Added sugars include all sugars used in processed or prepared foods, such as sugar-sweetened beverages, grain-based desserts, fruit drinks, dairy desserts, candy, ready-to-eat cereals, and yeast breads, but not naturally occurring sugar, such as in fruits and fruit juices. We used 24-hour dietary recall to estimate intake of added sugar. All NHANES participants who received physical examinations provided a single 24-hour dietary recall through in-person interviews. Availability of second dietary recall varied by time period. In NHANES III, approximately 8% of the adult participants provided a second dietary recall; from 1999 to 2002, second recalls were not available. In 2003-2004 and 2005-2010, 93% and 88% of participants participated in second dietary surveys through the telephone interviews 3 to 10 days after mobile examination center interviews.

Nutrient intake from foods was estimated with the corresponding US Department of Agriculture Food and Nutrient Databases for Dietary Studies (FNDDS). However, FNDDS do not include information on added sugar for many foods. To estimate the intake of added sugar, we merged individual food files from NHANES with the MyPyramid Equivalents Database (MPED). The MPED has 2 versions; we merged the NHANES III and NHANES 1999-2002 individual foods files with MPED 1.0 and NHANES 2003-2004 and 2005-2010 food files with MPED 2.0 to calculate intake of added sugars. Of 5440 unique US Department of Agriculture food codes (8-digit codes)
in NHANES 2005-2010, 5030 of these foods were available from MPED 2.0. We matched the remaining 410 foods to the nearest food codes (most of the matched food codes differed by the last 2 digits) to estimate added sugar content. For example, the food code 52302020 (muffin, fruit and/or nut, low fat) was matched to 52302010 (muffin, fruit and/or nut). A detailed description of the MPED and estimates of added sugar from foods are published elsewhere.39

Data from single 24-hour dietary recalls are subject to measurement errors caused by day-to-day variation in intakes,31,32 which tends to attenuate the association.33 To correct for measurement errors, we used a method developed by the National Cancer Institute (NCI) that can be used to estimate the distribution of the usual percentage of calories from added sugar in the population.34 This method also can be used to examine the nutrient-disease association corrected for measurement error, also known as the regression calibration.35 The NCI method requires that at least some respondents have multiple days of nutrient values to estimate the within-and-between-individual variations.34,36 For the trend analysis, the models included the following covariates: day of the week when 24-hour recall was collected (weekday vs weekends), age, sex, and race/ethnicity.36 For the association analysis, we also included educational attainment, smoking status, alcohol consumption, antihypertensive medication use, physical activity, family history of CVD, and 1995 Healthy Eating Index (HEI) scores.36,37

The covariates included race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, or other), educational attainment (<12, 12, or ≥12 years of education), smoking status (never, former, or current), alcohol consumption (0, <3, or ≥3 drinks/wk), physical activity (0, <5, or ≥5 times/wk of moderate-intensity to vigorous activities), BMI (≥25, 25 to <30, or ≥30), family history of CVD (yes/no), and antihypertensive medication use (yes/no). Systolic blood pressure and total serum cholesterol (milligrams per deciliter) were included as continuous variables. The HEI includes 10 components: fruits, vegetables, grains, dairy, meats, fats, saturated fat, cholesterol, sodium, and dietary variety. The total score ranges from 0 to 100, with a higher score indicating a healthier diet.37

Statistical Analysis
We calculated the weighted mean and 95% CI of the usual percentage of calories from added sugar across categories of selected covariates for NHANES III (1988-1994), 1999-2004, and 2005-2010. We also estimated the percentage of the population who consumed 10% or more6 or 25% or more7 of calories from added sugar. We conducted the pairwise 2-tailed t tests to identify the difference in means and prevalence across surveys.

We used Cox proportional hazards regression to estimate the hazard ratios (HRs) and 95% CIs for CVD mortality. Because the observed association between percentage of calories from added sugar and CVD mortality appeared to be nonlinear (P < .05 for linearity), we used the Box-Cox transformation, with λ = 2.5 when estimating the usual percentage of calories from added sugar using the NCI method.35 To present the results, we calculated the 10th, 30th, 50th, 70th, and 90th percentiles’ distribution of the estimated added sugar intake as the middle value of each quintile. We estimated the adjusted HRs by comparing the middle values of each quintile (Q) with the lowest quintile as reference (Q5, Q4, Q3, and Q2 vs Q1).35,38 To examine the association between added sugar intake and CVD mortality by different cut points, ie, less than 10% by the World Health Organization (in line with the American Heart Association’s recommendation)4,5 and less than 25% by the Institute of Medicine,3 we estimated the adjusted HRs by comparing participants who consumed 25% or more, more than 10%, and less than 25% of their calories from added sugar with those who consumed less than 10% of their calories from added sugar. We estimated age-, sex-, and race/ethnicity-adjusted HRs as well as the multivariable-adjusted HRs including age, sex, race/ethnicity, educational attainment, smoking status, alcohol consumption, antihypertensive medication use, physical activity level, family history of CVD, HEI score, BMI, systolic blood pressure, total serum cholesterol, and total calories. We also determined the results of stratified analysis by age group (<60 years vs ≥60 years), sex, race/ethnicity, educational attainment (<12 vs ≥12 years), physical activity (<5 times/wk of moderate-intensity vs vigorous activities vs others), HEI score (top 50% [score ≥63.5] vs other), and BMI (normal vs overweight/obese). We calculated the covariates-adjusted number needed to harm associated with each quintile of added sugar intake at 15-years of follow-up (15 years represents the median follow-up),39 and the 95% CI of the number needed to harm was based on 2.5th and 97.5th percentile values of 500 rescaled bootstrap weights.40,41

The proportional hazards assumption of the Cox models was evaluated with Schoenfeld residuals, which revealed no significant departures from proportionality in hazards over time. We tested for interactions of the usual percentage of calories from added sugar with covariates by including the interaction terms in the Cox models based on Satterthwaite-adjusted F tests.42,43

We conducted several sensitivity analyses (Supplement [eAppendix and eTables 1-7]). All analyses were conducted with SAS, version 9.3 (SAS Institute, Inc) or SUDAAN, version 11, to take into account the complex sampling design.44 All tests were 2-sided, and P < .05 was considered statistically significant.

Results
Of participants included in the study from the NHANES III (1988-1994) (n = 11,733), NHANES 1999-2004 (n = 8786), and NHANES 2005-2010 (n = 10,628), the proportion of non-Hispanic whites decreased from 76.3% in 1988-1994 to 69.6% in 2005-2010 (P = .004) and the Mexican American proportion increased from 5.1% to 9.0% in 2005-2010 (P < .001). The mean percentage of calories from added sugar increased from 15.7% (95% CI, 15.0%-16.4%) in 1988-1994 to 16.8% (16.0%-17.7%; P < .02) in 1999-2004 and decreased to 14.9% (14.2%-15.5%; P < .001) in 2005-2010 (Table 1). Most adults consumed 10% or more of calories from added sugar (71.4%), and

Table 1: Adjusted Hazard Ratios for CVD Mortality and Added Sugar Intake

<table>
<thead>
<tr>
<th>Quartile</th>
<th>Hazard Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>1.00 (Reference)</td>
</tr>
<tr>
<td>Q2</td>
<td>0.85 (0.75-0.96)</td>
</tr>
<tr>
<td>Q3</td>
<td>0.80 (0.71-0.90)</td>
</tr>
<tr>
<td>Q4</td>
<td>0.75 (0.67-0.84)</td>
</tr>
<tr>
<td>Q5</td>
<td>0.70 (0.62-0.79)</td>
</tr>
</tbody>
</table>

Downloaded From: https://archinte.jamanetwork.com/ by a Non-Human Traffic (NHT) User on 04/19/2019
Table 1. Estimated Mean, 10% or More, and 25% or More of Calories Participants Consumed From Added Sugars and Cardiovascular Diseases Mortality

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>NHANES 1988-1994&lt;sup&gt;a&lt;/sup&gt;</th>
<th>NHANES 1999-2004&lt;sup&gt;b&lt;/sup&gt;</th>
<th>NHANES 2005-2010&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (95% CI)</td>
<td>Mean (95% CI)</td>
<td>Mean (95% CI)</td>
</tr>
<tr>
<td>No. of</td>
<td>% of Calories</td>
<td>% Who Consumed ≥10% Calories</td>
<td>% Who Consumed ≥25% Calories</td>
</tr>
<tr>
<td>Participants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All participants</td>
<td>11,733</td>
<td>15.7</td>
<td>78.1 (73.8-82.4)*</td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;60</td>
<td>8835</td>
<td>16.3</td>
<td>80.5 (76.1-84.9)*</td>
</tr>
<tr>
<td>≥60</td>
<td>2898</td>
<td>13.3</td>
<td>66.7 (61.4-72.0)*</td>
</tr>
<tr>
<td>Smoking status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Former</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>5639</td>
<td>15.7</td>
<td>78.1 (73.3-83.0)*</td>
</tr>
<tr>
<td>Women</td>
<td>6094</td>
<td>15.7</td>
<td>78.0 (73.7-82.4)*</td>
</tr>
<tr>
<td>Educational attainment, y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-11</td>
<td>4318</td>
<td>15.1</td>
<td>75.1 (70.4-79.9)*</td>
</tr>
<tr>
<td>12</td>
<td>3777</td>
<td>15.9</td>
<td>78.8 (74.6-83.0)*</td>
</tr>
<tr>
<td>≥12</td>
<td>3638</td>
<td>15.9</td>
<td>79.0 (74.8-83.5)*</td>
</tr>
<tr>
<td>Smoking status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); NHANES, National Health and Nutrition Examination Survey.

<sup>a</sup>Among US adults 20 years or older; NHANES, 1988-1994, 1999-2004, and 2005-2010. P values are presented for difference across the categories of selected covariates within each NHANES. Pairwise P values are presented. All tests were 2-tailed and based on t tests.

<sup>b</sup>The mean usual percentage or prevalence of 10% or more or 25% or more of calories from added sugar across the NHANES surveys that were not sharing a common symbol (*, †, or ‡) were significantly different at just 5% based on t tests.
The observed association between usual percentage of calories from added sugar and CVD mortality was largely consistent across age group, sex, race/ethnicity (except among non-Hispanic blacks), educational attainment, physical activity level, HEI score, and BMI (Figure 2 and Supplement [eTable 1 and eFigure]). However, we observed a marginally significant interaction between percentage of calories from added sugar and race/ethnicity (P = .09), and the pattern of this association was observed in other groups but not among non-Hispanic blacks (Supplement [eTable 1]). Compared with the participants who consumed less than 10% of calories from added sugar (same as in Q1), those who consumed above the thresholds of 10% or 25% of calories from added sugar were younger; more likely to be non-Hispanic black; less likely to be currently smoking; had lower levels of physical activity, total serum cholesterol, systolic blood pressure, total serum cholesterol, and total calories intake.

Among the participants who consumed 25.0% or more of calories from added sugar, we used the 95th percentile value (28.7%) as a proxy of the midvalue.

Abbreviations: CVD, cardiovascular disease; HEI, Healthy Eating Index score; BMI, body mass index.

### Table 2. Adjusted HR of CVD Mortality According to Usual Percentage of Calories From Added Sugar

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Q1 (7.4%)</th>
<th>Q2 (11.4%)</th>
<th>Q3 (14.8%)</th>
<th>Q4 (18.7%)</th>
<th>Q5 (25.2%)</th>
<th>P Valueb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range (0–100)/usual percentage, %</td>
<td>0 to &lt;9.6</td>
<td>9.6 to &lt;13.1</td>
<td>13.1 to &lt;16.7</td>
<td>16.7 to &lt;21.3</td>
<td>≥21.3</td>
<td></td>
</tr>
<tr>
<td>HR (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted only for age, sex, race/ethnicity</td>
<td>1 [Ref]</td>
<td>1.09 (1.05 to 1.13)</td>
<td>1.23 (1.12 to 1.34)</td>
<td>1.49 (1.24 to 1.78)</td>
<td>2.43 (1.63 to 3.62)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Fully adjustedc</td>
<td>1 [Ref]</td>
<td>1.07 (1.02 to 1.12)</td>
<td>1.18 (1.06 to 1.31)</td>
<td>1.38 (1.11 to 1.70)</td>
<td>2.03 (1.26 to 3.27)</td>
<td>.004</td>
</tr>
<tr>
<td>Adjusted NNH at 15-y follow-upd</td>
<td>265 (166 to 715)</td>
<td>109 (67 to 297)</td>
<td>53 (33 to 152)</td>
<td>22 (13 to 66)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: CVD, cardiovascular disease; HR, hazard ratio; NNH, number needed to harm; Q, quintile; Ref, reference.

a Data on US adults 20 years or older from the National Health and Nutrition Examination Survey Linked Mortality Files, 1988-2006. There were 831 deaths due to CVD in 11 733 participants (163 039 total person-years).

b P value for testing significant association between the usual percentage of calories from added sugar and CVD mortality based on Satterthwaite test; all tests are 2-tailed.

c Adjusted for age, sex, race/ethnicity, educational attainment, smoking status, alcohol consumption, physical activity level, antihypertensive medication use, family history of CVD, Healthy Eating Index score, body mass index, systolic blood pressure, total serum cholesterol, and total calories intake.

d Adjusted for age, sex, race/ethnicity, educational attainment, smoking status, alcohol consumption, physical activity level, antihypertensive medication use, family history of CVD, healthy eating index score, body mass index, systolic blood pressure, total serum cholesterol, and total calories intake.

Abbreviations: CVD, cardiovascular disease; HR, hazard ratio; Ref, reference.

a Data on US adults 20 years or older from the National Health and Nutrition Examination Survey Linked Mortality Files, 1988-2006. There were 831 deaths due to CVD in 11 733 participants (163 039 total person-years).

Among the participants who consumed 25.0% or more of calories from added sugar, we used the 95th percentile value (28.7%) as a proxy of the midvalue.

Abbreviations: CVD, cardiovascular disease; HEI, Healthy Eating Index score; BMI, body mass index.

### Table 3. Adjusted HR of CVD Mortality Comparing Percentage of Calories From Added Sugar Greater Than or Equal to 10% or 25% With Less Than 10%

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>5.0%</th>
<th>17.5%</th>
<th>28.7%</th>
<th>P Valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range (0–100)/usual percentage, %</td>
<td>0 to &lt;10.0</td>
<td>10.0 to &lt;25.0</td>
<td>≥25.0</td>
<td></td>
</tr>
<tr>
<td>HR (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted only for age, sex, race/ethnicity</td>
<td>1 [Ref]</td>
<td>1.39 (1.20 to 1.62)</td>
<td>3.55 (2.00 to 6.29)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Fully adjustedd</td>
<td>1 [Ref]</td>
<td>1.30 (1.09 to 1.55)</td>
<td>2.75 (1.40 to 5.42)</td>
<td>.004</td>
</tr>
</tbody>
</table>

Abbreviations: CVD, cardiovascular disease; HR, hazard ratio; Ref, reference.

a Data on US adults 20 years or older from the National Health and Nutrition Examination Survey Linked Mortality Files, 1988-2006. There were 831 deaths due to CVD in 11 733 participants (163 039 total person-years).

b Adjusted for age, sex, race/ethnicity, educational attainment, smoking status, alcohol consumption, physical activity level, antihypertensive medication use, family history of CVD, healthy eating index score, body mass index, systolic blood pressure, total serum cholesterol, and total calories intake.
take was moderately and negatively correlated with total grain, vegetable, meat, and variety components ($r = -0.06, -0.20$, $-0.12$, and $-0.19$, respectively; $P < .05$) and moderately and positively correlated with total fat and cholesterol intake ($r = 0.17$ and $0.08; P < .05$). However, HRs remained largely unchanged after adjusting each component of the HEI (Supplement [eTable 6]). We observed a significant association between sugar-sweetened beverage consumption and risk of CVD mortality, with an adjusted HR of 1.29 (95% CI, 1.04-1.60) when comparing participants who consumed 7 or more servings/wk (360 mL per serving) with those who consumed 1 serving/wk or less (Supplement [eTable 7]).
Sugar Intake and Cardiovascular Diseases Mortality

Epidemiologic studies5,47 have suggested that higher consumption of added sugar is associated with increased consumption of total calories and unhealthy dietary patterns, which in turn might increase the risk of unhealthy outcomes, such as weight gain, type 2 diabetes mellitus, and CVD. Thus, added sugar intake may be a marker for unhealthy dietary patterns. However, when we adjusted for overall diet quality as reflected by HEI and its individual components, the results did not change appreciably, suggesting that the association between added sugar intake and CVD mortality was not explained by overall diet quality.

The biological mechanisms underlying the association between added sugar intake and CVD risk are not completely understood. Emerging evidence supports the hypothesis that excessive intake of added sugar might play a role through multiple pathways.14 Animal studies48 have suggested that high intake of refined sugars, independent of weight gain, was associated with the development of hypertension. A recent observational study50 suggested that excessive consumption of sugar-sweetened beverages and sugar was independently associated with increased blood pressure. Excessive intake of sugar was also associated with increased de novo lipogenesis in the liver, hepatic triglyceride synthesis, and increased triglyceride levels, a known risk factor for CVD.5,49 In one study,18 regular intake of added sugar was significantly associated with increased triglyceride levels and low-density lipoprotein cholesterol levels and decreased high-density lipoprotein cholesterol levels. Another proposed pathway of the relationship between excessive sugar intake and increased CVD risk is its association with inflammation markers, which are key factors in the pathogenesis of CVD.14,50,51 Several recent studies52,53 have indicated an association between higher consumption of sugar-sweetened beverages and inflammatory markers. In addition, a recent study12 suggested a significant interaction between genetic factors and sugar-sweetened beverage consumption in relation to BMI, in which higher consumption was associated with increased genetic effects of obesity. Another study54 suggested that carrying a genetic variant in the PNPLA3 gene might be susceptible to increased hepatic fat, which is associated with increased risk for CVD, when dietary sugar intake was high among Hispanic children. Further studies are needed to examine potential interactions between genetic susceptibility and added sugar intake in relation to CVD risk.

Our study has several strengths. First, the availability of data on added sugar intake from a series of nationally representative samples of US adults allowed us to examine trends of consumption. Second, we used a validated method to estimate the usual percentage of calories from added sugar. The use of the NCI method to estimate usual nutrient intake provided a more powerful way to assess nutrient-disease associations compared with the use of a single 24-hour dietary recall.34-36,38 Finally, our study adjusted for a wide range of potential confounding variables.

There are also several limitations to our study. First, in NHANES III (1988-1994), approximately 8% (n = 962) of the participants provided a second-day 24-hour dietary recall. However, these data were adequate to provide a robust estimate of usual intake of added sugar.31-34 For further NHANES...
years, more than 88% of the participants provided a second 24-hour recall. When we pooled 1999-2002 data (which had single 24-hour dietary recalls) with 2003-2004 data to estimate usual intake, our results were consistent when restricting analysis to NHANES 2003-2004 data (results not shown). Second, for the association analysis, added sugar intake was assessed at baseline and not updated during the follow-up period. The baseline exposure might not capture changes in intake over time. Third, although we adjusted for a comprehensive set of covariates in our multivariable models, the associations reported in our study may partially result from other unobserved confounding variables, from residual confounding, or by other dietary variables. However, use of the HEI provided a comprehensive assessment of overall dietary pattern and should have significantly reduced the confounding effect of other dietary variables. Further adjusting the sodium intake did not alter the results. Fourth, the observed association between added sugar and CVD mortality was significant in other groups but not among non-Hispanic blacks, perhaps because of a limited number of events in subgroups. Another possible explanation is that non-Hispanic blacks may be less susceptible to the metabolic effects of sugars, although this hypothesis needs to be further tested. Finally, although observational studies are important in improving our understanding of nutrient-disease relationships, they should not be directly interpreted as evidence of causal relationships without considering other lines of evidence.

Conclusions

Our findings indicate that most US adults consume more added sugar than is recommended for a healthy diet. A higher percentage of calories from added sugar is associated with significantly increased risk of CVD mortality. In addition, regular consumption of sugar-sweetened beverages is associated with elevated CVD mortality. Our results support current recommendations to limit the intake of calories from added sugars in US diets.

ARTICLE INFORMATION

Accepted for Publication: November 6, 2013.
Published Online: February 3, 2014.

Author Contributions: Drs Yang and Zhang had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Yang, Gregg, Hu.

Acquisition of data: Zhang.

Analysis and interpretation of data: Yang, Zhang, Flanders, Merritt, Hu.

Drafting of the manuscript: Yang.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Yang, Zhang, Flanders.

Administrative, technical, or material support: Gregg.

Study supervision: Yang, Hu.

Conflict of Interest Disclosures: None reported.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Additional Contributions: Victor Kipnis, PhD (Division of Cancer Prevention, NCI), provided advice on using the NCI method to estimate the usual percentage of total calories from added sugar and its association with CVD mortality with data from the NHANES III Linked Mortality Files. Cathleen Gillespie, MS (Epidemiology and Surveillance Branch), and Yuling Hong MD, PhD (Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention), provided helpful comments. The contributors received no compensation for their services.

REFERENCES