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Authors
Prather, Aric A
Leung, Cindy W
Adler, Nancy E
et al.

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Short and sweet: Associations between self-reported sleep duration and sugar-sweetened beverage consumption among adults in the United States

Aric A. Prather, Ph.D.[1,2], **Cindy Leung, Sc.D, M.P.H.**[2], **Nancy E. Adler, Ph.D.**[1,2], **Lorrene Ritchie, Ph.D., R.D.**[3], **Barbara Laraia, Ph.D., M.P.H., R.D.**[2,4], and **Elissa S. Epel, Ph.D.**[1,2]

[1]Department of Psychiatry, University of California, San Francisco

[2]Center for Health and Community, University of California, San Francisco

[3]Nutrition Policy Institute, University of California, Division of Agriculture and Natural Resources

[4]Division of Community Health and Human Development, School of Public Health, University of California, Berkeley

Abstract

Objectives—Sugar sweetened beverages (SSBs) are a major factor in the development of obesity and cardiometabolic disease. Shortened sleep duration has also been linked to increased appetite and obesity. Here, we examined whether there was an association between self-reported sleep duration and SSB consumption among adults aged 18 years and older.

Methods—Using data from 2005–12 NHANES we examined self- reported sleep duration and beverage intake (types of SSBs, juice, water, coffee, tea) from two 24-hour dietary recalls among 18,779 adults. Adults who slept 7–8 hours/night were considered the reference group. Generalized linear models were computed adjusting for sociodemographics and health characteristics as well as total energy intake.

Results—Thirteen percent slept 5 or fewer hours per night. In fully adjusted models, those who slept 5 hours or less had 21% higher SSB consumption, (RD = 1.21, 95% CI 1.11–1.32). When broken down by beverage type this was due to caffeinated sugary beverages. Longer sleepers (≥9 hour sleepers) consumed fewer servings of coffee and water. There were no associations between self-reported sleep duration and consumption of 100% juice, tea, or diet drinks.

Conclusions—Short sleep is associated with greater intake of sugared caffeinated sodas, a relationship which may have important, though unrecognized, implications for physical health. Directionality of this relationship cannot be determined from this study. While caffeinated drinks could account for impaired sleep, it is possible that short sleep could influence one's appetitive

Corresponding Author: Aric A. Prather, Ph.D., Center for Health and Community, University of California, San Francisco, 3333 California St., Suite 465, San Francisco, CA 94118, aric.prather@ucsf.edu, Work: (415) 476-7758, Fax: (415) 502-1010.

drive for sugared caffeine drinks. Further examination of this relationship using prospective designs is warranted.

Keywords

sleep; sugar-sweetened beverage; diet; NHANES

INTRODUCTION

Sugar sweetened beverages (SSBs) are the primary source of added sugar in the American diet (1). SSBs are linked to weight gain (2, 3) and increased incidence of coronary heart disease and type 2 diabetes (4–6). Epidemiologic data indicate that approximately 50% of the U.S. population consumes a SSB on any given day (7) and from the late 1970s to 2001 there was a three-fold increase in SSB consumption (3.9% to 9.2% of calories consumed) (8). The new 2015–20 U.S Department of Agriculture (USDA) Dietary Guidelines recommends added sugar consumption be limited to less than 10% of an individual's daily caloric intake (9). While the consumption of added sugars has declined in recent years, average consumption among Americans remains above recommended levels (10) (i.e., 88 grams of sugar per day) (11); excess SSB consumption significantly contributes to these high levels.

Factors that contribute to SSB consumption are multifaceted, and include a range of social, environmental, and behavioral determinants. One factor that has received little attention is the role of sleep, despite the fact the growing cross-sectional and prospective evidence linking short sleep duration (e.g., sleeping less than 6 hours per night) to weight gain and obesity (12–15) as well as other negative physical health outcomes (e.g. type 2 diabetes (16–19)) observed at greater frequency among those who consume high levels of SSBs.

The relationship between sleep and SSB consumption is likely complex. Experimental evidence indicates that acute and prolonged sleep loss can have substantial biologic and behavioral effects that may influence SSB consumption. For instance, adults exposed to either total or partial sleep restriction display alterations in satiety hormonal regulators such as ghrelin (20) and leptin (20, 21), report increases in hunger (20, 22), consume food beyond the energy costs of being awake (23), and report preferences for high fat, high carbohydrate-rich foods (22, 24). In addition to food preferences, sleep loss also affects food choice. In this regard, compared to a night of normal sleep, participants who undergo a night of total sleep deprivation and then subjects to a food purchasing task were significantly more likely to use their fixed budget to purchase high caloric foods, including those high in fat and sugar (25). Alternatively, SSB consumption may result in shorter sleep duration. Many SSBs include caffeine, a well-recognized stimulant that increases alertness and, when consumed near bedtime, negatively influences one's ability to sleep. Indeed, caffeine avoidance is one of the key components of sleep hygiene recommendations (26). Research on associations between sleep and SSB consumptions, in general, has been limited and there are no studies exploring the sleep-SSB link in adults.

If there is evidence that sleep duration is related to amount of SSB consumption, adequate sleep may serve as a viable intervention target for curbing weight-related disease risk.

Accordingly, the aim of the present study was to examine the associations between self-reported measures of sleep duration and sugar-sweetened beverage consumption in a nationally representative sample from the National Health and Nutrition Survey (NHANES).

PARTICIPANTS AND METHODS

Study Population

NHANES is an ongoing, multi-stage cross-sectional survey administered by the National Center for Health Statistics. NHANES is designed to be representative of the civilian, non-institutionalized U.S. population and collects information on general health status, nutritional intake, health-related behaviors, and physiologic measurements from a questionnaire and a physical examination. This study combined data from 2005–12 NHANES cycles (i.e., 2005–06; 2007–08; 2009–10; 2011–12), yielding data on 18,779 adults aged 18 years and older.

Self-reported sleep

Questions about sleep habits and sleep disorders were added to the NHANES questionnaire beginning in 2005 and were asked to adults aged 16 years and older. Average sleep duration was calculated from the question, "How much sleep do you usually get on weekdays or workdays?" and collapsed into four categories: ≤5 hours/day, 6 hours/day, 7–8 hours/day, ≥9 hours/day (27).

Sugar-sweetened beverage consumption

Two 24-hour dietary recalls were administered to NHANES study participants; the first was conducted in person, and the second was conducted over the phone 3–10 days after the examination. Data from the USDA Food and Nutrient Database for Dietary Studies were used to estimate dietary variables of interest.

Daily consumption (in 8 ounce servings) of beverages was estimated and averaged across two days of intake for each participant. Because our interest was in total SSB intake, we created a summary measure of total SSB consumption as our primary outcome, which included sugar-sweetened sodas (i.e., regular soda) and non-carbonated sugary beverages (e.g. fruit drinks, smoothies, sports drinks, energy drinks, flavored milk, sweetened coffee and tea drinks, and sweetened waters). We also included other frequently consumed beverages, such as 100% fruit juice, diet drinks (e.g. beverages containing artificial sweeteners), plain (unsweetened) coffee, plain (unsweetened) tea, and plain water. Beverages associated with sleep duration were further categorized into caffeinated and de-caffeinated.

Study covariates

Covariates of interest included sociodemographics and health characteristics. Sociodemographic characteristics included age, gender, race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, other race/multiracial), highest level of education (< 12 years, high school diploma or equivalent, some college, college graduate), ratio of household income to the federal poverty level (FPL; 0–100% FPL, 100–200% FPL, 200–300% FPL, 300–400% FPL, >400% FPL), and marital status (married or living with partner, separated/widowed/divorced, never married). Health characteristics and behaviors included smoking status (never, former, current), physical activity (sedentary, moderately active, vigorously active), self-reported health status (fair or poor, good, very good or excellent), and self-reported diagnosis of a sleep disorder (yes/no). Total energy intake and survey year (e.g. 2005–06; 2007–08; 2009–10; 2011–12) were also included as covariates. Missing indicators were used to account for missing information for educational level (n=17), marital status (n=713), household income (n=1394), smoking status (n=110), physical activity (n=1478), self-reported health status (n=1102) and diagnosis of a sleep disorder (n=24).

Statistical analysis

To make nationally representative estimates, complex dietary survey weights were used to account for different sampling probabilities and participation rates across the eight-year period. Individuals with an incomplete dietary recall, with total energy intake <500 or >5,000 calories, and women pregnant at the time of the survey were excluded from the analysis, resulting in an analytic sample of 18,779 participants.

Descriptive statistics were used to compare distributions of sociodemographic and health characteristics by sleep categories. To account for the skewed distribution of beverage intakes, we examined associations with sleep categories using generalized linear models (GLM), assuming a gamma distribution and log link. These results are interpreted as the relative differences (RD) in beverage intakes between groups, using 7–8 hours/day of sleep as the reference. Models were adjusted for all sociodemographic and health characteristics listed previously. All statistical significance tests were two-sided and significance was considered at $P<0.05$. Statistical analyses were performed using SAS 9.3 (SAS Institute Inc., Cary, NC) and Stata/ SE 12.1 (Stata Corp, College Station, TX).

RESULTS

Sample Characteristics

Of the 18,779 participants in this sample, 2,879 (weighted 13.0%) reported sleeping 5 or fewer hours per night while 4,350 (weighted 22.8%) reported 6 hours, 10,075 (weighted 56.6%) reported between 7 and 8 hours, and 1,475 (weighted 7.7%) reported sleeping 9 or more hours per night (Table 1). Compared to other sleep categories, participants reporting 5 or fewer hours of sleep were more likely to be Black, to have less than a high school education, have a lower household income, be separated, divorced or widowed, be a current smoker and sedentary, report fair/poor health, and diagnosed with a sleep disorder. Individuals sleeping 9 or more hours were also more likely to have lower household income and lower educational attainment when compared to 7 to 8 hour sleepers.

Sleep duration and sugar-sweetened beverage consumption

SSB consumption by sleep category is presented in Table 2. Total consumption of SSBs was greater with shorter sleep duration. More specifically, those who reported sleeping ≤5 hours per night on average consumed significantly more SSBs compared to individuals who slept 7 to 8 hours per night independent of survey cycle, sociodemographic factors (age, sex, race/

ethnicity, education level, household income, marital status), health characteristics (smoking status, physical activity, and self-reported health status, sleep disorder diagnosis) and total energy intake (RD = 1.21, 95% CI 1.11–1.32). Elevated levels of consumption were also observed among 6-hour sleepers (RD = 1.11, 95% CI 1.05–1.18) compared to 7–8 hour sleepers.

Examination of beverage type further illuminated the link between self-reported sleep duration and SSB consumption. In our models (Table 2), sleeping ≤5 hours was associated with 26% higher intake of sodas (RD = 1.26, 95% CI 1.13–1.40) and sleeping 6 hours was associated with 14% higher intake of sodas (RD = 1.14, 95% CI 1.04–1.25); ≤5 hours (RD = 1.18, 95% CI 1.05–1.32) and 6-hour sleepers (RD = 1.09, 95% CI 1.01–1.19) also consumed significantly more non-carbonated sugary beverages compared to 7–8 hour sleepers. Self-reported sleep duration was unrelated to diet drinks, 100% juice, and tea consumption. Individuals who reported sleeping ≥9 hours on average consumed less coffee and less water than 7–8 hour sleepers.

Sugar sweetened beverages were further categorized as caffeinated or decaffeinated. As displayed in Table 3, the consumption of decaffeinated SSBs was similar across sleep categories. In contrast, total consumption of caffeinated SSBs were 33% higher in ≤5 hours (RD = 1.33, 95% CI 1.18–1.50) and 15% higher in 6-hour sleepers (RD = 1.15, 95% CI 1.06–1.26) compared to 7–8 hour sleepers. Greater consumption was observed among ≤5 and 6 hour sleepers for both caffeinated sodas and caffeinated non-carbonated sugary drinks compared to 7–8 hour sleepers.

DISCUSSION

Sugar sweetened beverage consumption is one of the key dietary habits shown to contribute to the development and progression of several cardiometabolic conditions linked to obesity (1, 2); however, the factors that lead to excess SSB consumption are not well elucidated. In the present study, analyses revealed that short self-reported sleep duration (≤5 hours and 6 hours per night) was associated with greater SSB consumption in a nationally representative sample of nearly 19,000 adults in the United States, after holding constant a bevy of sociodemographic factors (age, gender, race/ethnicity, marital status, level of education, household income), as well as health variables (total energy intake, smoking status, physical activity, self-reported health status, reports of sleep disorders). After these statistical adjustments, there was a dose response relationship with total consumption of SSBs was 21% higher among ≤5 hour sleepers and 11% higher among 6 hour sleepers relative 7 to 8 hour sleepers.

The association between sleep duration and total SSB consumption was observed when beverages were separated into sodas and non-carbonated sugary beverages; however, the effects appeared somewhat stronger for sodas. Indeed, compared to 7–8 hours sleepers, individuals who averaged ≤5 hours per night consumed 26% more sodas while this same category of sleepers consumed 18% more non-carbonated sugary beverages. Regardless of the source, such excess sugar consumption may have considerable health implications (3, 28). For instance, high levels of fructose, such as those observed in sodas, have been linked to increased insulin resistance (29, 30), disruption in lipid processing (30), excess inflammation (31), oxidative damage (32), and the development of the metabolic syndrome (32, 33) and non-alcoholic fatty liver disease (32).

The present findings align with a small but emerging literature investigating sleep and SSBs in children and adolescents. In recent study of nearly 2,500 elementary school students, participants obtaining fewer hours of sleep than recommended for their age reported greater soda consumption than students obtaining "optimal" sleep (i.e., ≥10 hours/weekday) (34). In a study of 676 children (aged 8 to 11), shorter sleep duration, measured objectively using wrist actigraphy, was associated with greater SSB consumption (35); the present study is the first to extend these findings to a nationally representative sample of adults.

Associations in this sample varied as a function of caffeine content. In this regard, ≤5 hour and 6-hour sleepers reported greater consumption of caffeinated SSBs compared to 7–8 hour sleepers; such differences were not observed for de-caffeinated SSBs. As such, the excess consumption among shorter sleepers is most prominent in beverages with both added sugar and caffeine. It also raises the possibility that short sleepers may seek out caffeinated SSBs to increase alertness and stave off daytime sleepiness. Of course, an alternative explanation may be that excess caffeinated SSB consumption leads to shortened sleep duration. Indeed, experimental evidence suggests that regular caffeine consumption can result in significant decrements in sleep (36). High levels of consumption of beverages with the combination of high caffeine and sugar, such as energy drinks, has been raised as a cause of short sleep duration and the metabolic conditions that appear at high prevalence among short sleepers (e.g., type 2 diabetes) (37). Unfortunately, the cross-sectional nature of the data, including the lack of information about when a participant routinely consumes SSBs (e.g., during the day vs. near bedtime) precludes any inferences regarding the directionality of these findings.

This study is not without its limitations. As noted, the cross-sectional nature of the data precludes any clear inferences about causality or temporality. While accurate assessments of dietary intake are inherently challenging, the 24-hour dietary recall employed in the NHANES protocol uses the five-step multiple-pass method, which has been validated previously (38, 39) and is considered the best method for assessing population-level intakes (40). In contrast, sleep assessment relied on a single item self-report measure, which has not been validated using gold-standard measures (e.g., polysomnography). Studies examining associations of sleep with dietary intake using objective measures of sleep are needed. Additionally, while analyses adjusted for sociodemographic and health characteristics known to show prior associations with sleep and SSB consumption, other potential confounders (e.g., psychological stress, neighborhood socioeconomic status) unmeasured in NHANES may play a role in the sleep-SSB link. Replications and extensions of this work in large prospective cohort studies are warranted.

The long-term health consequences of excessive SSB consumption, including obesity, and economic burden that obesity and obesity-related medical conditions place on the health care system are substantial (41). There is a need to identify tractable behavioral pathways that may serve as opportunities for prevention. Self-control efforts are impaired by sleep debt (42). It may be that sufficient sleep can help bolster individual's ability to resist SSBs when in a neighborhood or work environment highly saturated with SSB availability. These findings provide novel evidence that sleep duration may reflect a possible target for attenuating SSB consumption in adults, although there are likely bidirectional relationships between sleep and SSB consumption, particularly among caffeinated SSBs. Prospective studies tracking longitudinal changes in sleep and SSB consumption are warranted.

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Table 1

Descriptive statistics of 18,779 adults aged 18 and older: National Health and Nutrition Examination Surveys, United States, 2005–2012.

	≤5 hours (n=2879)		6 hours (n=4350)		7–8 hours (n=10075)		≥9 hours (n=1475)		*P*
	n	%[a]	n	%[a]	n	%[a]	n	%[a]	
Age (mean ± SE)	46.1 ± 0.6		45.9 ± 0.4		46.4 ± 0.4		46.6 ± 0.9		*0.55*
Female	1463	51.7	2167	47.9	5141	52.4	808	59.9	*<0.0001*
Race/ethnicity									
White	1075	59.1	1842	66.6	5017	72.9	772	72.1	*<0.0001*
Black	1002	22.1	1129	14.0	1745	8.3	281	10.6	
Hispanic	640	13.0	1072	13.3	2603	12.9	342	12.8	
Other race	162	5.8	307	6.2	710	6.0	80	4.6	
Highest education level									
<12 years	890	23.6	1076	15.8	2602	16.4	489	25.3	*<0.0001*
High school diploma or equivalent	735	27.3	1069	25.6	2278	21.9	370	24.9	
Some college	873	33.9	1317	33.6	2796	29.6	399	29.0	
College graduate	377	15.0	885	25.0	2392	32.1	214	20.5	
Marital status									
Married or living with partner	1528	53.7	2434	61.7	5976	63.3	708	53.8	*<0.0001*
Never married	521	19.5	798	18.3	1805	17.9	304	20.7	
Separated, divorced, or widowed	758	25.5	984	17.9	1897	16.0	353	19.2	
Household income (ratio to FPL)									
0–100% FPL	728	19.9	825	13.8	1872	12.1	354	18.8	*<0.0001*
100–200% FPL	753	25.5	1058	18.0	2347	17.9	407	21.7	
200–300% FPL	393	15.2	639	14.9	1362	13.4	213	16.7	
300–400% FPL	279	11.4	441	11.7	1135	13.3	155	12.2	
>400% FPL	502	21.3	1071	35.6	2608	37.4	243	25.8	
Smoking status									
Never smoker	1356	44.5	2294	52.3	5525	55.9	736	52.8	*<0.0001*
Former smoker	658	22.4	994	23.5	2491	24.8	353	20.4	
Current smoker	849	32.8	1045	24.1	2003	19.0	365	25.8	

	≤5 hours (n=2879)		6 hours (n=4350)		7–8 hours (n=10075)		≥9 hours (n=1475)		***P***
	n	**%[a]**	**n**	**%[a]**	**n**	**%[a]**	**n**	**%[a]**	
Physical activity in last 30 days									
Vigorous and moderate activity	1718	29.5	955	15.8	237	7.3	164	19.4	*<0.0001*
Moderate activity only	1962	30.3	1989	31.0	815	22.5	270	24.5	
No physical activity	2271	30.0	3555	45.3	2780	66.8	585	48.3	
Self-reported health status									
Excellent or very good	713	29.1	1466	40.7	3996	47.8	485	38.7	*<0.0001*
Good	1060	38.1	1670	38.1	3732	33.8	564	38.2	
Fair or poor	920	26.7	957	15.5	1769	12.6	345	18.3	
Diagnosed with sleep disorder	461	16.6	337	7.5	561	6.3	107	7.8	*<0.0001*

[a] weighted percentage

Table 2

Associations between self-reported sleep duration and beverage intake*

	≤5 hours			6 hours			7–8 hours			≥9 hours		
	Mean (SE) servings	**RD**	**95% CI**	**Mean (SE) servings**	**RD**	**95% CI**	**Mean (SE) servings**	**RD**	**95% CI**	**Mean (SE) servings**	**RD**	**95% CI**
100% fruit juice	0.3 (0.02)	0.98	0.87, 1.11	0.3 (0.01)	0.96	0.86, 1.06	0.3 (0.01)	Ref.	-	0.3 (0.03)	1.17	0.91, 1.50
Sugar-sweetened beverages (total)	2.4 (0.11)	**1.21**	**1.11, 1.32**	2.0 (0.05)	**1.11**	**1.05, 1.18**	1.6 (0.04)	Ref.	-	1.8 (0.11)	1.01	0.91, 1.12
Regular Sodas	1.3 (0.08)	**1.26**	**1.13, 1.40**	1.0 (0.04)	**1.14**	**1.04, 1.25**	0.8 (0.03)	Ref.	-	1.0 (0.09)	1.04	0.89, 1.20
Non-carbonated sugary beverages	1.2 (0.07)	**1.18**	**1.05, 1.32**	1.0 (0.03)	**1.09**	**1.01, 1.19**	0.9 (0.03)	Ref.	-	0.8 (0.05)	0.95	0.84, 1.08
Diet drinks	0.6 (0.05)	1.02	0.82, 1.26	0.6 (0.04)	1.00	0.88, 1.14	0.6 (0.03)	Ref.	-	0.5 (0.06)	1.00	0.80, 1.26
Tea (plain)	0.4 (0.05)	1.10	0.87, 1.39	0.4 (0.04)	0.92	0.77, 1.09	0.5 (0.02)	Ref.	-	0.4 (0.08)	0.87	0.71, 1.06
Coffee (plain)	1.3 (0.07)	1.00	0.89, 1.12	1.3 (0.06)	1.00	0.93, 1.09	1.3 (0.03)	Ref.	-	0.9 (0.05)	**0.76**	**0.67, 0.86**
Water (plain)	4.3 (0.13)	1.04	0.98, 1.10	4.44 (0.12)	1.01	0.97, 1.07	4.4 (0.08)	Ref.	-	3.7 (0.15)	**0.92**	**0.86, 0.99**

*Models adjusted for sociodemographics (age, sex, race/ethnicity, education level, household income, marital status), health characteristics (smoking status, physical activity, and self-reported health status, sleep disorder diagnosis) and total energy intake.

Bolded values are statistically significant compared to the reference group (7–8 hours).

Table 3

Associations between self-reported sleep duration and caffeinated and decaffeinated sugar sweetened beverages*

	≤5 hours			6 hours			7–8 hours			≥9 hours		
	Mean (SE) servings	**RD**	**95% CI**	**Mean (SE) servings**	**RD**	**95% CI**	**Mean (SE) servings**	**RD**	**95% CI**	**Mean (SE) servings**	**RD**	**95% CI**
With caffeine												
Sugar-sweetened beverages (total)	1.5 (0.10)	**1.33**	**1.18, 1.50**	1.1 (0.04)	**1.15**	**1.06, 1.26**	0.9 (0.04)	Ref.	-	1.0 (0.09)	1.02	0.89, 1.17
Sodas	1.0 (0.08)	**1.37**	**1.17, 1.61**	0.7 (0.04)	**1.18**	**1.07, 1.31**	0.6 (0.03)	Ref.	-	0.8 (0.08)	1.12	0.92, 1.35
Non-carbonated sugary drinks	0.5 (0.06)	**1.30**	**1.09, 1.55**	0.4 (0.02)	**1.15**	**1.02, 1.29**	0.3 (0.02)	Ref.	-	0.3 (0.03)	0.87	0.69, 1.11
Without caffeine												
Sugar-sweetened beverages (total)	1.0 (0.05)	1.03	0.93, 1.15	0.9 (0.03)	1.05	0.97, 1.14	0.8 (0.02)	Ref.	-	0.8 (0.05)	0.99	0.88, 1.12
Sodas	0.3 (0.02)	0.94	0.78, 1.13	0.3 (0.02)	1.03	0.87, 1.21	0.2 (0.01)	Ref.	-	0.2 (0.03)	0.79	0.63, 1.00
Non-carbonated sugary drinks	0.7 (0.04)	1.08	0.94, 1.24	0.6 (0.03)	1.07	0.96, 1.19	0.5 (0.02)	Ref.	-	0.6 (0.04)	1.06	0.90, 1.24

*Models adjusted for sociodemographics (age, sex, race/ethnicity, education level, household income, marital status), health characteristics (smoking status, physical activity, and self-reported health status, sleep disorder diagnosis) and total energy intake.

Bolded values are statistically significant compared to the reference group (7–8 hours).