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Journal
Sleep health, 5(4)

ISSN
2352-7218

Authors
Nuyujukian, Daniel S
Anton-Culver, Hoda
Manson, Spero M
et al.

Publication Date
2019-08-01

DOI
10.1016/j.sleh.2019.02.003

Associations of sleep duration with cardiometabolic outcomes in American Indians and Alaska Natives and other race/ethnicities: results from the BRFSS

Daniel S. Nuyujukian, Ph.D., M.P.H. [a], Hoda Anton-Culver, Ph.D. [a,b], Spero M. Manson, Ph.D. [c], Luohua Jiang, Ph.D. [a,*]

[a] Department of Epidemiology, School of Medicine, University of California, Irvine, Irvine, California
[b] Genetic Epidemiology Research Institute, University of California, Irvine, Irvine, California
[c] Centers for American Indian and Alaska Native Health, Colorado School of Public Health, University of Colorado Anschutz Medical Campus, Aurora, Colorado

ABSTRACT

Objectives: This study assessed the associations between short and long sleep duration and prevalence of cardiometabolic outcomes in American Indians and Alaska Natives (AI/ANs) and compared these associations to those evident among other race/ethnicities.

Methods: We analyzed data from the 2013-2014 Behavioral Risk Factor Surveillance System. In total, 14,536 AI/ANs, 729,962 non-Hispanic whites, 71,765 blacks, and 59,472 Hispanics were included. Logistic regressions were conducted to compute unadjusted and adjusted odds ratios (OR) for the associations of interest. Results: Among AI/ANs, 38.6% reported sleeping b7 hours per night (short sleepers) while 39.3% reported 8+ hours of sleep (long sleepers). After adjusting for age and gender, both short and long sleep durations were associated with higher odds of reporting diabetes, stroke, coronary heart disease and heart attack in almost all race/ethnic groups. After multiple adjustments, the sleep-diabetes association was more pronounced (OR = 1.71 and OR = 1.56 for short and long sleepers, respectively) among AI/ANs than other race/ethnicities.

Conclusions: Future studies are warranted to examine race/ethnic variability in the association between sleep duration and cardiometabolic outcomes.

Introduction

Sleep duration influences risk of cardiometabolic disease. Both short and long sleep durations are associated with increased risk of diabetes[1,2]; short sleep duration is associated with metabolic syndrome.[3] Risk of coronary heart disease and stroke is significantly heightened among short sleepers,[4] though the association between sleep duration and cardiovascular disease (CVD) may not remain if one excludes individuals with baseline illness.[5] A more recent systematic review suggests that sleep is an essential factor influencing cardiometabolic health and stresses the need for further inquiry into possible differential contribution of race/ethnic status.[6]

Cardiometabolic diseases are highly prevalent in many under-served populations. It is unclear whether sleep duration plays a role in the cardiometabolic disparities experienced by those populations.6 In an analysis of national survey data from 2014, the Centers for Disease

Control reported lower age-adjusted prevalence of healthy sleep duration among non-Hispanic blacks, American Indians and Alaska Natives (AI/ANs), Native Hawaiians/Pacific Islanders, and multiracial respondents compared to non-Hispanic whites, Asians, and Hispanics.[7] Re-cent findings in regard to the relationship between sleep duration and cardiometabolic conditions among different race/ethnic groups, however, have been inconsistent. For example, the National Health Interview Survey, 2004-2011, revealed a U-shaped distribution of diabetes with sleep duration among both whites and blacks, but the association of diabetes with short and long sleep duration was stronger in whites than blacks in that cohort.[8] Varied, and sometimes conflicting, results have been reported with respect to the sleep-diabetes association in other race/ethnicities.[9–11] Differential vulnerability to short sleep length by race/ethnicity as well as variability by race/ethnicity in correlates linked to CVD such as hypertension have also been noted.[12]

Diabetes and CVD pose a particularly notable public health challenge in the AI/AN population. The prevalence of diabetes among AI/ANs is excessive, at 15.1% among U.S. AI/AN adults aged 18 or older.[13] This is over twice the prevalence in non-Hispanic whites and higher than the other race/ethnic groups surveyed (blacks: 12.7%; Hispanics: 12.1%). Of equal concern, the prevalence of CVD is rising among AI/ANs.[14] Between 1999 and 2009, mortality due to heart disease[15] and stroke[16] was higher in AI/ANs than their white peers, calling for improved prevention efforts. Yet, previous studies of sleep duration have not carefully considered AI/ANs separately from other race/ethnic groups, nor have they examined the relationship between sleep duration and cardiometabolic outcomes in this population. Risk factors contributing to obesity such as sedentariness and poor diet have also been found to be related to sleep duration,[17,18] behaviors re-ported to be common in AI/ANs.[19] Thus, understanding the potential association of sleep duration and adverse cardiometabolic outcomes in AI/ANs —as well as how the association may differ from other race/ethnicities—represent important steps in filling critical knowledge gaps.

In this study, we drew on data from the 2013-2014 Behavioral Risk Factor Surveillance System (BRFSS) to investigate the association between sleep duration and cardiometabolic outcomes in AI/ANs and compared the findings to those for whites, blacks, and Hispanics. We hypothesized a higher prevalence of short sleep duration among AI/ANs than other race/ethnic groups as well as significant associations between cardiometabolic outcomes and short and long sleep duration among AI/ANs.

Methods

The data for this study derived from the BRFSS, 2013-2014. The BRFSS, initiated in 1984, is a random-digit dialed telephone survey conducted in all 50 US states, the District of Columbia, and U.S. territories to collect uniform, state-specific data on practices and behaviors linked to chronic disease, injuries, and preventable infectious diseases in the adult population. It is the largest, continuous health survey worldwide, completed by over 400,000 adults annually.[20]

Study measures

Beginning with the 2009 survey year, the BRFSS included a question on self-reported sleep duration. Respondents were asked “on average, how many hours of sleep do you get in a 24-hour period?”, with responses ranging from 1-24 hours. We defined 7 hours of sleep as the reference group, consistent with many other studies of sleep duration.[1,4] Short sleepers were defined as sleeping 6 or fewer hours in a 24-hour period; long sleepers were defined as sleeping 8 or more hours.

Sociodemographic characteristics included in the analysis were age, gender, education level, employment status, marital status, and income. Analyses were further adjusted for health behavioral characteristics, including alcohol use (drinks per day) and smoking status. Physical activity was queried as: "during the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?" Body mass index (BMI, in kg/m^2) was computed from height and weight self-reports. A self-reported health status measure asks participants to weight their general health on a scale of 1 to 5 (excellent, very good, good, fair, or poor).

Diabetes and other chronic conditions were ascertained as self-reported responses to questions such as, "has a doctor or nurse ever told you that you have diabetes?" Available CVD outcomes of interest were coronary heart disease (CHD), heart attack, and stroke. Less than 1% of AI/AN respondents were missing a response to these questions.

Study population

The analytic cohort was selected to maximize response rate on sleep duration among AI/ANs. While the sleep duration question was available in an optional module beginning in 2009, it was not integrated into the core questionnaire until 2013. Over 98% of AI/ANs provided a response for usual sleep duration in 2013 and 2014. Other race/ethnicities also had relatively high response rates for sleep duration (whites: 97.7%; blacks: 95.5%; Hispanics: 81.4%). Therefore, this analysis was based on the 2013-2014 BRFSS survey. In the analysis of all race/ethnicities, we excluded subjects who re-sided outside the 50 US states (n = 16,213), did not report sleep du-ration (n= 13,864), or did not report age (n=9,788). The final analytical sample includes 729,962 non-Hispanic whites, 71,765 blacks, 59,472 Hispanics, and 14,536 AI/ANs (7,463 from 2013 and 7,073 from 2014). Sociodemographic and other key characteristics of AI/ANs were similar between survey years (Supplementary Table 1). The Institutional Review Board (IRB) of the University of California, Irvine determined that this project does not constitute human subjects research, and therefore the activities in this project are not subject to IRB review and approval.

Data analysis

Sociodemographic and health behavioral characteristics were first presented among white, black, Hispanic, and AI/AN respondents. We then stratified these characteristics by usual sleep duration categories among each race/ethnic group. Logistic regression models were constructed to determine the association between sleep duration and diabetes, CHD, heart attack, or stroke. First, model 0 examined the unadjusted association between sleep duration and the outcome variables with sleep duration being the only independent variable. We subsequently introduced, in stepwise fashion, potential con-founding covariates to determine how they may affect the sleep-disease relationship. Model 1 adjusted for age and gender. Model 2 added sociodemographic measures (income, education, marital status, and employment). Model 3 added alcohol intake (categorized as yes/no), smoking status, physical activity, and BMI, which is a potential mediator for the oft-reported short sleep-diabetes relationship. The potential modifying effect of race/ethnicity on the association between sleep duration and cardiometabolic outcomes was tested by adding an interaction term for sleep duration with race/ethnicity in

Model 3. To evaluate the robustness of the findings in the sleep-diabetes analysis, we conducted a sensitivity analysis after excluding individuals in younger age strata (0-44 years) for whom chronic diseases are less common. Because results were essentially the same, we did not restrict the primary analysis on age. Another sensitivity analysis was conducted using Poisson regression to estimate prevalence ratios, and the results of this analysis were compared to those from logistic regression models. We also conducted a sensitivity analysis of the sleep-diabetes association using a more detailed definition of short sleep (<6 hours, 6 hours, 7 hours as the reference category, and >7 hours) as well as a sensitivity analysis of the sleep-diabetes association using 7-9 hours of sleep as the reference category, as recommended by the National Sleep Foundation.[21]

All analyses were conducted in STATA/IC 14.2 (College Station, TX) using the 'svy' command to account for the complex survey de-sign of the BRFSS.20 A P value less than .05 was considered statistically significant.

Results

Selected sample characteristics, by race/ethnicity, are presented in Table 1. AI/ANs reported shorter mean sleep duration (6.86 hours [95%CI = 6.80-6.92]) than whites (7.01 hours [95% CI = 7.00-7.01]) and Hispanics (7.03 hours [95% CI = 7.01-7.05], but not blacks (6.84 hours [95% CI = 6.81-6.86]). AI/ANs had the highest proportion of cur-rent smokers (29.1%) of all race/ethnic groups surveyed and also had the largest percentage of those earning less than $10,000 per year (12.0%). With respect to self-reported health status, AI/ANs had a higher percentage (24.2%) of participants who reported fair or poor health status than whites and blacks, but not Hispanics.

Table 2 illustrates sample characteristics by self-reported sleep duration in each race/ethnic group. Among AI/ANs, normal sleepers reported the highest education levels; for example, 17.5% of normal sleepers had college or higher education vs. 12.2% among short-sleeping AI/ANs and 12.3% among long-sleeping AI/ANs. Both alcohol consumption and levels of current smoking were higher among AI/ANs than other race/ethnicities in most categories. The highest level was observed among short sleeping AI/ANs, at 3.59 drinks per day and 35.1% current smokers. Diabetes, stroke, CHD, and heart attack were most common among short-sleeping AI/ANs (17.0%, 6.1%, 5.6%, and 8.1%, respectively); diabetes was least common among whites sleeping 7 hours per day (7.4%); stroke, CHD, and heart attack were least common among Hispanics with 7 hours of sleep (1.1%, 1.6%, and 2.1%, respectively). Among long sleepers, diabetes, stroke, and heart attack, but not CHD, were more prevalent among AI/ANs than whites (14.2% vs. 10.6% for diabetes, 4.6% vs. 3.7% for stroke, and 6.4% vs. 5.5% for heart attack). Long-sleeping Hispanics reported a higher prevalence of diabetes (11.2%) than whites, and long-sleeping blacks reported high diabetes prevalence (15.8%) and relatively high prevalence of stroke (4.8%) and heart attack (4.7%).

Tables 3 and 4 summarize the strength of the association between sleep duration and cardiometabolic outcomes. In the age- and gender-adjusted models, both short and long sleep duration were statistically significantly associated with diabetes among all four race/ethnic groups (Table 3). After additional adjustments (Model 3), the association between short sleep and diabetes in AI/ANs remained statistically significant (OR = 1.71, 95% CI = 1.24-2.28) and was stronger than that of the other race/ethnic groups (OR = 1.07, 95% CI = 0.95-1.21 for blacks; OR = 1.28, 95% CI = 1.10-1.49 for Hispanics; and OR = 1.22, 95% CI = 1.17-1.27 for whites). Similarly, the association between long sleep and diabetes in AI/ANs remained statistically significant (OR = 1.56, 95% CI = 1.17-2.07) and was stronger than the other groups (OR = 1.13, 95% CI = 0.98-1.27 for blacks; OR = 1.32, 95% CI = 1.13-1.54 for Hispanics; and OR = 1.16, 95% CI = 1.11-1.21 for whites). The interactions of both short and long sleep duration with black or white race/ethnicity (with AI/ANs as the referent group) were statistically significant.

In the age- and gender-adjusted models, both short and long sleep duration were statistically significantly associated with increased risk of stroke in all four race/ethnic groups (Table 4). As potential con-founders were introduced, the stroke-sleep association was attenuated. In Model 3, the association was still statistically significant for short sleep duration but was no longer statistically significant for long sleep among AI/ANs (OR = 1.78, 95% CI = 1.08-2.91; OR = 1.42, 95% CI = 0.86-2.34, respectively). In the other race/ethnic groups, the associations remained statistically significant through Model 3 except long sleep duration among Hispanics. However, the interactions between sleep duration and race/ethnicity were not statistically significant.

Table 1

Percentages and means of selected sociodemographic, health behavioral, and clinical characteristics among U.S. adults, by race/ethnicity, 2013-2014 BRFSS*

Age (years) (%)				
18-24	11.0 (10.9-11.2)	14.7 (14.2-15.3)	19.5 (18.3-20.8)	15.6 (14.2-17.0)
25-34	15.0 (14.9-15.2)	18.8 (18.2-19.4)	22.4 (21.3-23.7)	17.3 (16.0-18.7)
35-44	14.7 (14.5-14.9)	17.7 (17.2-18.3)	22.7 (21.5-24.0)	16.7 (15.3-18.1)
45-54	18.3 (18.1-18.5)	18.9 (18.4-19.4)	14.3 (13.3-15.4)	19.7 (18.4-21.1)
55-64	18.0 (17.8-18.1)	15.7 (15.3-16.1)	11.2 (10.3-12.3)	16.3 (15.2-17.6)
65+	22.9 (22.8-23.1)	14.2 (13.8-14.6)	9.8 (8.9-10.7)	14.5 (13.4-15.6)
Female (%)	51.2 (51.0-51.4)	53.9 (53.2-54.6)	49.9 (48.4-51.4)	50.0 (48.3-51.8)
Education (%)				
< High school	9.3 (9.2-9.5)	16.6 (16.0-17.1)	38.5 (37.8-39.3)	21.9 (20.4-23.5)
HS diploma	29.0 (28.8-29.2)	32.2 (31.6-32.9)	26.8 (26.2-27.4)	32.3 (30.7-33.9)
Some college	32.6 (32.4-32.8)	32.8 (32.1-33.4)	23.7 (23.1-24.3)	32.6 (30.9-34.3)
≥ College graduate	29.0 (28.9-29.2)	18.5 (18.0-18.9)	11.0 (10.7-11.4)	13.3 (12.2-14.5)
Employment (%)				
Employed	55.9 (55.7-56.1)	52.5 (51.8-53.2)	58.0 (57.3-58.7)	48.9 (47.1-50.7)
Unemployed	5.6 (5.5-5.7)	11.4 (10.9-11.8)	8.7 (8.3-9.2)	11.6 (10.4-12.8)
Homemaker/student	11.1 (10.9-11.2)	9.2 (8.7-9.6)	18.3 (17.7-18.9)	11.7 (10.6-12.9)
Retired	20.6 (20.4-20.7)	14.0 (13.6-14.5)	6.5 (6.2-6.8)	12.9 (11.9-14.0)
Unable to work	6.2 (6.1-6.3)	11.7 (11.3-12.1)	6.4 (6.1-6.8)	14.0 (12.9-15.2)
Income (%)				
Less than $10,000	3.6 (3.6-3.7)	10.6 (10.2-11.0)	10.8 (10.3-11.3)	12.0 (10.9-13.1)
$10,000-$25,000	16.2 (16.1-16.4)	28.2 (27.6-28.8)	33.7 (33.0-34.4)	30.0 (28.5-31.7)
$25,000-$50,000	21.4 (21.2-21.6)	22.5 (22.0-23.1)	21.5 (20.9-22.1)	21.9 (20.5-23.4)
$50,000+	45.0 (44.8-45.2)	24.5 (23.9-25.1)	19.0 (18.5-19.6)	22.0 (20.6-23.6)
Refused/missing	13.7 (13.6-13.9)	14.3 (10.2-11.0)	14.9 (14.0-15.9)	14.0 (12.8-15.4)
Marital status (%)				
Single (never married)	19.2 (19.0-19.5)	39.1 (38.5-39.8)	27.6 (27.0-28.3)	28.9 (27.3-30.7)
Married	56.4 (56.1-56.6)	32.6 (32.0-33.3)	45.0 (44.3-45.7)	39.2 (37.5-40.9)
Divorced/separated	12.8 (12.6-12.9)	17.9 (17.5-18.4)	13.8 (13.3-14.3)	19.0 (17.7-20.4)
Widowed	7.6 (7.6-7.7)	6.6 (6.4-6.9)	3.5 (3.3-3.8)	7.0 (6.3-7.8)
Health behavioral characteristics				
Sleep duration, mean (hours)	7.01 (7.00-7.01)	6.84 (6.81-6.86)	7.03 (7.01-7.05)	6.86 (6.80-6.92)
Sleep duration (%)				
< 7 hours	32.9 (32.7-33.1)	46.2 (45.6-46.9)	34.8 (34.1-35.5)	41.7 (40.0-43.5)
7 hours	31.4 (31.2-31.6)	19.7 (19.1-20.2)	26.7 (26.1-27.4)	20.8 (19.5-22.3)
> 7 hours	35.8 (35.6-36.0)	34.1 (33.5-34.8)	38.5 (37.8-39.2)	37.5 (35.8-39.2)
Drinks per day, mean	2.40 (2.38-2.41)	2.39 (2.34-2.44)	3.31 (3.23-3.40)	3.25 (3.03-3.47)
Any alcohol intake (% yes)	53.9 (53.6-54.1)	41.8 (41.1-42.4)	40.9 (40.2-41.7)	38.0 (36.3-39.7)
Smoking status (%)				
Current	17.9 (17.7-18.1)	18.9 (18.4-19.5)	13.0 (12.5-13.5)	29.1 (27.5-30.7)
Former	27.5 (27.3-27.7)	15.6 (15.1-16.1)	16.0 (15.4-16.5)	22.8 (21.4-24.3)
Never	51.0 (50.8-51.2)	59.7 (59.1-60.4)	63.6 (62.9-64.2)	43.1 (41.4-44.9)
Any physical activity (%)	76.3 (76.2-76.5)	69.4 (68.8-70.1)	66.6 (65.9-67.4)	71.8 (70.2-73.3)
BMI, mean (kg/m^2)	27.5 (27.5-27.6)	29.3 (29.3-29.4)	28.3 (28.2-28.4)	28.6 (28.3-28.8)
Self-reported health status				
Excellent/very good/good	84.3 (84.2-84.5)	77.4 (76.8-77.9)	73.6 (73.0-74.3)	75.3 (73.9-76.7)
Fair/poor	15.4 (15.2-15.5)	22.2 (21.6-22.7)	25.6 (25.0-26.3)	24.2 (22.9-25.6)

* Exclusions: outside 50 U.S. states (n = 16,213), no reported sleep (n =13,864), no reported age (n =9,788).

** Abbreviations: NHW = non-Hispanic white; NHB = non-Hispanic black; AI/AN = American Indians/Alaska Natives.

Table 2

Sociodemographic, health behavioral, and clinical characteristics among 2013-2014 BRFSS participants, by self-reported sleep duration*

	≤ 6 hours sleep/night	7 hours sleep/night	≥ 8 hours sleep/night
American Indians/Alaska Natives			
Sample size (*n*, %)	5,605 (38.6)	3,213 (22.1)	5,718 (39.3)
Age (years) (%)			
18-24	12.3 (10.3-14.7)	14.0 (11.7-16.6)	20.1 (17.7-22.6)
25-34	17.6 (15.5-19.8)	16.3 (13.8-19.2)	17.5 (15.4-19.8)
35-44	18.6 (16.5-20.9)	16.4 (13.8-19.3)	14.7 (12.6-17.1)
45-54	22.9 (20.7-25.1)	19.0 (16.2-22.1)	16.6 (14.6-18.8)
55-64	17.7 (15.9-19.7)	18.0 (15.3-21.0)	13.9 (12.4-15.6)
65+	11.0 (9.7-12.4)	16.3 (13.7-19.3)	17.3 (15.6-19.1)
Female (%)	49.0 (46.3-51.8)	50.2 (46.6-53.9)	51.0 (48.2-53.9)
Education (%)			
<High school	23.4 (21.0-25.8)	18.5 (15.5-22.0)	22.1 (19.8-24.6)
HS diploma	30.4 (28.1-32.9)	30.6 (27.3-34.1)	35.2 (32.6-37.9)
Some college	34.0 (31.4-36.7)	33.4 (30.0-37.0)	30.5 (27.9-33.2)
≥College graduate	12.2 (10.7-13.8)	17.5 (15.2-20.1)	12.3 (10.5-14.2)
Health behaviors			
Sleep duration, mean (h)	5.26 ± 0.98	7.00	8.55 ± 1.34
Alcoholic drinks per day	3.59	2.79	3.14
Smoking (%)			
Current	35.1 (32.6-37.8)	22.4 (19.6-25.6)	26.1 (23.8-28.5)
Former	22.4 (20.3-24.7)	23.4 (20.5-26.4)	23.0 (20.7-25.4)
Never	37.2 (34.5-39.9)	49.8 (46.1-53.6)	46.1 (43.3-48.9)
Any physical activity (%)	66.3 (63.8-68.8)	73.9 (70.6-77.0)	67.5 (64.8-70.1)
Clinical characteristics			
BMI, mean (kg/m^2)	29.0 ± 7.4	28.2 ± 6.2	28.3 ± 6.6
Diabetes (%)	17.0 (15.1-19.0)	10.8 (9.1-12.8)	14.2 (12.4-16.1)
Coronary heart disease (%)	5.6 (4.7-6.7)	3.3 (2.5-4.4)	5.0 (3.9-6.2)
Stroke (%)	6.1 (5.1-7.3)	2.9 (2.1-4.1)	4.6 (3.9-5.4)
Heart attack (%)	8.1 (6.8-9.7)	5.0 (3.9-6.4)	6.4 (5.2-7.8)
Self-reported health status (%)			
Excellent/very good/good	66.7 (64.3-69.1)	84.8 (82.4-86.9)	79.5 (77.4-81.4)
Fair/poor	32.6 (30.3-35.1)	14.8 (12.7-17.1)	20.1 (18.2-22.2)
Non-Hispanic Whites			
Sample size (*n*, %)	218,189 (29.9)	230,660 (31.6)	281,113 (38.5)
Age (years) (%)			
18-24	10.2 (9.9-10.5)	10.2 (9.9-10.5)	12.5 (12.2-12.9)
25-34	17.2 (16.9-17.6)	14.7 (14.4-15.0)	13.3 (13.1-13.6)
35-44	16.7 (16.4-17.0)	15.7 (15.4-16.0)	12.0 (11.7-12.2)
45-54	20.7 (20.4-21.0)	19.6 (19.3-19.9)	14.9 (14.7-15.2)
55-64	17.9 (17.7-18.2)	19.0 (18.7-19.2)	17.2 (16.9-17.4)
65+	17.2 (17.0-17.4)	20.8 (20.6-21.1)	30.1 (29.8-30.4)
Female (%)	49.8 (49.4-50.2)	50.2 (49.8-50.6)	53.4 (53.0-53.8)
Education (%)			
<High school	11.8 (11.5-12.1)	6.0 (5.8-6.3)	9.9 (9.7-10.2)
HS diploma	31.6 (31.2-31.9)	25.2 (24.9-25.6)	30.0 (29.7-30.4)
Some college	33.7 (33.3-34.0)	32.3 (31.9-32.7)	32.0 (31.6-32.3)
≥College graduate	23.0 (22.7-23.3)	36.5 (36.1-36.8)	28.1 (27.8-28.4)

Health behaviors			
Sleep duration, mean (h)	5.53 ± 0.76	7.00	8.37 ± 0.99
Alcoholic drinks per day	2.65	2.23	2.34
Smoking (%)			
Current	25.0 (24.7-25.4)	13.5 (13.2-13.8)	15.3 (15.0-15.6)
Former	26.3 (26.0-26.6)	27.2 (26.9-27.6)	28.9 (28.6-29.2)
Never	45.1 (44.7-45.5)	56.0 (55.6-56.4)	52.0 (51.7-52.4)
Any physical activity (%)	69.6 (69.2-69.9)	79.5 (79.2-79.8)	73.4 (73.1-73.7)
Clinical characteristics			
BMI, mean (kg/m^2)	28.2 ± 6.1	27.2 ± 5.6	27.3 ± 6.2
Diabetes (%)	10.5 (10.3-10.7)	7.4 (7.2-7.5)	10.6 (10.4-10.8)
Coronary heart disease (%)	5.4 (5.2-5.5)	3.6 (3.5-3.8)	5.5 (5.4-5.6)
Stroke (%)	3.5 (3.4-3.6)	1.9 (1.8-2.0)	3.7 (3.6-3.8)
Heart attack (%)	5.6 (5.4-5.8)	3.4 (3.2-3.5)	5.5 (5.3-5.6)
Self-reported health status (%)			
Excellent/very good/good	77.8 (77.4-78.1)	90.8 (90.6-91.1)	84.6 (84.3-84.8)
Fair/poor	21.9 (21.6-22.2)	8.9 (8.7-9.2)	15.0 (14.8-15.3)
Non-Hispanic Whites			
Sample size (*n*, %)	31,834 (44.4)	14,454 (20.1)	25,477 (35.5)
Age (years) (%)			
18-24	13.0 (12.3-13.8)	17.3 (16.0-18.7)	15.7 (14.7-16.6)
25-34	20.4 (19.6-21.3)	17.7 (16.6-18.9)	17.2 (16.3-18.1)
35-44	19.6 (18.8-20.4)	17.3 (16.1-18.5)	15.4 (14.6-16.3)
45-54	20.7 (19.9-21.5)	17.8 (16.7-19.0)	17.0 (16.2-17.9)
55-64	15.7 (15.1-16.4)	15.1 (14.2-16.1)	16.0 (15.3-16.8)

(continued on next page)

	≤ 6 hours sleep/night	7 hours sleep/night	≥ 8 hours sleep/night
65+	10.6 (10.1-11.1)	14.8 (13.9-15.8)	18.8 (17.9-19.6)
Female (%)	53.9 (53.2-54.6)	53.3 (51.8-54.9)	55.1 (54.0-56.3)
Education (%)			
<High school	16.0 (15.2-16.8)	11.7 (10.6-12.8)	20.2 (19.2-21.2)
HS diploma	29.9 (29.1-30.9)	29.8 (28.5-31.3)	36.7 (35.6-37.8)
Some college	35.5 (34.6-36.5)	33.4 (31.9-34.9)	28.7 (27.6-29.8)
≥College graduate	18.6 (17.9-19.2)	25.1 (24.0-26.3)	14.5 (13.8-15.2)
Health behaviors			
Sleep duration, mean (h)	5.37 ± 0.69	7.00	8.72 ± 1.30
Alcoholic drinks per day	2.46	2.18	2.41
Smoking (%)			
Current	21.4 (20.6-22.2)	14.2 (13.2-15.3)	18.3 (17.4-19.2)
Former	15.0 (14.3-15.7)	16.1 (15.0-17.2)	16.2 (15.3-17.0)
Never	58.0 (57.1-59.0)	64.5 (63.0-65.9)	59.3 (58.2-60.5)
Any physical activity (%)	67.9 (67.0-68.9)	75.5 (74.2-76.8)	75.5 (74.2-76.8)
Clinical characteristics			
BMI, mean (kg/m^2)	29.7 ± 5.4	28.7 ± 4.9	29.2 ± 5.5
Diabetes (%)	13.8 (13.2-14.5)	12.1 (11.2-13.0)	15.8 (15.0-16.6)
Coronary heart disease (%)	4.0 (3.7-4.4)	2.8 (2.4-3.4)	4.0 (3.5-4.5)
Stroke (%)	4.4 (4.1-4.8)	2.6 (2.2-3.0)	4.8 (4.4-5.3)
Heart attack (%)	4.2 (3.9-4.4)	3.0 (2.5-3.5)	4.7 (4.2-5.3)
Self-reported health status (%)			
Excellent/very good/good	73.4 (72.5-74.3)	84.3 (83.1-85.3)	78.8 (77.9-79.7)
Fair/poor	26.2 (25.3-27.0)	15.3 (14.2-16.4)	20.7 (19.8-21.6)
Hispanics			
Sample size (*n*, %)	21,171 (35.6)	15,976 (26.9)	22,325 (37.5)
Age (years) (%)			
18-24	16.6 (15.7-17.6)	17.6 (16.5-18.7)	19.2 (18.3-20.3)
25-34	23.8 (22.7-24.8)	24.7 (23.5-25.9)	25.9 (24.9-27.1)
35-44	20.8 (19.9-21.8)	23.3 (22.1-24.5)	20.5 (19.6-21.5)
45-54	18.6 (17.7-19.6)	16.7 (15.7-17.7)	14.7 (13.9-15.5)
55-64	12.4 (11.7-13.2)	10.9 (10.1-11.9)	10.1 (9.5-10.8)
65+	7.8 (7.2-8.3)	6.8 (6.3-7.4)	9.5 (8.9-10.2)
Female (%)	50.2 (49.0-50.5)	47.0 (45.7-48.4)	48.8 (47.6-50.0)
Education (%)			
<High school	34.9 (33.7-36.1)	35.7 (34.3-37.1)	43.7 (42.5-45.0)
HS diploma	26.9 (25.9-28.0)	25.9 (24.7-27.1)	27.3 (26.3-28.4)
Some college	27.1 (26.1-28.2)	24.2 (23.0-25.4)	20.2 (19.3-21.1)
≥College graduate	11.1 (10.6-11.7)	14.2 (13.5-15.0)	8.8 (8.3-9.3)
Health behaviors			
Sleep duration, mean (h)	5.48 ± 0.85	7.00	8.44 ± 1.14
Alcoholic drinks per day	3.39	3.11	3.40
Smoking (%)			
Current	15.9 (15.0-16.8)	10.6 (9.8-11.5)	12.0 (11.2-12.8)
Former	17.2 (16.4-18.1)	15.7 (14.8-16.7)	15.0 (14.1-15.8)
Never	59.8 (58.6-60.9)	66.4 (65.1-67.7)	65.0 (63.8-66.1)
Any physical activity (%)	65.3 (64.2-66.5)	70.1 (68.7-71.5)	65.4 (64.2-66.6)
Clinical characteristics			
BMI, mean (kg/m^2)	28.8 ± 6.5	27.9 ± 5.6	28.3 ± 3.9
Diabetes (%)	11.9 (11.2-12.7)	8.1 (7.4-8.8)	11.2 (10.5-11.9)
Coronary heart disease (%)	3.4 (3.0-3.8)	1.6 (1.3-1.9)	2.2 (1.9-2.5)
Stroke (%)	2.5 (2.1-2.8)	1.1 (0.9-1.4)	1.8 (1.5-2.1)
Heart attack (%)	3.7 (3.3-4.1)	2.1 (1.8-2.5)	2.6 (2.3-3.0)
Self-reported health status (%)			
Excellent/very good/good	67.8 (66.7-68.9)	79.2 (78.1-80.3)	75.1 (74.0-76.1)
Fair/poor	31.6 (30.5-32.7)	20.3 (19.1-21.4)	24.0 (23.0-25.0)

⁎ Percentages may not sum to 100 due to missing data.

Table 3

Odds ratios for diabetes by sleep duration categories, BRFSS 2013-2014

	American Indians/Alaska Natives			Non-Hispanic Blacks			Hispanics			Non-Hispanic Whites		
Diabetes	Sample size (*n*)	6 or less hrs.	8 or more hrs.	Sample size (*n*)	6 or less hrs.	8 or more hrs.	Sample size (*n*)	6 or less hrs.	8 or more hrs.	Sample size (*n*)	6 or less hrs.	8 or more hrs.
Model 0^	14,536	**1.69*** **	**1.36***	71,765	**1.17****	**1.37*** **	59,472	**1.54*** **	**1.44*** **	729,962	**1.48*** **	**1.50*** **
Model 1	14,536	**1.88*** **	**1.55****	71,765	**1.26*** **	**1.27*** **	59,472	**1.47*** **	**1.45*** **	729,962	**1.65*** **	**1.36*** **
Model 2	12,524	**1.67*** **	**1.51*** **	61,404	**1.14***	**1.15***	50,454	**1.33*** **	**1.32*** **	625,260	**1.33*** **	**1.20*** **
Model 3	11,742	**1.71*** **	**1.56****	56,878	1.07	1.13	44,607	**1.28****	**1.32*** **	591,873	**1.22*** **	**1.16*** **
P for interaction†		ref	ref		**.004**	**.039**		.159	.414		**.046**	.073

^Model 0: sleep only; model 1: sleep + age, sex; model 2: model 1 + income, education, marital status, employment status; model 3: model 2 + alcohol, smoking, physical activity, and BMI;.

***P b 0.001; **P b 0.01; *P b 0.05; †short sleep-race interaction; long sleep-race interaction

With respect to CHD, again the age- and gender-adjusted models in all race/ethnic groups indicated statistically significantly higher risk associated with both short and long sleep duration (Table 4). Attenuation was observed for both short and long sleep as potential confounders were added to the models. In Model 3, only short sleep duration was associated with statistically significantly increased risk of CHD in AI/ANs. According to Model 3, short sleep was statistically significantly associated with higher risk of CHD in all race/ethnic groups. Long sleep duration was significantly associated with CHD in whites only. Meanwhile, there was no significant interaction observed by race/ethnicity for sleep duration and CHD.

Results for heart attack were similar to those for CHD (Table 4). A statistically significantly higher risk of heart attack was evident for both short and long sleepers among all groups in age- and gender-adjusted models, except long-sleeping Hispanics. The association be- tween sleep duration and heart attack was attenuated when adjusting for more covariates and was non-significant in Model 3, except among whites and short sleep among blacks. The interactions between race/ethnicity and sleep duration in the heart attack analysis did not reach statistical significance.

Table 4

Odds ratios for stroke, CHD, and heart attack by sleep duration categories, BRFSS 2013-2014

	American Indians/Alaska Natives			Non-Hispanic Blacks			Hispanics			Non-Hispanic Whites		
	Sample size (*n*)	6 or less hrs.	8 or more hrs.	Sample size (*n*)	6 or less hrs.	8 or more hrs.	Sample size (*n*)	6 or less hrs.	8 or more hrs.	Sample size (*n*)	6 or less hrs.	8 or more hrs.
Stroke												
Model 0^	14,536	2.16***	1.59*	71,765	1.76***	1.93***	59,472	2.29***	1.61**	729,962	1.86***	1.96***
Model 1	14,536	2.48***	1.70*	71,765	1.86***	1.80***	59,472	2.17***	1.53**	729,962	2.07***	1.70***
Model 2	12,162	1.73*	1.41	59,129	1.51***	1.38**	48,349	1.63*	1.30	611,817	1.44***	1.37***
Model 3	11,742	1.78*	1.42	56,878	1.51***	1.40**	44,607	1.68*	1.39	591,873	1.43***	1.36***
P for interaction†		ref	ref		.817	.701		.613	.734		.725	.817
CHD												
Model 0^	14,536	1.74***	1.52*	71,765	1.44***	1.43***	59,472	2.17***	1.40***	729,962	1.51***	1.55***
Model 1	14,536	2.11***	1.68**	71,765	1.58***	1.29*	59,472	2.07***	1.31*	729,962	1.76***	1.30***
Model 2	12,162	1.60*	1.53	59,129	1.29*	1.06	48,349	1.75***	1.20	611,817	1.38***	1.11***
Model 3	11,742	1.60*	1.54	56,878	1.27*	1.08	44,607	1.78***	1.23	591,873	1.37***	1.10***
P for interaction†		ref	ref		.672	.248		.481	.532		.487	.185
Heart attack												
Model 0	14,536	1.68**	1.29	71,765	1.45***	1.61***	59,472	1.76***	1.25	729,962	1.69***	1.67***
Model 1	14,536	1.96***	1.43*	71,765	1.56***	1.48***	59,472	1.68***	1.19	729,962	1.98***	1.43***
Model 2	12,162	1.42	1.30	59,129	1.31*	1.17	48,349	1.27	0.93	611,817	1.44***	1.15***
Model 3	11,742	1.40	1.29	56,878	1.30*	1.17	44,607	1.29	0.95	591,873	1.42***	1.14***
P for interaction†		ref	ref		.869	.697		.870	.273		.468	.354

^Model 0: sleep only; model 1: sleep + age, sex; model 2: model 1 + income, education, marital status, employment status; model 3: model 2 + alcohol, smoking, physical activity, and BMI. ***P b .001; **P b .01; *P b .05; †short sleep-race interaction; long sleep-race interaction.

Supplementary Table 2 presents the estimated prevalence ratios (PRs) for the association between sleep duration and cardiometabolic outcomes from Poisson regression models. All of the estimated PRs were similar to or slightly lower than the corresponding ORs. The major conclusions remained the same, including a statistically significant interaction between race/ethnicity and sleep duration in the sleep-diabetes analysis, indicating a higher PR of diabetes among AI/AN short-sleepers than most other race/ethnic groups. In the sensitivity analysis, using 7-9 hours as the reference group as recommended by the National Sleep Foundation, in the age- and gender-adjusted models, the association between short/long sleep duration and diabetes was similar to or stronger than the corresponding association with 7 hours as the reference category. Similarly, most of the fully-adjusted ORs were statistically significant for diabetes, except for long-sleeping AIANs as well as short-sleeping blacks and Hispanics (Supplementary Table 3). Finally, when we separated very short sleepers (b6hours) from short sleepers (6 hours), the age- and gender- adjusted ORs were larger for the very short sleepers than those who sleep 6 hours per day. However, most of the differences between very short sleepers and short sleepers attenuated or disappeared in the fully-adjusted models (Supplementary Table 4).

Discussion

To our knowledge, this is the largest cross-sectional examination of self-reported sleep duration focusing on the AI/AN population. We found a high proportion of AI/ANs reporting a usual short sleep duration—41.7%, compared to 32.9% of whites, 34.8% of Hispanics, and 46.2% of blacks from the same survey years. This corroborates our conclusion from a previous investigation that lack of sleep may be a substantial public health burden among minority populations, including AI/ANs.[22] AI/ANs also reported the second highest percentage of long sleepers (37.5%) among all race/ethnic groups surveyed. It will be important in future studies to understand the underlying cause of the high prevalence of reported short and long sleep in this population.

The present study revealed that the age- and gender-adjusted risks for all four cardiometabolic outcomes were significantly elevated in both short and long sleepers (a so-called "U-shaped" distribution). While this is consistent with results from previous work,[1,2,4] the magnitude of risk for diabetes among AI/ANs in the BRFSS is larger than that for other race/ethnic counterparts. Importantly, the sleep-diabetes association remained strong in AI/ANs after adjustment through Model 3, while adjusting for demographic and behavioral factors, attenuated the association in the other race/ethnic groups. These results indicate some of the factors that are important confounders or mediators for the association between sleep duration and diabetes[1,23] in other race/ethnic groups may not play a role in the sleep-diabetes association as important as that among AI/ANs.

Few epidemiologic studies have considered sleep duration among AI/ANs. The Native Elder Care Study, a small cross-sectional study of AI/ANs aged 55 or older, revealed that short sleep duration (5 hours or less) as well as daytime sleepiness were associated with increased risk of CVD.[24] The Special Diabetes Program for Indians-Diabetes Prevention Demonstration Project (SDPI-DP) revealed that short, but not long sleep duration was associated with an increased risk of diabetes in a cohort of AI/ANs with prediabetes who participated in a lifestyle intervention.[22] Ehlers and colleagues, drawing upon data from an on-going cross-sectional study of AI/ANs, reported that a higher degree of AI/AN ancestry was associated with short sleep duration, but not sleep quality.[25] While previous analyses of BRFSS data indicated that frequent insufficient sleep is more common among AI/ANs than their peers in other groups,[26] that work did not examine the as-sociation between sleep duration and health outcomes. Consistent with our results here, an analysis of 2014 BRFSS data has placed AI/ANs along with other minority populations such as blacks and Native Hawaiians/Pacific Islanders as at high risk for unhealthy sleep durations, with state-specific estimates suggesting the burden among all race/ethnicities may be especially clustered in states along the Appalachian Mountains.[7]

Many potential biological mechanisms have been advanced to ex-plain the relationships between sleep duration and cardiometabolic disease. For instance, the increased risk of diabetes due to short sleep is thought to be linked to decreased leptin and elevated ghrelin levels, which alter appetite regulation and increase hunger.[27] Abnormal glucose control has also been linked to snoring and obstructive sleep apnea.6 Other potential mechanisms contributing to short sleep and diabetes include inadequate secretion of insulin from the pancreas due to reduced β-cell responsiveness,[28] as well as decreased testosterone or melatonin secretion during sleep disruption.[29] Re-ported associations between long sleep duration and diabetes are more speculative and less likely of biological origin. The observed significant long sleep-diabetes association may be confounded by other conditions.[2] Depression, unemployment, poor underlying health, and physical inactivity common among long sleepers likely contribute to this association.[6]

With respect to CVD, nocturnal hypertension and sleep-disordered breathing are two sleep-related phenomena which have been offered as explanations for the relationship between poor sleep and heightened risk.[30,31] In a cohort of elderly Japanese hypertensives, a sleep duration under 7.5 hours per night was linked to in-creased stroke risk (HR = 2.21, P =.003).[32] Additional inquiry into the relationship between sleep duration and stroke is warranted. Mechanisms hypothesized to explain the association between sleep duration and CHD include increased blood pressure as well as secretion of pro-inflammatory cytokines. There are few explanations for the connection between heart attack and sleep duration. Proposed mechanisms include development of atherosclerosis, coagulation, or effects on cardiac and endothelial function due to sleep loss.[33]

A significant U-shaped association between sleep duration and diabetes was observed among AI/ANs in the present analysis, in contrast to previous findings in the SDPI-DP study which only showed a significantly increased risk among short sleepers.[22] We hypothesized previously that the lack of an association between long sleep duration and diabetes in that cohort was due to the lifestyle intervention, which may have mitigated this relationship. Evidence of a significant association between long sleep duration and diabetes among BRFSS AI/AN participants who did not undergo intervention further suggests, as others have since speculated,[27] that lifestyle intervention may alter the mediators for the association between long sleep and diabetes risk.

Previous studies have noted disparities in sleep duration among other race/ethnic groups. Some investigators suggest that sleep may fundamentally contribute to disparities in cardiovascular health, driving socioeconomic and other inequities that lead to a range of poor health outcomes in underserved populations.6 Strong associations between sleep duration and both diabetes and CVD found among Hispanics in our study add to the sparse literature in this area.[11,34] With respect to AI/ANs, a recent analysis advances a novel genetic argument that one variant in the AI/AN population is associated with evening preference (i.e., "being an owl vs. being a lark").[35] Moreover, there is evidence of an interaction for sleep duration and evening preference on CVD risk factors.[36] Our interaction analysis suggests that the mechanisms for the sleep-diabetes relationship in AI/ANs may be different from those of other race/ethnic populations. Future studies are needed to elucidate the underlying reasons for the racial differences found here, and to build on prior work implicating race/ethnic interactions for diabetes, obesity, and hyperlipidemia. In particular, a recent study using NHANES highlights that subtle differences in risk patterns by race/ethnicity may have previously been overlooked; for example, a significant association be-tween very short sleep and diabetes was only found among non-Hispanic whites, not in other race/ethnic groups. However, that study did not examine the association among AI/ANs.[37]

The strengths of this analysis include a large sample size, use of a nationally representative sample, as well as a broad spectrum of cardiometabolic outcomes, in contrast to some previous similar studies in AI/ANs. However, several limitations need to be acknowledged. First, the BRFSS data are self-reported and are subject to measurement error and/or recall bias. A previous study examined the extent to which self-reported sleep duration correlates with objective measures.[38] On average, those sleeping 5 to 7 hours over-reported sleep duration by 0.4 to 1.2 hours, indicating that the self-reported sleep metric could be systematically biased. Data with more precise means of sleep duration measurement among AI/ANs are needed to confirm the findings of the current study. While the cardiometabolic outcomes are also based on self-reported data, a comprehensive systematic review of the validity and reliability of BRFSS measures[39] indicates high levels of agreement in reliability testing for some chronic conditions such as diabetes. Yet, fair to moderate agreement between self-reports and claim-based data has been reported for heart disease and stroke.[40,41] Second, we did not adjust for dietary covariates in this analysis; complete dietary questionnaires were not available in either survey years. Third, because this is a cross-sectional study, we are unable to infer causation in the observed associations. Future longitudinal studies are required to confirm these associations and to assess their directionality. Fourth, the BRFSS lacks information on comorbid sleep conditions, limiting our ability to examine these in tandem with sleep duration. Finally, questions regarding sleep quality were not available, limiting our ability to evaluate the association between sleep quality and the outcomes of interest.

Despite the above limitations, our results add to the argument that inadequate sleep duration, and its sequelae, is a prevalent public health problem among AI/ANs as in other segments of the US population.[2,4,6,8] Given recent, alarming reports of higher mortality rates due to cardiometabolic conditions[15,16] among AI/ANs than their white peers, our findings suggest that future interventions to reduce the cardiometabolic disparities experienced by the AI/AN population should more carefully take sleep duration into account.

Disclosure Statement

The authors declare no conflict of interest.

Acknowledgements

Manuscript preparation was supported in part by National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)(R21DK108187, L. Jiang; and 1P30DK092923, S.M. Manson).

We thank Trina M. Norden-Krichmar, PhD for helpful scientific input and Christopher R. Kawata for assistance in preparation of tables.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleh.2019.02.003.

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* Corresponding author at: Department of Epidemiology, School of Medicine University of California, Irvine, Irvine Hall 205B, Irvine, CA 92697-7550. Tel.: +1 949 824 7325; fax: +1 949 824 4773.

E-mail address: lhjiang@uci.edu. (L. Jiang).