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Sleep Duration and Chronic Diseases among US Adults Age 45 Years and Older: Evidence From the 2010 Behavioral Risk Factor Surveillance System

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Study Objective: To examine the effects of obesity and frequent mental distress (FMD) on the relationship of sleep duration with coronary heart disease (CHD), stroke, and diabetes.
Design: Cross-sectional study.
Setting: Population-based surveillance.
Participants: There were 54,269 adults age 45 y or older who completed the 2010 Behavioral Risk Factor Surveillance System survey in 14 states.
Results: Nearly one third (31.1% or an estimated 11.1 million) of respondents age 45 y and older reported being short sleepers (≤ 6 h), 64.8% being optimal sleepers (7-9 h), and 4.1% being long sleepers (≥ 10 h) in a 24-h period. Compared with the optimal sleep duration, both short and long sleep durations were significantly associated with obesity, FMD (mental health was not good ≥ 14 days during the past 30 days), CHD, stroke, and diabetes after controlling for sex, age, race/ethnicity, and education. The U-shaped relationships of sleep duration with CHD, stroke, and diabetes were moderately attenuated by FMD. The relationship between sleep duration and diabetes was slightly attenuated by obesity.
Conclusions: Sleep duration had U-shaped relationships with leading chronic diseases. Further prospective studies are needed to determine how mental health and maintenance of a normal weight may interact with sleep duration to prevent chronic diseases.
Keywords: Chronic disease, mental health, population-based survey, sleep duration
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INTRODUCTION

There is a perception that the proportion of US adults who report short sleep duration (≤ 6 h per 24-h period) is greater than that of decades ago; however, survey trends are not consistent.[1-3] It has been suggested that short sleep duration may be explained by longer working hours; lifestyle changes, such as increased family time; use of electronics such as television or computers; and shift work.[3,4] Research has demonstrated that both short and long sleep duration are associated with obesity, depression, anxiety, diabetes mellitus, and cardiovascular disease,[5-14] although definitions of short and long sleep duration vary across studies.[1] However, underlying mechanisms for relationships between sleep duration and chronic diseases are understudied.

Evidence-based studies suggest that there are at least two potential pathways that may explain why short sleep duration is associated with chronic diseases. First, short sleep duration may result in greater insulin resistance, as well as decreased leptin and increased ghrelin through regulation of the hypothalamic-pituitary-adrenal axis. This may lead to metabolic abnormalities and weight gain.[15,16] Chronic metabolic impairments such as obesity may subsequently lead to the development of diabetes, heart disease, and stroke.[8,9,17-19] This is corroborated by results from a prospective study with 10-y follow-up among women that body mass index (BMI) may significantly attenuate the association of short and long sleep duration with diabetes.[17] Therefore, obesity may play an intermediate or mediating role on relationships between sleep duration and chronic diseases. Evidence also demonstrates that sleep duration is associated with depression and anxiety.[20,21] Depression and/or anxiety, whether present separately or simultaneously, are independent risk factors for type 2 diabetes, hypertension, and cardiovascular disease.[17,22-24] Therefore, mental disorders also may mediate relationships between sleep duration and chronic diseases.

This study assesses relationships between sleep duration and selected chronic diseases among US adults age 45 y or older in 14 states using data from the 2010 Behavioral Risk Factor Surveillance System (BRFSS) and examines whether those relationships were attenuated by frequent mental distress (FMD) and/or obesity. Because of the variety of public health information collected from the nation's largest annual number of adult respondents, the BRFSS sleep data have been utilized to examine socioeconomic determinants, state and regional differences, and correlations with chronic diseases and health risk behaviors.[14,25-40]

METHODS

Data Source

The BRFSS is a random-digital-dialing telephone survey of more than 450,000 annual respondents that is conducted by the state health departments in collaboration with the Centers for Disease Control and Prevention in all 50 states, the District of Columbia, and US territories. The BRFSS collected data on health-related behaviors that are linked to chronic diseases and other conditions among the adult population (age 18 y or older) living in households with landline telephones in 2010. Disproportional sampling of respondents defined by race/ethnicity, sex,

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or age may vary between states and each sample is weighted to the respondent's probability of selection in order to obtain a study population representative of a given state. Trained interviewers administered standardized questionnaires to all adult respondents. In addition to the core questionnaire about chronic diseases and mental health, 14 states (Arkansas, California, Connecticut, Delaware, District of Columbia, Hawaii, Kansas, Maryland, Michigan, Minnesota, Missouri, Nebraska, Nevada, and Oregon) administered the optional sleep module in 2010. All respondents had given oral informed consent to participate in the interview. The response rate (complete and partial interview relative to total eligible households) varied by state among the 14 states and ranged from 39.0% to 68.8% (median = 52.7%) in 2010.[41] A detailed description of the BRFSS survey design, data collection, and full-text questionnaires as well as the public access electronic data files with no personal identifiers can be found at http://www.cdc.gov/brfss.

Measures

Awareness of having chronic diseases was defined through subjects' affirmative responses to the question of whether they had ever been told by a doctor or other health professional that they had diabetes mellitus; coronary heart disease (CHD), which included a heart attack, angina pectoris, and/or CHD; or stroke. Persons who reported "don't know/not sure" were defined as not having the condition. Those who reported having borderline diabetes or prediabetes or having diabetes only during pregnancy were defined as not having diabetes mellitus. Including the small number of persons with borderline diabetes or prediabetes in the nondiabetes group biases the results toward the null finding (a conservative approach) if these persons are also more likely to have a short sleep duration while excluding these persons from the analyses would have led to an overestimate of the actual relationship.

Sleep duration was based on the response to the question, "On average, how many hours of sleep do you get in a 24-h period? Think about the time you actually spend sleeping or napping, not just the amount of sleep you think you should get." As in all other CDC surveillance systems, duration of sleep was reported as whole numbers rounded to the nearest hour. The National Sleep Foundation suggests that most adults need 7-9 h of sleep per night (www.sleepfoundation.org) whereas the National Heart, Lung, and Blood Institute recommends 7-8 h a day for adults (www.nhlbi.nih.gov/health/health-topics/topics/sdd/howmuch.html/). The Institute of Medicine report on sleep disorders refers to an average basal need of 7-8 h per night for adults.[42] However, preliminary data analyses for this study showed that the number of sleep hours was not linearly associated with chronic diseases, and another study had observed that the strength of the associations with chronic disease was quite similar for 7, 8, and 9 h of sleep.[11] Therefore, sleep duration for these analyses was defined as short (≤ 6 h), optimal (7-9 h), and long (≥ 10 h).

Sociodemographic characteristics that were examined as covariates in the association between sleep duration and chronic diseases included sex, age in y (45-54, 55-64, and 65 y or older), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other non-Hispanic), and education (less than high school graduate, high school diploma or general equivalency diploma recipient, and some college or college graduate).

FMD was defined if respondents indicated ≥ 14 days to the question "about your mental health, which includes stress, depression and problems with emotions, for how many days during the past 30 days was your mental health not good?" Because a lengthy telephone survey such as the BRFSS is limited to a single-item mental health question, FMD was developed as an indicator of the perceived mental distress burden of common mental disorders and had been utilized previously to examine correlations with a sleep indicator, depression, anxiety, physical impairments, and sociodemographic characteristics, as well as to examine geographic variations between states.[25,43,44] FMD was derived based on the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR).[45] Receiver operating characteristic (ROC) analyses of the number of days of the BRFSS FMD measure with other measures of clinically relevant psychiatric symptomatology (the Patient Health Questionnaire-8 in a US population sample of 170,814 adults, and the Kessler-6 in a US population sample of 141,560 adults) demonstrated 0.87 and 0.84 of the respective areas under the curve, which suggest good accuracy for FMD.[46]

Assessment of obesity was based on the BMI (kg/m^2) calculated from self-reported height in inches and weight in pounds and was dichotomized into nonobese (BMI < 30.0 kg/m^2) and obese (BMI ≥ 30 kg/m^2). The BMI-based weight classification has been used often in epidemiological surveys.[47,48] It has been widely recognized from validation studies that the prevalence of obesity calculated from self-reported height and weight are underestimated.[49-51] However, it is a cost-effective approach to obtain BMI information from respondents in such a large-scale population-based study.

Study Population

Because of the low prevalence of chronic diseases among adults aged 18-44 y (1.2% with CHD, 0.7% with stroke, and 2.8% with diabetes), only data for respondents aged 45-99 y were analyzed in this study, as analyses incorporating the younger age groups were assumed to provide unstable estimates of mediation effects. Restricting the population sample did not affect the sampling weight because of the BRFSS study design. In 2010, 56,640 adults age 45 y or older in the 14 states answered BRFSS questions about sociodemographic characteristics, self-reported height and weight, chronic disease, and sleep duration. Those respondents who had missing information on sleep duration (n = 2,352) and chronic diseases (n = 19) were excluded. The remaining 54,269 respondents (95.8%) were included in the current study. The excluded population who were missing information for sleep duration were more likely to report having diabetes (16.3% versus 13.2%, $P < 0.05$) and stroke (6.4% versus 4.3%, $P < 0.001$) than in the included population. The prevalence of obesity, FMD, and CHD was similar in excluded and included populations. However, due to the relatively small sample size of the excluded population, the influence of the missing data on our results is likely limited.

Statistical Analyses

First, the distributions of selected characteristics and sleep duration among study respondents were examined. Then, weighted prevalence estimates of obesity, FMD, and selected

chronic diseases were obtained for groups defined by selected sociodemographic characteristics and sleep duration. Logistic regression analyses were performed to examine associations of short and long sleep duration with FMD, obesity, and selected chronic diseases and were adjusted for sex, age, race/ethnicity, and education. The magnitude of a potential mediation effect was assessed by measuring the percentage of change in effect between models with and without the specific proposed mediator = $[(OR_{\text{no mediator}} - OR_{\text{with mediator}}) / (OR_{\text{no mediator}} - 1)] \times 100$.[52,53] A significant mediation effect was defined only if sleep duration also was significantly associated with both the potential mediator and chronic disease and the potential mediator was significantly associated with chronic disease.[54] A modified Sobel test, which is tailored for a dichotomized outcome variable, was conducted to assess whether there was a significant effect for the potential mediator in the relationship between sleep duration and each of the three chronic diseases.[55] A partial mediating effect was determined to be present if the relationship between sleep duration and chronic disease still remained significant when the potential mediator was added to the model. A complete mediating effect was defined if the relationship between sleep duration and chronic disease was no longer significant with the potential mediator included in the model. All analyses were conducted using SAS-callable SUDAAN to account for the complex sampling design.[56] The statistical significance level was denoted as $P < 0.05$.

RESULTS

Among 54,269 respondents age 45 y and older, 33.1% were age 65 y and older; 52.8% were women; 76.5% were non-Hispanic white; 5.7% were non-Hispanic black; 10.2% were Hispanic; and 64.5% had more than a high school education (Table 1). Sleeping on average ≤ 6 h was reported by 31.1% of respondents (an estimated 11.1 million adults age 45 y or older), and only 4.1% (an estimated 1.4 million adults age 45 y or older) reported usually sleeping ≥ 10 h in a 24-h period. In addition, 28.8% of respondents were obese and 9.7% had FMD. Respondents reported having CHD (10.9%), stroke (4.3%), or diabetes (13.2%). Of all study respondents, only a small percentage reported having all three diseases (0.6%), whereas 4.1% reported having any two, 9.6% reported diabetes only, 6.8% reported CHD only, and 2.2% reported stroke only.

Table 2 presents the weighted percentages of obesity, FMD, and chronic diseases by selected characteristics. Compared to respondents age 65 y and older, those age 45-54 y and 55-64 y had higher percentages of obesity and FMD but had a lower prevalence of CHD, stroke, and diabetes ($P < 0.05$). Men reported a higher percentage of obesity, CHD, and diabetes but reported a lower percentage of FMD than women ($P < 0.05$). Non-Hispanic blacks and Hispanics had a higher prevalence of obesity, FMD, and diabetes than non-Hispanic whites ($P < 0.05$). There was an inverse relationship between education and each of the five conditions ($P < 0.05$). Obese respondents were more likely to report having FMD, CHD, and diabetes than did nonobese respondents ($P < 0.05$). Persons reporting FMD were more likely than those without FMD to report being obese ($P < 0.05$) or to report having one or more of the three chronic diseases ($P < 0.05$).

Table 1—Distributions of selected characteristics among adults age 45 years and older, 14 states,[a] Behavioral Risk Factor Surveillance System, 2010

Characteristic	N[b]	% (95% CI)[c]
Total	54,269	100.0
Age, y		
45-54	13,813	37.7 (36.8-38.6)
55-64	16,461	29.2 (28.5-30.0)
65 or older	23,995	33.1 (32.3-33.8)
Women	33,359	52.8 (52.0-53.7)
Race/ethnicity		
White, non-Hispanic	42,757	76.5 (75.6-77.3)
Black, non-Hispanic	4,174	5.7 (5.4-6.0)
Hispanic	1,968	10.2 (9.4-10.9)
Other, non-Hispanic	4,788	6.7 (6.2-7.2)
Education attainment, years		
Less than high school graduate	3,986	9.3 (8.7-9.9)
High school diploma or GED	15,817	25.5 (24.8-26.2)
At least some college	34,314	64.5 (63.7-65.4)
Sleep duration, h		
≤ 6	16,161	31.1 (30.3-32.0)
7-9	35,766	64.8 (64.0-65.6)
≥ 10	2,337	4.1 (3.7- 4.4)
Obesity (BMI ≥ 30.0 kg/m^2)	14,412	28.8 (28.0-29.6)
Frequent mental distress[d]	4,881	9.7 (9.2-10.2)
Chronic disease		
Coronary heart disease	6,310	10.9 (10.0-11.4)
Stroke	2,814	4.3 (4.0-4.6)
Diabetes	7,738	13.2 (12.7-13.8)

[a]States are Arkansas, California, Connecticut, Delaware, District of Columbia, Hawaii, Kansas, Maryland, Michigan, Minnesota, Missouri, Nebraska, Nevada, and Oregon. [b]Unweighted sample size. [c]Weighted percentage and 95% confidence interval (CI) were derived using the sampling weight. [d]Mental health (which included stress, depression and problems with emotion) was not good ≥ 14 days in the past 30 days. BMI, body mass index; CI, confidence interval; GED, general equivalency diploma.

Associations Between Sleep Duration, Obesity, FMD, and Chronic Disease

Compared to respondents reporting the optimal 7-9 h, short sleepers reported a higher prevalence of obesity, FMD, CHD, stroke, and diabetes ($P < 0.05$; Table 3). Long sleepers also reported a higher prevalence of obesity, FMD, and the three chronic diseases than did the optimal sleepers. Odds ratios were obtained to examine the association of sleep duration with obesity, FMD, and chronic diseases using logistic regression models. Without controlling for any covariates, the likelihood for reporting obesity, FMD, CHD, stroke, and diabetes were significantly greater among both short and long sleepers compared to optimal sleepers (Model 1). These associations persisted after controlling for sex, age, race/ethnicity, and education (Model 2; $P < 0.05$).

Mediation Effects

The increased likelihoods of CHD and stroke among short and long sleepers in comparison with optimal sleepers were not affected by adding obesity to the previous multivariable

Table 2—Weighted percentages of potential mediators and chronic diseases by selected characteristics among adults age 45 years and older, 14 states,[a] Behavioral Risk Factor Surveillance System, 2010

	Potential mediators		Chronic diseases		
	Obesity % (95% CI)	FMD[b] % (95% CI)	Coronary heart disease % (95% CI)	Stroke % (95% CI)	Diabetes % (95% CI)
Total	28.8 (28.0-29.6)	9.7 (9.2-10.2)	10.9 (10.4-11.4)	4.3 (4.0-4.6)	13.2 (12.7-13.8)
Age, y					
45-54	29.7 (28.0-31.2)	10.5 (9.5-11.5)	4.3 (3.6- 4.9)	1.9 (1.5-2.3)	7.7 (6.9-8.6)
55-64	33.0 (31.5-34.5)	12.1 (11.0-13.2)	9.9 (9.0-10.9)	3.2 (2.7-3.7)	14.9 (13.8-16.0)
65 or older	24.0 (23.0-25.0)	6.6 (6.0-7.3)	19.2 (18.2-20.1)	8.0 (7.4-8.7)	18.1 (17.2-19.0)
Sex					
Men	30.0 (28.7-31.3)	8.1 (7.3-8.9)	13.9 (13.0-14.7)	4.2 (3.8-4.7)	14.5 (13.6-15.4)
Women	27.6 (26.6-28.6)	11.1 (10.4-11.8)	8.2 (7.6-8.7)	4.4 (4.0-4.8)	12.1 (11.4-12.8)
Race/ethnicity					
White, non-Hispanic	27.4 (26.6-28.2)	8.7 (8.2-9.2)	11.0 (10.5-11.5)	4.2 (3.8-4.5)	11.8 (11.2-12.3)
Black, non-Hispanic	41.8 (38.9-44.7)	13.2 (10.5-15.9)	11.8 (9.7-13.8)	6.7 (5.1-8.2)	22.8 (20.4-25.3)
Hispanic	35.2 (31.0-39.3)	13.6 (10.9-16.4)	8.2 (6.1-10.4)	3.5 (2.2-4.8)	16.4 (13.6-19.2)
Other, non-Hispanic	21.8 (18.7-24.9)	11.3 (8.6-13.9)	9.9 (7.9-11.8)	4.6 (3.4-5.8)	17.1 (14.3-20.0)
Education attainment, y					
Less than high school graduate	36.0 (32.3-39.7)	17.6 (14.9-20.3)	14.0 (11.9-16.2)	6.8 (5.4- 8.1)	19.5 (16.8-22.2)
High school diploma or GED	33.4 (31.9-35.0)	10.4 (9.4-11.4)	13.5 (12.5-14.5)	5.3 (4.6-5.9)	14.9 (13.9-15.9)
At least some college	25.9 (25.0--26.9)	8.3 (7.7- 8.9)	9.3 (8.7- 9.9)	3.6 (3.2-3.9)	11.7 (11.1-12.4)
BMI, kg/m^2					
< 30		8.6 (8.0-9.3)	10.0 (9.4-10.6)	4.1 (3.7-4.4)	9.0 (8.4-9.6)
≥ 30		11.9 (10.9-13.0)	13.5 (12.4-14.5)	5.0 (4.3- 5.6)	23.6 (22.3-24.9)
Frequent mental distress[b]					
No	28.0 (27.2-28.9)		10.1 (9.6-10.6)	3.8 (3.5-4.1)	12.4 (11.8-13.0)
Yes	35.8 (33.1-38.6)		17.4 (15.3-19.5)	8.5 (7.1-9.9)	20.3 (17.9-22.8)

[a]States are Arkansas, California, Connecticut, Delaware, District of Columbia, Hawaii, Kansas, Maryland, Michigan, Minnesota, Missouri, Nebraska, Nevada, and Oregon. [b]Mental health (which included stress, depression and problems with emotion) was not good ≥ 14 days in the past 30 days. BMI, body mass index; CI, confidence interval; GED, general equivalency diploma.

regression models and remained statistically significant (Model 3). However, the likelihood of diabetes was slightly attenuated after further controlling for obesity (Model 3). When adjusting for FMD in addition to age, sex, race/ethnicity, and education, a moderate reduction in the likelihood of CHD (Model 4) was observed for both short and long sleep duration, whereas moderate reductions in the odds of stroke and diabetes were observed for short sleep duration. In contrast, FMD only slightly attenuated the association of long sleep duration with stroke and diabetes (Model 4). In addition, the significant U-shaped association between sleep duration and obesity persisted after controlling for the sociodemographic covariates and FMD (Model 4), as did the significant U-shaped association between sleep duration and FMD after the adjustment for sociodemographics and obesity (Model 3). The results from the Sobel test for mediation supported these findings (data not shown).

DISCUSSION

This study demonstrated that compared with optimal sleep duration (7-9 h per day), both short (≤ 6 h per day) and long (≥ 10 h per day) sleep duration were significantly associated with CHD, stroke, and diabetes among adults age 45 y or older. These associations were more pronounced with long sleep duration than with short sleep duration. Furthermore, these relationships were moderately attenuated but not completely explained by either FMD or obesity. Therefore, our findings add some insights into the possible underlying mechanism of the association between sleep duration and chronic disease.

Previous findings have indicated that both short and long sleep duration are associated with increased risk for obesity. Obesity, in turn, has been shown as a robust risk factor for diabetes and cardiovascular diseases.[9,12,18,57,58] For example, the results observed among 70,026 women age 30-55 y in the Nurse's Health Study suggested that compared to optimal sleep (defined as 8 h per day in the study), the significant relationship of diabetes with short sleep (defined as ≤ 5 sleep h) did not persist after adjustment for categorical BMI but still remained with long sleep (defined as ≥ 9 sleep h).[9] Another prospective study indicated that significant relationships between short and long sleep duration and diabetes were attenuated by obesity among 1,139 men aged 40-70 y in the Massachusetts Male Aging Study.[12] The consistency of these and previous findings might be explained by obesity playing a potential mediator between short sleep and diabetes. However, the association between long sleep duration and chronic disease is less clearly understood. One

Table 3—The association of sleep duration with potential mediators and chronic diseases among adults age 45 years or older, 14 states,[a] Behavioral Risk Factor Surveillance System, 2010

Conditions/ sleep duration (h)	Weighted prevalence % (95% CI)	Model 1[b] OR (95% CI)	Model 2[c] OR (95% CI)	Model 3[d] OR (95% CI)	Model 4[e] OR (95% CI)
Potential mediators					
Obesity (BMI ≥ 30.0 kg/m^2)					
≤ 6	32.2 (30.8-33.7)	1.32 (1.21-1.43)	1.23 (1.13-1.34)		1.21 (1.1-1.32)
7-9	26.5 (25.6-27.5)	1.00 (referent)	1.00 (referent)		1.00 (referent)
≥ 10	37.5 (33.5-41.6)	1.66 (1.39-1.99)	1.60 (1.34-1.93)		1.57 (1.31-1.89)
FMD[f]					
≤ 6	16.2 (14.9-17.4)	3.00 (2.64-3.41)	2.78 (2.45-3.17)	2.78 (2.43-3.18)	
7-9	6.0 (5.5-6.6)	1.00 (referent)	1.00 (referent)	1.00 (referent)	
≥ 10	19.0 (15.8-22.1)	3.64 (2.91-4.56)	3.64 (2.87-4.61)	3.75 (2.95-4.76)	
Chronic diseases					
Coronary heart disease					
≤ 6	11.1 (10.1-12.1)	1.19 (1.06-1.33)	1.45 (1.29-1.63)	1.45 (1.29-1.63)	1.35 (1.19-1.52)[g]
7-9	7.9 (7.3-8.5)	1.00 (referent)	1.00 (referent)	1.00 (referent)	1.00 (referent)
≥ 10	14.8 (12.0-17.6)	2.36 (1.91-2.91)	1.92 (1.52-2.43)	1.85 (1.45-2.35)	1.73 (1.36-2.21)[g]
Stroke					
≤ 6	4.3 (3.7-4.9)	1.18 (1.00-1.39)	1.34 (1.14-1.59)	1.36 (1.15-1.61)	1.22 (1.03-1.45)[g]
7-9	3.0 (2.7-3.4)	1.00 (referent)	1.00 (referent)	1.00 (referent)	1.00 (referent)
≥ 10	7.7 (5.8-9.5)	3.13 (2.42-4.05)	2.47 (1.89-3.22)	2.46 (1.88-3.22)	2.23 (1.71-2.92)[h]
Diabetes					
≤ 6	15.0 (13.8-16.1)	1.30 (1.17-1.44)	1.34 (1.20-1.49)	1.28 (1.13-1.44)[h]	1.25 (1.12-1.40)[g]
7-9	10.8 (10.2-11.5)	1.00 (referent)	1.00 (referent)	1.00 (referent)	1.00 (referent)
≥ 10	20.9 (17.8-24.0)	2.39 (1.97-2.89)	1.96 (1.60-2.39)	1.83 (1.48-2.27)[h]	1.79 (1.46-2.20)[h]

[a]States are Arkansas, California, Connecticut, Delaware, District of Columbia, Hawaii, Kansas, Maryland, Michigan, Minnesota, Missouri, Nebraska, Nevada, and Oregon. [b]Model 1: Weighted odds ratio (OR) and 95% confidence interval (CI) were obtained from an univariate logistic regression model without adjustment. [c]Model 2: Adjusted ORs were obtained from a multivariable logistic regression model with adjustment for age, sex, race/ethnicity, education. [d]Model 3: Adjustment for covariates in Model 2 plus obesity. [e]Model 4: Adjustment for covariates in Model 2 plus FMD. [f]Frequent mental distress: mental health (which included stress, depression and problems with emotion) was not good ≥ 14 days in the past 30 days. [g]20-40% change in OR due to a potential mediator effect. [h]10% to < 20% change in OR due to the addition of a potential mediator to the model.

possible explanation is that the longer sleep duration could also be linked to obesity or impaired mental health.[5,6] Additionally, associations of CHD and stroke with sleep duration were not attenuated by obesity. One possible explanation was that sleep duration might be associated with CHD or stroke through other mediators such as mental distress or hypertension.

Depression and anxiety often coexist with sleep loss and many chronic diseases.[5,6,20,21] Previously observed relationships between frequent insufficient sleep (defined as ≥ 14 days of inadequate sleep or rest in the past 30 days) and FMD indicated that perceived sleep loss was highly associated with mental health.[44] Results regarding significant relationships between FMD and chronic diseases from prospective studies were also consistent with our findings.[59] Prior research among 60,028 women age 25-46 y in a prospective Nurse's Health Study suggested that depression might confound or mediate the association between long sleep duration and mortality.[60] The current investigation appears to be the first to assess FMD as a potential mediator in the relationship between sleep duration and chronic disease. However, well-designed prospective studies are needed to assess whether psychological distress or depression are causal intermediates or confounders of this association. In addition, experimental studies with sleep deprivation suggest that prolonged sleep loss reduces human natural immune function,[61,62] exacerbates inflammation,[63,64] and could lead to metabolic syndrome disease and other chronic diseases.[65] Therefore, future research is warranted to explore other potential pathways.

Although this is the largest study to date to address the potential mediation effect in the relationship between sleep duration and chronic diseases, several limitations should be noted. First, because the BRFSS is a cross-sectional study, it is not possible to make causal inferences and determine whether short or long sleep duration result in obesity, FMD, and chronic conditions, or *vice versa*. Second, sample selection bias due to the low response rate may also have occurred because institutionalized persons, persons residing in households without landline telephones, younger adults who only have cellular telephones, and persons with severely impaired physical or mental health might not have been reached or have had the means to complete the BRFSS survey and thus were not included in the survey. However, the effect of potential systematic bias is likely limited as the moderately positive relationship between sleep duration and chronic disease revealed in our study is consistent with results from prior research.[7-9] Third, self-reported sleep duration on national surveillance systems has not been validated by polysomnography or actigraphy and may not be as accurate as these objective measures and may

have underestimated a true association with chronic diseases association if poor sleep duration is overreported. In addition, due to the self-reported nature of all examined variables, an underreporting of chronic diseases (not confirmed by medical records or self-reported medication usage), FMD, and obesity (calculated from respondents' self-reported height and weight) may have occurred,[66,67] potentially resulting in a stronger relationship of short and long sleep duration with the outcomes in this study. Finally, our results were derived from a sample of the population that was restricted to adult respondents in 14 states and may not represent findings for the entire US. However, the overall percentage of short sleep duration and the distribution of sleep duration in the BRFSS study population are comparable to findings for sleep duration in study populations for the National Health and Nutrition Examination Survey[68] and the National Health Interview Survey.[69]

Sleep duration may not reflect quality of sleep because persons with long sleep durations also may have poor sleep quality.[70] Thus, sleep duration tends to have a U-shaped relationship with health outcomes, with at least one study suggesting a significant relationship for sleep durations < 5 h with diabetes, myocardial infarction, and stroke compared to 7 h of sleep but no significant differences for persons reporting 5-6 h.[14] Another sleep indicator, perceived insufficient sleep (number of days without enough rest or sleep in the past 30 days), may be a good alternative to address the quality of sleep and tends to have a direct linear relationship with health outcomes. Several studies of BRFSS sleep data demonstrate that both perceived insufficient sleep and sleep duration are correlated with obesity, diabetes, cardiovascular disease, high blood pressure, arthritis, and asthma.[14,28,30,31,39] One study demonstrated that when both sleep indicators are evaluated together, each demonstrates unique effects with different cardiometabolic health outcomes.[14] This is the first study to examine potential mediators for the association of sleep duration with chronic diseases. These findings are consistent with previous findings that the significant associations of the number of days of frequent insufficient sleep with various chronic disease outcomes are mediated significantly but not fully by frequent mental distress and/or obesity.[39]

CONCLUSION

The current study suggests that short and particularly long sleep durations ($\leq$ 6 h and $\geq$ 10 h, respectively) are significantly associated with CHD, stroke, and diabetes among adults age 45 y or older, even after controlling for age, sex, race/ethnicity, education, obesity, or FMD. These results suggest that physicians should monitor mental well-being and body weight in addition to sleep health for patients with chronic disease.

DISCLOSURE STATEMENT

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