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Self-Reported Sleep Duration in Relation to Incident Stroke Symptoms: Nuances by Body Mass and Race from the REGARDS Study

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Abstract

Objectives—Determine, amongst employed persons with low risk for obstructive sleep apnea (OSA), if sleep duration is associated with incident stroke symptoms, independent of body mass index (BMI), and if sleep duration mediates racial differences in stroke symptoms.

Methods—In 2008, 5,666 employed participants (US blacks and whites, ≥45years) from the longitudinal and nationally-representative REasons for Geographic And Racial Differences in Stroke (REGARDS) study, self-reported their average sleep duration. Participants had no history of stroke, transient ischemic attack, or stroke symptoms, and were low risk for OSA. After the sleep assessment, self-reported stroke symptoms were collected at six-month intervals, up to 3 years (*M*=751 days). Interval-censored, parametric survival models were conducted to estimate hazard ratios predicting time from sleep duration measurement (<6, 6-6.9, 7-7.9(reference), 8-8.9, ≥9 hours) to first stroke symptom. Adjusted models included demographics, stroke risk factors, psychological symptoms, health behaviors, and diet.

Results—During follow-up, 224 participants reported ≥1 stroke symptom. In the unadjusted model, short sleep (<6hrs) significantly predicted increased risk of stroke symptoms, but not in adjusted models. Stratification by BMI revealed a significant association between short sleep duration and stroke symptoms only for normal BMI persons in unadjusted (HR: 2.93, 95%CI: 1.38-6.22) and fully adjusted models (HR: 4.19, 95%CI: 1.62-10.84). The mediating effect of

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Competing Interests

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sleep duration on the relationship between race and stroke symptoms was borderline significant in normal weight participants.

Conclusions—Among middle-aged to older employed individuals of normal weight and low risk of OSA, self-reported short sleep duration is prospectively associated with increased risk of stroke symptoms.

Keywords

self-reported sleep duration; stroke symptoms; body mass index; race

Sleep duration is a potential risk factor for stroke (1-8). Long sleep duration (≥9 hours) and short sleep duration (<6 hours) are implicated in the development of stroke (1-4,6,7), though some studies have found no association (5,8). A meta-analysis of six prospective studies indicated that the relative risk of developing or dying from stroke amongst short sleepers and long sleepers was 15% and 65% greater than 7-8 hour sleepers, respectively (9). Over the past few decades, self-reported sleep duration in the general population has steadily decreased (10,11). The decline is primarily occurring among full-time employed individuals (10,11). Therefore, full-time workers with shortened sleep hours may be at increased risk for stroke compared to the general population, which over time may become a greater public health problem.

It is unknown if the self-reported sleep duration-stroke relationship among employed individuals will remain significant after excluding the influence of symptoms of obstructive sleep apnea (OSA). No previous studies excluded participants with OSA symptoms even though OSA is associated with stroke events (12,13), and could be a major confounder. Chen and colleagues found when controlling for non-specific symptoms of OSA (i.e., frequent sleepiness and snoring, body mass index, hypertension), short and long sleep duration still significantly increased risk for ischemic stroke (3). However, this study's conclusions were limited because the sample was dominated by non-Hispanic women, and OSA symptoms were not measured with a standardized instrument. Therefore, the nature of the relationship without the influence of OSA in an ethnically-diverse population of adults is yet to be realized. This lack of data is particularly salient given known disparities in stroke by race between non-Hispanic blacks and whites (14,15). Furthermore, being overweight or obese is a risk factor for OSA, and it is associated with extremes in sleep duration;(1-3,7) thus body mass index may be a major confounder even when OSA symptoms are excluded from analysis. To date, no studies have identified whether the sleep duration-stroke relationship is independent of weight status in persons of low risk for OSA.

The proposed investigation analyzed the prospective association between self-reported sleep duration and stroke symptoms amongst employed persons with low risk for symptoms of OSA using data from the REasons for Geographic and Racial Differences in Stroke (REGARDS) Study. Within the REGARDS study, stroke symptoms were discovered to be significant independent predictors of future stroke events (16). Their predictive impact is similar in magnitude to diabetes and heart disease, and greater in magnitude than smoking and hypertension. Therefore, these symptoms may represent risk factors late in the causal chain to stroke events. Additionally, we investigated if there were disparities in these predictive relationships between blacks and non-Hispanic whites since these two ethnic groups tend to differ in sleep duration (17), and blacks have poorer clinical outcomes and stroke-related mortality rates than non-Hispanic whites (14,15).

Methods

Study design

The present study was initiated in 2008 as an ancillary study to the ongoing REGARDS study. The REGARDS study is a nationally-based longitudinal cohort study that recruited non-Hispanic black and white adults, ≥45 years of age, from 2003 to 2007. The purpose of the study is to examine the factors that increase risk for vascular events with emphasis on racial and regional disparities. For those reasons, non-Hispanic blacks and whites residing in the Stroke Belt (AL, AK, GA, LA, MS, NC, SC, and TN), a region with excess stroke mortality, were oversampled. Institutional review boards from all participating institutions reviewed and approved the study methods. Written consent was obtained from all participants. Through mailing and subsequent telephone contact, a total of 30,239 participants were recruited with 42% of the sample consisting of non-Hispanic blacks, and 56% consisting of residents from the Stroke Belt. At entry into the main study, a combination of telephone interviews and a baseline in-person visit were used to obtain medical and stroke/transient ischemic attack (TIA) risk factor histories, demographic information, and physical measurements including body mass index (BMI), blood and urine samples and an electrocardiogram. Self-administered questionnaires including the Block98 (Food Frequency Questionnaire (FFQ), Nutrition Quest™, Berkeley, CA) were left with the participants to collect additional information. A more detailed account of the study methodology has been published previously (18). At six-month follow-up intervals after the initial baseline visit, telephone contact was used to identify potential stroke and stroke symptoms occurring in the interval since the last telephone contact.

Stroke Symptoms

Stroke symptoms, as opposed to stroke events, were used as the outcome measure in the present study. The number of verified stroke events was low due to a relatively short follow-up interval. However, self-reported stroke symptoms have significant predictive impact on future stroke events. There is a 36% increased risk for incident stroke for any reported stroke symptom, and the risk increases by 21% per symptom (16). Thus, the use of stroke symptoms as the main outcome is justified. Stroke symptoms were assessed with the Questionnaire for Verifying Stroke-Free Status, a well-validated 8-item questionnaire (19-22). Six items within the questionnaire request information about the occurrence of stroke-like symptoms if there is no prior history of stroke/TIA. These symptoms include the sudden onset of: 1) painless hemibody weakness, 2) painless hemibody numbness, 3) loss of vision in one or both eyes, 4) loss of hemifield vision, 5) inability to understand, or 6) inability to express oneself verbally or in writing. Only stroke symptoms that were reported on the follow-up phone calls after the telephone contact when the sleep parameter module was assessed were included. Because the exact date of these symptoms cannot be reliably recalled, the occurrence of these symptoms was only documented as having occurred since the last telephone contact. Follow-up time was calculated from the date the sleep parameters module was answered to the first incidence of any stroke symptom. If no stroke symptom occurred, then time was censored at the most recent six-month interval follow-up assessment.

Sleep Measures

From 2008 to 2010, a sleep parameter module was introduced during one of the participant's next six-month telephone follow-up contacts. The sleep metrics examined in the present study were as follows: risk for symptoms of OSA and self-reported habitual sleep duration. OSA symptoms were assessed using the Berlin Sleep Questionnaire and objective, clinical data from the baseline in-home visit. The Berlin Sleep Questionnaire (23), a well-validated and reliable measure, assesses three categories of risk factors related to having OSA that

includes snoring, sleepiness, and high blood pressure/body mass index (BMI). Reporting positively to two or more of the categories indicates the respondent is at high risk for OSA. Although information for the risk category of high blood pressure and BMI were self-reported in the Berlin Sleep Questionnaire, we used objective data for these two variables from the in-person REGARDS baseline visit to improve accuracy. Habitual, self-reported sleep duration among employed individuals was assessed with the questions 'How many hours of sleep do you usually get at night, or during your main sleep period, on your work days' and 'How many hours of sleep do you usually get at night, or during your main sleep period, on your non-work days?' The responses to these two questions were averaged and used as the main predictor variable. Sleep duration was categorized into < hours, 6-6.9 hours, 7-7.9 hours (reference group), 8-8.9 hours, and ≥9 hours.

Covariates

Relevant covariates and risk factors were included in the analyses to control for their possible confounding influences on the true relationship between self-reported sleep duration and the incidence of stroke symptoms. All covariates included were chosen because previous literature indicated relationships between each covariate with sleep duration, stroke, or both. These covariates were extracted from the in-person baseline visit, and grouped in the adjusted analyses as demographic information, traditional stroke/TIA risk factors, psychological symptoms, health behaviors, and diet quality. Demographic information consisted of age, race (self-reported as either non-Hispanic black or white), sex, income (i.e., <$20K, $20K-$34K, $35K-$74K, ≥75K), education (i.e., <high school, high school graduate, some college, ≥college graduate), and region (Southeast United States Stroke Belt vs. not). Stroke/TIA risk factors were comprised of BMI category (underweight <18.5kg/m^2, normal 18.5-24.9kg/m^2, overweight 25-29.9kg/m^2, obese ≥30kg/m^2), waist circumference, dyslipidemia (i.e., total cholesterol ≥240 mg/dL, low-density lipoprotein ≥160 mg/dL, high-density lipoprotein ≤40mg/dL, or on medication), hypertension (i.e., systolic ≥140mmHg, diastolic ≥90mmHg, or self-report of taking antihypertensive medication), diabetes (fasting glucose ≥126mg/dL or non-fasting glucose ≥200mg/dL, or on pills or insulin), and history of heart disease (i.e., one or more occurrence of self-reported myocardial infarction, coronary artery bypass graft, bypass, angioplasty, stenting, or evidence of myocardial infarction via electrocardiogram). Psychological symptoms included depressive symptoms measured by the 4-item Center for Epidemiologic Studies Depression Scale (CESD-4; 24), and perceived stress assessed by the Perceived Stress Scale (PSS; 25). Both questionnaires were analyzed as continuous measures. Health behaviors consisted of smoking status (i.e., never smoked, past smoker, currently smoking) alcohol use (none; moderate: up to 7 times per week for women and 14 times for men; heavy), exercise (none, 1-3 times per week, ≥4 times per week), and perceived, general health status (poor or fair, good, very good, excellent). Diet quality was measured based on data from the FFQ using the validated and reliable U.S. Department of Agriculture Healthy Eating Index (HEI; 26). The HEI conforms to the 2005 federal dietary guidelines for Americans. The index ranges from 0 to 100 with higher scores indicating better diet quality.

Sampling frame

Of the active participants in the REGARDS cohort at the time of the sleep assessment, 14,097 were not employed and were therefore excluded. Employment was determined through a response of 'employed for wages' or 'self-employed' to the question 'Are you currently employed for wages, self-employed, out of work for more than 1 year, out of work for less than 1 year, a homemaker, a student, retired, or unable to work?' A further 7,003 were excluded due to self-reported stroke, TIA or stroke symptoms at baseline, 282 for missing hypertension or BMI information at baseline, 1,224 for self-reported stroke, TIA or stroke symptoms during follow-up but before the sleep module was asked, and 1,901 for

high risk of symptoms of OSA. Ten participants were finally excluded due to zero values for sleep duration. Thus, the final sample size was 5,666.

Statistical analysis

We compared the distributions of self-reported sleep duration across demographic characteristics using chi square tests of independence for categorical variables and ANOVA for continuous variables. Then, we conducted three sets of analyses to address the three major research questions posed in this investigation: 1) the sleep duration-stroke symptom relationship among persons at low risk for OSA; 2) the modifying effect of weight status on the sleep duration-stroke symptom relationship among employed persons at low risk for OSA; and 3) the mediating role of self-reported sleep duration in the race-stroke symptom relationship. First, interval-censored parametric survival analysis (accelerated failure time analysis) using an exponential distribution was used to estimate hazard ratios for having ≥1 stroke symptom compared to none associated with habitual, self-reported sleep duration in a sequence of unadjusted to accumulative adjusted models. As noted above, the exact date of the incident stroke symptoms was not documented; rather these symptoms occurred sometime since the last telephone contact. Hence, the timing of stroke symptom events is limited to within a six-month interval, a data structure known as "interval censored data." Commonly used statistical techniques such as proportional hazards analysis can provide biased estimates for such interval censored data, a shortcoming that we addressed through the use of parametric accelerated failure time models (27-29). Because there was no intervention, it was reasonable to assume a relatively constant hazard over the follow-up period (up to 3 years), as such, an underlying exponential survival was assumed. There were five adjusted models that incrementally and sequentially added factors to the previously entered factors. The first adjusted model included demographic factors (Model 1). The second model added the stroke/TIA risk factors (Model 2). The third model added depressive symptoms and perceived stress (Model 3), the fourth added health behaviors (Model 4), and the fifth added diet quality (Model 5). Note that Model 5 had a smaller sample size due to the reduced number of completed HEI questionnaires.

Second, we conducted interval-censored parametric survival analysis using interaction terms between self-reported sleep duration and that of the following covariates for Model 4: age, race, sex, income, education, region, and with particular interest, BMI. The variables were not transformed specifically to construct interaction terms. Interactions were introduced as product terms on a multiplicative scale (i.e. variable a * variable b). If a significant interaction term was found, then the adjusted models were analyzed stratified by the covariate.

Third, mediation analyses were investigated to determine the association between race and incident stroke symptoms, and the intermediate effects of sleep duration that contribute to the relationship between race and incident stroke symptoms. We used a "difference of coefficients approach" to measure the indirect or mediated effect of sleep duration because assessing the mediated effect of a continuous mediator (sleep duration) on a binary outcome (≥1 stroke symptom compared to none) has been argued to reduce specification error better than the product of coefficients method (30,31). The regression estimate for race (β_{race}) as a predictor for incident stroke symptoms was estimated using proportional hazards analysis. A second regression estimate, race (β^*_{race}) as a predictor of incident stroke symptoms, was then made after adjustment for sleep duration. The degree to which adjustment for sleep duration attenuates (or mediates) the association between race and incident stroke symptoms is indexed by the change in these two estimates (β_{race} - β^*_{race}). Confidence bounds for the mediation were calculated using the standard error approach of the estimate ± 1.96(SE), where the standard error of the estimated mediation was made as the standard deviation of

the estimated attenuation in 1,000 resampled bootstrap samples. If these 95% confidence intervals did not include the null of zero, then that would suggest that sleep duration is a "significant" mediator of the relationship between race and incident stroke symptoms.

Results

Descriptive Characteristics of the Sample

Of the 5,666 participants, men represented 44.1% of the sample (n = 2,501) and blacks 32.9% (n = 1,865). The sample on average was 60.6-years-old (SD=8.5), and 56.4% resided within the Stroke belt region of the U.S. The sample was significantly younger and were more likely to be non-Hispanic white than the rest of the REGARDS cohort (ps<.001). Average follow-up time from the sleep assessment was 751 days. The maximum follow-up time was 1,110 days. Over this time frame, 224 participants reported at least one stroke symptom. Of 283 stroke symptoms reported from these participants, difficulty understanding others was the most commonly reported (21.9%) followed by loss of vision (20.1%), painless hemibody numbness (15.9%), inability to express oneself (15.9%), loss of hemifield vision (13.4%), and painless hemibody weakness (12.7%). Baseline sample characteristics and characteristics by sleep duration category are displayed in Table 1. Self-reported, short sleep duration was associated with being obese, black, or male. Self-reported, long sleep duration was associated with being a heavy alcohol consumer. Both short and long sleep durations were associated with having lower income, more depressive symptoms, more perceived stress, poorer diet quality, larger waist circumference, being less educated, older, hypertensive, diabetic, sedentary, currently smoking, poorer perceived health, and having a history of heart disease.

Unadjusted & Adjusted Models for Self-Reported Sleep Duration

In Table 2, the unadjusted and adjusted models for the association between self-reported sleep duration and incident stroke symptoms are represented. There was a significant association among participants with less than 6 hours of habitual sleep duration (HR: 1.67; 95% CI, 1.04-2.68) and a borderline significant relationship among participants sleeping 9 hours or greater (HR: 1.67; 95% CI, 1.00-2.79). However, after adjustment for demographic factors both of these associations became statistically non-significant and remained non-significant in further adjusted models.

Interactions between Sleep, Demographic Factors, and BMI

Interaction terms between demographic factors and BMI with self-reported sleep duration revealed only a significant interaction between sleep duration and log-normalized BMI after adjusting for Models 1 through 4 (p = 0.047). Therefore, BMI-stratified analyses were pursued. Participants who had underweight BMIs were not entered into the interaction term because this subgroup had a small sample size (see Table 1). Stratifying by BMI (normal BMI: 18.5-24.9; overweight BMI: 25–29.9; obese BMI ≥30) in the unadjusted model revealed a significant overall association between self-reported sleep duration and incident stroke symptoms only in participants who were within normal BMI limits (p = 0.026). There were no significant associations in the overweight and obese groups. Specifically, only short, reported sleep duration (< 6 hours) increased the risk of incident stroke symptoms in participants within normal BMI limits by almost three times the risk of the referent sleep duration group (HR: 2.93; 95% CI: 1.38-6.22; see Table 3). Adjusting for multivariable Models 1 to 5, in general, incrementally increased the strength of the association. Therefore, after controlling for relevant covariates, short, reported sleep duration remained a significant independent predictor of increased risk of incident stroke symptoms in participants with normal BMIs by more than four times the risk of the referent sleep duration group (HR: 4.19; 95% CI: 1.62-10.84).

Self-Reported Sleep Duration as a Mediator of Race and Incident Stroke Symptoms

We used mediation analyses to measure the contribution of self-reported sleep duration to the relationship between race and incident stroke symptoms in the full sample and stratified by BMI. The minimum requirements for mediation to exist are for the predictor (race) to be related to the mediator (sleep duration), and the mediator to be associated with the outcome (stroke symptoms).[31] The latter association was established above. We were also able to establish a significant association between race and sleep duration such that blacks had significantly shorter, reported sleep (<6 hours) than whites (blacks: 12.2% vs. whites: 4.8%, overall $\chi^2(4) = 200.08$, $p < 0.001$) in the full sample and within the normal BMI subgroup (blacks: 15.8% vs. whites: 4.3%,overall $\chi^2(4) = 83.80$, $p < 0.001$). Using mediation analyses with bootstrapping in the unadjusted model, we were able to find that sleep duration partially explained the relationship between race and incident stroke symptoms in the normal BMI subgroup (see Table 4; HR: 1.23, 95%CI: 1.02-1.52), but not in the full sample. In the fully adjusted model (Model 5) for the normal BMI subgroup, we found the mediating effect estimate of sleep duration increased, though the confidence interval indicated the effect was not significant (see Table 4; HR:1.33, 95%CI: 0.99-2.11).

Discussion

Our prospective study revealed short, self-reported sleep duration is a significant, independent predictor of increased risk of incident stroke symptoms among employed individuals with low risk for OSA and normal BMI compared to individuals with moderate, reported sleep durations. Self-reported sleep duration significantly mediated the relationship between race and incident stroke symptoms within individuals with normal BMIs in the unadjusted model. Black race was associated with a greater prevalence of short sleep duration which in turn was related to increased risk of incident stroke symptoms. After accounting for multiple empirical and theoretical covariates, the mediating effect of sleep duration among persons of normal weight was attenuated and no longer statistically significant.

This is one of the first studies to examine these relationships prospectively among a national sample of individuals at low risk for symptoms of OSA. The present results on stroke symptoms appear to bolster previous investigations that have shown associations between short sleep duration and stroke (1-4,6,7). The results also expand our understanding of this association such that self-reported sleep duration is a risk factor for stroke symptoms among participants who are at low risk for symptoms of OSA and are of normal weight. This result is interesting in two ways. First, the estimate of the hazard ratio increased as covariates were added to the model, which is atypical. Usually, adding covariates into a model leads to attenuation of the effect. This may have occurred because the directions of the associations between certain covariates with sleep duration and incident stroke symptoms may have been opposing (e.g., a positive relationship with sleep duration and an inverse relationship with incident stroke symptoms), hence increasing the hazard ratio. Second, the association between short sleep duration and incident stroke symptoms among normal weight participants is counterintuitive considering the association between short sleep duration and obesity found in this study and the previous literature (1-3,7), and markers of obesity have been linked to incidence of stroke (32). However, many previous studies still found significant associations between short sleep duration and stroke after controlling for BMI (1-3,5,7). Additionally, previous studies did not exclude participants with OSA or who were at high risk for OSA. Therefore, this result may suggest that in persons relatively free of major risk factors for stroke, such as obesity and OSA, self-reported sleep duration exacts its own negative influence and may be a precursor to other traditional stroke risk factors that

once are present become stronger risk factors than sleep duration itself or are additive in their effects.

Our results deviate from the literature in that long sleep duration was not significantly associated with incident stroke symptoms. In previous investigations, the effect size for long sleep duration on stroke was greater than that of short sleep duration. It has been hypothesized that long sleep duration as a risk factor for stroke may actually be confounded by the presence of OSA or some other chronic illness that routinely affects the quality of the sleep period (1,33). OSA, for example, is associated with sleep fragmentation which contributes to daytime sleepiness and perhaps increased physiological sleep need. Therefore, OSA itself rather than long sleep duration may be primarily associated with incident stroke symptoms. Our results appear to substantiate this speculation.

If short, reported sleep duration is truly an independent risk factor for stroke symptoms in this population, what might be the underlying mechanisms? Sleep deprivation has been shown to induce systemic inflammation (34), dysregulate blood pressure mechanisms (35), and alter autonomic functioning and metabolic hormones (36). All of these alterations are associated with endothelial dysfunction, a known marker of compromised integrity of the cardiovascular system and common risk factor for artherosclerosis and stroke. Considering the mediating role of self-reported sleep duration in the unadjusted relationship between race and stroke symptoms, it may be important to investigate what influences are inducing habitual short sleep duration. Our study suggests race, socioeconomic disadvantage, higher BMI, being male and a smoker are related, some of which are potentially modifiable.

The results of the mediation analysis provide further evidence that self-reported sleep duration may be on the causal pathway between race and health disparities as was previously suggested by Lauderdale and colleagues (37). Since potential mediation was only observed among participants of normal weight, the results suggest that among fairly healthy middle-aged to older employed individuals, certain racial groups may be less resilient to the negative consequences of sleep restriction, which may increase the risk of stroke. The present study and previous studies on racial determinants of sleep duration cannot confirm that there is a racial difference in sleep due to a biological basis; (15,38) particularly since sleep duration on a given night is determined by multiple, interacting biopsychosocial factors. Furthermore race is often tied to socioeconomic status, and associations between race and sleep duration tend to attenuate with adjustment of socioeconomic factors. However, it is important to note that previous studies found race to remain significantly associated with sleep duration after controlling for various indices of socioeconomic status, living conditions, and health-related determinants of short sleep duration (37-39). Further research is needed to gain a better understanding of the causal pathways between race, sleep, and stroke including genomic-environment interaction studies, inclusion of comprehensive measures of social and environmental factors experienced across the lifespan, and exploring differences in self-reporting of sleep and health information since it has been suggested there may be reporting biases by race and ethnicity (40).

This study had several limitations. First, sleep duration was retrospectively self-reported which is prone to bias and error. Nevertheless, strong associations were found similar to other studies that have used self-reported sleep duration. Second, these results may only apply to employed persons of normal weight, thus our analyses primarily represent a certain subgroup of individuals. Nonetheless, the results may have acceptable external validity because this subsample represents persons nationwide and included a substantial number of black individuals. Third, self-reported short sleep duration may actually be capturing some level of unmeasured sleep fragmentation that may more prominently affect stroke risk. Fourth, there was discrepancy in time between covariate information collection (at baseline,

2003-2007) and the sleep assessment (2008-2010). Fifth, the Berlin Questionnaire has proven to not be the most sensitive OSA screening tool in comparison to other measures (41,42), and in particular amongst full-time employed persons as was noted by Geiger-Brown and colleagues within their study of a small sample of nurses (43). Therefore, there is the possibility that a proportion of the study sample had false negative screenings which may have introduced some influence of OSA into the model. Lastly, only 283 stroke symptoms were reported over 3-year follow-up, though significant results were still noted despite the low number of stroke symptoms. As REGARDS follow-up continues and stroke events accrue, future work will examine the association of sleep duration with risk of incident, physician-verified stroke.

The findings of this study suggest a need to improve sleep and increase physician and public health awareness of the role sleep might have on risk for stroke symptoms. Future studies of stroke risk should examine objectively-measured sleep duration and other sleep parameters, and include non-working and retired persons to verify if the present results may be related to the sleep schedules of employed individuals or generalize to other populations.

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Table 1

Descriptive characteristics of the total sample and by average sleep duration

	Total Sample	By Average Sleep Duration (in hours)				
	n*(%) or *M(SD)	**< 6**	**6-6.9**	**7-7.9**	**8-8.9**	**≥ 9**
Variable	**n=5,666**	**n=410**	**n=1,121**	**n=2,216**	**n=1,585**	**n=334**
Age**	60.6 (8.5)	61.5 (9.0)	60.0 (8.1)	60.1 (8.4)	61.2 (8.5)	61.8 (9.1)
U.S. stroke belt	3,198 (56.4)	228 (55.6)	623 (55.6)	1216 (54.9)	928 (58.6)	203 (60.8)
Black**	1,865 (32.9)	228 (55.6)	482 (43.0)	638 (28.8)	410 (25.9)	107 (32.0)
Male*	2,501 (44.1)	193 (47.1)	477 (42.6)	995 (44.9)	711 (44.9)	125 (37.4)
Education**						
< HS	287 (5.1)	27 (6.6)	65 (5.8)	82 (3.7)	88 (5.6)	25 (7.5)
HS graduate	1,207 (21.3)	106 (25.9)	239 (21.3)	438 (19.8)	336 (21.2)	88 (26.4)
Some college	1,487 (26.2)	116 (28.3)	307 (27.4)	568 (25.6)	419 (26.4)	77 (23.1)
≥ College graduate	2,683 (47.4)	161 (39.3)	509 (45.4)	1128 (50.9)	742 (46.8)	143 (42.8)
Income**						
< $20k	500 (8.8)	43 (10.5)	93 (8.3)	181 (8.2)	148 (9.3)	35 (10.5)
$20k-$34k	1,074 (19.0)	97 (23.7)	219 (19.5)	379 (17.1)	307 (19.4)	72 (21.6)
$35k-$74k	1,978 (34.9)	148 (36.1)	414 (36.9)	781 (35.2)	522 (32.9)	113 (33.8)
≥ $75k	1,555 (27.4)	83 (20.2)	283 (25.3)	668 (30.1)	448 (28.3)	73 (21.9)
Refused	559 (9.9)	39 (9.5)	112 (10.0)	207 (9.3)	160 (10.1)	41 (12.3)
BMI**						
Underweight	71 (1.3)	5 (1.2)	22 (2.0)	14 (0.6)	24 (1.5)	6 (1.8)
Normal	1,651 (29.1)	114 (27.8)	285 (25.4)	672 (30.3)	495 (31.2)	85 (25.5)
Overweight	2,372 (41.9)	145 (35.4)	484 (43.2)	957 (43.2)	640 (40.4)	146 (43.7)
Obese	1,572 (27.7)	146 (35.6)	330 (29.4)	573 (25.9)	426 (26.9)	97 (29.0)
Waist(cm)	91.8 (14.5)	93.5 (14.6)	92.3 (14.8)	91.5 (14.4)	91.3 (14.4)	92.9 (14.9)
Hypertensive*	2,276 (40.2)	181 (44.2)	471 (42.0)	851 (38.4)	626 (39.5)	147 (44.0)
Heart Disease**	514 (9.1)	43 (10.5)	68 (6.1)	200 (9.0)	167 (10.5)	36 (10.8)
Dyslipidemia	2,766 (48.8)	201 (49.0)	530 (47.3)	1056 (47.7)	803 (50.7)	176 (52.7)
Diabetes**	653 (11.5)	60 (14.6)	145 (12.9)	202 (9.1)	195 (12.3)	51 (15.3)

	Total Sample	By Average Sleep Duration (in hours)				
	n(%) or *M(SD)*	< 6	6-6.9	7-7.9	8-8.9	≥ 9
Variable	**n=5,666**	**n=410**	**n=1,121**	**n=2,216**	**n=1,585**	**n=334**
CESD-4**	0.7 (1.5)	0.9 (1.7)	0.8 (1.6)	0.7 (1.4)	0.6 (1.5)	0.8 (1.6)
PSS**	2.7 (2.5)	3.0 (2.8)	2.9 (2.7)	2.7 (2.4)	2.4 (2.4)	2.7 (2.8)
Smoking Status						
Current	688 (12.1)	69 (16.8)	130 (11.6)	247 (11.2)	195 (12.3)	47 (14.1)
Past	2,043 (36.1)	140 (34.2)	397 (35.4)	785 (35.4)	595 (37.5)	126 (37.7)
Never	2,916 (51.5)	198 (48.3)	590 (52.6)	1177 (53.1)	791 (49.9)	160 (47.9)
Alcohol use**						
Heavy	258 (4.6)	14 (3.4)	43 (3.8)	84 (3.8)	91 (5.7)	26 (7.8)
Moderate	2,244 (39.6)	136 (33.2)	414 (36.9)	936 (42.2)	642 (40.5)	116 (34.7)
None	3,095 (54.6)	253 (61.7)	650 (58.0)	1167 (52.7)	837 (52.8)	188 (56.3)
Exercise*						
None	1,462 (25.8)	125 (30.5)	316 (28.2)	532 (24.0)	394 (24.9)	95 (28.4)
1-3×/week	2,293 (40.5)	143 (34.9)	442 (39.4)	925 (41.7)	650 (41.0)	133 (39.8)
≥ 4×/week	1,848 (32.6)	136 (33.2)	352 (31.4)	729 (32.9)	528 (33.3)	103 (30.8)
Health Status**						
Poor or Fair	352 (6.2)	44 (10.7)	83 (7.4)	111 (5.0)	90 (5.7)	24 (7.2)
Good	1,583 (27.9)	132 (32.2)	363 (32.4)	595 (26.9)	398 (25.1)	95 (28.4)
Very Good	2,270 (40.1)	151 (36.8)	412 (36.8)	913 (41.2)	666 (42.0)	128 (38.3)
Excellent	1,455 (25.7)	83 (20.2)	261 (23.3)	594 (26.8)	431 (27.2)	86 (25.8)
HEI**	61.6 (12.5)	59.5 (11.4)	60.5 (12.3)	62.3 (12.3)	62.1 (12.9)	60.8 (12.1)

Note. M(SD)=mean/standard deviation; HS=high school; BMI=body mass index; CESD-4=Center for Epidemiologic Studies Depression Scale 4-item; PSS=Perceived Stress Scale; HEI=Healthy Eating Index.

* $p<.05$,

** $p<.01$

Table 2

Unadjusted and Multivariate Associations of Sleep Duration with Incident Stroke Events: Hazard Ratio with 95% Confidence Limits

Sleep Duration (hours)	Unadjusted n=5666	Model 1[a] n=5664	Model 2 n=5293	Model 3 n=5238	Model 4 n=5093	Model 5 n=3954
< 6	1.67* (1.04-2.68)	1.43 (0.88-2.32)	1.47 (0.89-2.45)	1.44 (0.86-2.39)	1.31 (0.77-2.24)	1.55 (0.82-2.91)
6-6.9	1.16 (0.80-1.69)	1.16 (0.79-1.69)	1.22 (0.82-1.81)	1.21 (0.81-1.79)	1.22 (0.82-1.81)	1.26 (0.80-2.00)
7-7.9	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
8-8.9	1.27 (0.91-1.77)	1.17 (0.84-1.62)	1.30 (0.92-1.83)	1.30 (0.92-1.83)	1.31 (0.92-1.85)	1.38 (0.92-2.06)
≥ 9	1.67† (1.00-2.79)	1.44 (0.86-2.42)	1.42 (0.82-2.45)	1.41 (0.81-2.44)	1.33 (0.76-2.35)	0.96 (0.45-2.05)

[a]Model 1=Demographics; Model 2=Stroke risk factors; Model 3=Psychological symptoms; Model 4=Health behaviors; Model 5=Diet Quality
Note. ref=reference group

*$p<.05$;

†$p<.06$

Table 3

Unadjusted and Multivariate Associations of Sleep Duration with Incident Stroke Events by BMI: Hazard Ratio with 95% Confidence Limits [a]

	Normal BMI			Overweight			Obese		
Sleep Duration (hours)	**Unadjusted*** **n=1,651**	**Model 4[b] n=1,485**	**Model 5[c] * n=1,189**	**Unadjusted n=2,372**	**Model 4[b] n=2,142**	**Model 5[c] n=1,682**	**Unadjusted n=1,572**	**Model 4[b] n=1,405**	**Model 5[c] n=1,028**
< 6	2.93** (1.38–6.22)	3.50** (1.44–8.51)	4.19** (1.62–10.84)	1.51 (0.67–3.42)	0.99 (0.40–2.46)	1.14 (0.37–3.52)	0.95 (0.36–2.51)	0.75 (0.21–2.62)	0.41 (0.05–3.26)
6-6.9	1.36 (0.67–2.76)	1.67 (0.78–3.59)	1.26 (0.53–2.99)	1.27 (0.73–2.23)	1.15 (0.64–2.08)	1.25 (0.63–2.48)	0.81 (0.38–1.72)	0.92 (0.40–2.12)	1.06 (0.39–2.88)
7-7.9	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
8-8.9	0.98 (0.50–1.90)	0.85 (0.41–1.76)	0.70 (0.31–1.61)	1.23 (0.73–2.07)	1.28 (0.75–2.18)	1.48 (0.81–2.70)	1.56 (0.87–2.79)	1.94 (1.00–3.76)	2.14 (0.96–4.76)
≥ 9	2.29 (0.92–5.66)	1.54 (0.51–4.65)	1.21 (0.34–4.33)	1.06 (0.41–2.73)	0.87 (0.33–2.28)	0.72 (0.21–2.45)	2.03 (0.86–4.78)	2.11 (0.79–5.61)	1.23 (0.26–5.73)

[a] Sample size for underweight participants was too small to estimate hazard ratios.

[b] Controlling for variables in Models 1-4: Model 1=Demographics; Model 2=Stroke risk factors; Model 3=Psychological symptoms; Model 4=Health behaviors;

[c] Controlling for variables in Model 5 = Model 4 + Diet Quality Note. ref=reference group; BMI=body mass index;

* $p<.05$,

** $p<.01$

Table 4

Sleep duration as a Mediator in the Race-Stroke Symptom Relationship using the 'Difference of Coefficients Approach,' in the Full and Normal BMI Samples.

Sample	Model	β_{race}	β^*_{race}	$\beta_{race} - \beta^*_{race}$	Bootstrap 95% CI	HR (95% CI)[a]
Full	Unadjusted	−0.13	−0.10	−0.03	−0.09, 0.03	1.03 (0.97-1.09)
(n=5,666)	Model 4[b]	−0.05	−0.03	−0.02	−0.08, 0.05	1.02 (0.95-1.08)
	Model 5[c]	0.11	0.13	−0.03	−0.12, 0.05	1.03 (0.95-1.13)
Normal BMI	Unadjusted	0.10	0.30	−0.21	−0.42, −0.02	1.23 (1.02-1.52)
(n=1,561)	Model 4[b]	0.14	0.37	−0.23	−0.50, −0.03	1.26 (1.03-1.65)
	Model 5[c]	0.28	0.56	−0.28	−0.75, 0.01	1.33 (0.99-2.11)

Note. β_{race} = the regression estimate for race without sleep duration as a covariate; β^*_{race} = regression estimate for race when sleep duration was included as a covariate; $\beta_{race} - \beta^*_{race}$ = difference in the regression estimates; CI=confidence interval; Bootstrap 95%CI = 95% confidence intervals obtained using percentile bootstrap with 1,000 samples; HR=hazard ratio; BMI=body mass index.

[a] Hazard ratios greater than 1 indicate increased stroke symptom risk for blacks while accounting for sleep duration as a mediator.

[b] Controlling for all variables in Models 1-4: Model 1=Demographics; Model 2=Stroke risk factors; Model 3=Psychological symptoms; Model 4=Health behaviors;

[c] Controlling for all variables in Model 5=Model 4 + Diet Quality