

Sleep and obesity: the mediating role of health behaviors among African Americans

Ivan H.C. Wu, PhD^{a,*}, Nga Nguyen, MS^a, Diwakar D. Balachandran, MD^b,
Qian Lu, M.D, PhD^{a,c}, Lorna H. McNeill, PhD, MPH^a

^a Department of Health Disparities Research, University of Texas MD Anderson Cancer Center, Houston, TX

^b Department of Pulmonary Medicine, University of Texas MD Anderson Cancer Center, Houston, TX

^c Department of Psychology, University of Houston, Houston, TX

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ABSTRACT

Objectives: To examine the role of health behaviors (eg, physical activity, sedentary behaviors, and diet) in the relationship between sleep (ie, duration and quality) and BMI among African American adults.

Design: A cross-sectional self-report questionnaire included questions related to health and health-related behaviors.

Setting: This study was based on data from the CHURCH study, which aimed to address cancer health disparities among church-going African Americans in Houston, TX.

Participants: African American adults were recruited from three large community churches. The sample included a total of 1837 participants (75.2% female; mean age 48.2 ± 13.7 y; mean BMI 32.0 ± 7.5 kg/m²).

Measurements: Linear regression models and path analyses controlling for demographic characteristics and depression estimated the associations between sleep and BMI as well as the mediating roles of health behaviors.

Results: The average self-reported sleep duration was 6.2 ± 1.5 h/night with 61%, 35.8%, and 1.6% reporting short (≤ 6 h/night), normal (7–9 h/night), and long sleep (≥ 10 h/night), respectively. Short sleep was related to greater BMI ($b = 1.37$, $SE = 0.38$, $P = .01$), and the relationship was mediated by sedentary behaviors (est. = 0.08, $SE = 0.04$, 95% CI: 0.02, 0.17).

Conclusions: Short sleep and poor quality sleep was related to poor diet and physical activity-related health behaviors, and BMI. The link between sleep and obesity is, in part, due to energy imbalance from increased sedentary behavior.

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Since the early 19th century changes in the society's social structure, labor force participation, attitudes toward work, and technological advances have led to decreases in sleep among Americans.¹ Indeed, epidemiological data show that Americans obtain less sleep, especially full-time workers,² although this trend has leveled off since 2003.³ Of particular public health concern is the sleep disparity among African Americans who report worse and overall less sleep than White/European Americans.⁴ On average, African Americans obtain 28.2 minutes less sleep, 7.6% less slow wave sleep, and spend 5.8 minutes longer to fall asleep than their White/European American counterparts.⁵ Given the link between insufficient sleep and obesity,⁶ the concurrent rise of obesity rates among African Americans suggest that the observed sleep disparity may account for some of the racial

disparities present in cardiovascular health and metabolic diseases.⁷ However, more research is needed to examine the relationship between sleep and obesity among African Americans, and further research into the mechanisms can help identify targets for future interventions for this population.

A large body of work links sleep duration and risk for obesity. Meta-analyses of observational studies consistently find that short sleep duration (≤ 6 hours/night) predicts greater likelihood of obesity⁶ and larger waist circumference.⁸ Pooled estimates including both domestic and international studies suggested that an hour decrease in sleep was related to an increase in .35 kg/m² (BMI) among adults.⁹ However, few studies examine how sleep and the resulting health and diet behaviors may contribute to the high rates of obesity among African Americans.

Energy intake is an important mediator in the relationship between sleep and obesity. Experimental studies suggest that insufficient sleep can promote poor diet behaviors. Healthy normal sleepers

* Corresponding author at: University of Texas M.D. Anderson Cancer Center, 1400 Pressler St., FCT9. 6053, Houston, TX 77030-3906.

E-mail address: ihwu@mdanderson.org. (I.H.C. Wu).

placed under sleep restriction, compared to control, conditions consume more calories and foods high in carbohydrate, sugar, and fat content^{10–12} due to dysregulated appetite regulating hormones leptin and ghrelin¹³ as well as elevated activity in reward-related brain regions.¹⁴ A recent meta-analysis showed an average of 385 kcal increase in energy intake within partial sleep deprivation conditions compared to control conditions across 11 studies,¹⁵ which represents a 15% and 19% increase in the recommended caloric intake for adult males and females, respectively.

Another mechanism that may account for the relationship between sleep and obesity is physical activity and sedentary behavior. Although this area of research is less developed, several observational and experimental studies also show a significant link between sleep and physical activity. Obtaining sufficient quantity and quality of sleep may encourage physical activity¹⁶ as individuals may feel more rested, energetic, and willing to engage in physical activity during the following day. In contrast, sleep deprivation increases the salience of negative events potentially causing chronic stressors to deplete energy, motivation, and physical activity. Although the additional time spent awake due to sleep restriction can also inflate physical activity counts,^{10,17} insufficient sleep may lead to lethargy, fatigue, and increased sedentary behaviors.^{18,19}

Despite advances in our understanding of how sleep relates to physical activity, diet, and obesity, greater research in this area with African American populations warrants further investigation for the following reasons. First, formal evidence of the mechanisms between sleep and obesity are limited in the broader literature and even less among racial/ethnic minority populations. For example, two large-scale observational studies found that work-related sedentary behavior²⁰ and diet²¹ partially explained the link between short sleep and weight gain; and a third large-scale observational study showed that the relationship between short sleep and BMI decreased, yet remained significant, after physical activity, sedentary behavior, and diet were included in the regression model as covariates²². Further, results from an experimental study ($n = 16$) suggested that increased energy intake accounted for weight gain among participants undergoing sleep restriction.¹² However, the observational studies included predominantly non-obese White older adults in the US²² or adults residing in Europe,²⁰ Which contrast the proportion of obese adults among African Americans; differences in culturally-based sleep practices may limit the generalizability of the Japanese study²¹ to the US; and the small sample size limited power to conduct a formal test of mediation in the experimental study of non-obese participants.¹² The study contributes to the literature by formally testing health behaviors as mechanisms between sleep and obesity among African Americans in the US context using a large data set that would not otherwise be testable in smaller experimental designs underpowered to test mediation.

Second, sleep appears to disproportionately affect African Americans compared to other groups, which perhaps is related to disparate rates of obesity. For example, African Americans, compared to non-Hispanic Whites, are at greater risk for obesity.²³ During a sleep restriction study, African Americans were found to consume more carbohydrates, less protein, and more caffeine-free soda and juice compared to White participants despite similar total energy intake.²⁴ Thus, sleep duration may be an important factor contributing to poor health behaviors among African Americans who, compared to non-Hispanic Whites, disproportionately report greater sedentary behavior, less physical activity,²⁵ less fruits and vegetables consumption, and more sugar-sweetened beverage consumption.²⁶ It is likely that the sleep and health behavior link will show similar directions, but reveal different magnitudes between African Americans and Whites. However, the current data do not allow for this hypothesis to be tested.

Lastly, results can inform future interventions among African Americans. A recent narrative review concluded that African

Americans, compared to Whites, lose less weight in response to standard behavioral treatments for obesity.²⁷ Inadequate sleep might be contributing to this conclusion because sleep loss can undermine weight loss efforts.²⁸ By examining how inadequate sleep relates to obesity and through which health behaviors, future investigations can tailor health promotion efforts among African Americans.

The primary aim of the study was to investigate the link between sleep and obesity and how such link is mediated by health behaviors. The accumulation of evidence supports the notion that insufficient sleep is related to increased energy consumption, due in part to changes in diet and physical activity. Increased energy intake and decreased energy expenditure creates an energy imbalance that contributes to weight gain, yet few studies simultaneously examine diet, physical activity, and sedentary behavior as mediators in the relationship between sleep and obesity. We propose the following two hypotheses: (1) poor sleep quality, short sleep, and long sleep will be related to greater BMI; and (2) the relationship between sleep (quality and quantity) and BMI will be mediated by diet and health behaviors (ie, physical activity, sedentary behavior, fruit and vegetable, sugary drink, fast food, red meat, and overall percentage energy from fat consumption).

Methods

Participants and Procedures

Data were from a final year of a longitudinal cohort study examining factors associated with cancer risk among African American adults. Participants ($n = 1827$) were originally recruited into the cohort study from three African American churches in Houston, Texas. Recruitment strategies included printed and televised media within the church and in-person solicitation during church services and at a church health fair. Individuals were eligible to participate if they were ≥ 18 years old, residents of the Houston area, had a functional telephone number, and attended church (church membership was not a requirement). The study is described in greater detail elsewhere.²⁹

Participants completed surveys about sociodemographics, health, and health behaviors in person at the church. Participants completed a computer-assisted questionnaire and were compensated with a \$30 Visa Debit Card following survey completion. Data used in this study was collected in the period of 2012–2014.

Measures

Covariates

Sociodemographics. Participants self-reported sociodemographic factors including age, sex, education level (High school or below, Some college but no degree, Associate/vocational degree, or College degree or above), and average annual household income (<\$19,999, \$20,000–39,999, \$40,000–79,999, or \geq \$80,000). Average annual household income was reduced to four groups from nine (\$0–4999, \$5000–9999, \$10,000–19,999, \$20,000–29,999, \$30,000–39,999, \$40,000–49,999, \$50,000–79,999, \$80,000–99,999, \geq \$100,000).

Depressive symptoms. Depressive symptoms were measured using the Center for Epidemiological Studies Depression 10-item scale (CESD-10).³⁰ This scale was developed to measure the degree of depressive symptoms experienced over the past week. It includes items such as “I was bothered by things that usually don't bother me,” and “I felt hopeful about the future” (reverse scored) on a four-point Likert scale (0 = “Rarely or none of the time,” 3 = “All the time”). Responses were summed with a potential range of 0 to 30, where higher scores indicate more depressive symptoms. Participants

were categorized as depressed if they received a score >10. The CES-D-10 demonstrated adequate reliability (Cronbach's alpha = .85). Depression symptoms were included as a covariate because of the high comorbidity between depression and sleep loss.

Predictor

Sleep. Self-reported sleep duration and sleep quality were measured using two-items assessing sleep quality and duration in the previous month. Sleep quality (ie, "During the past month, how would you rate your sleep quality overall?") was rated on a 4-point Likert scale (ie, 0 = *very bad*, 1 = *fairly bad*, 2 = *fairly good*, 3 = *very good*). Sleep quality was considered as a continuous and dichotomized variable (ie, 0 = *very/fairly bad*, 1 = *fairly/very good*) in analyses. Sleep duration was an open-ended response asking participants to indicate the number of hours of sleep obtained in the past month (ie, "During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spend in bed)"). Sleep duration was considered as a continuous and categorical variable in the analyses. As a categorical variable, two dummy coded sleep duration variables were created to represent short (≤ 6 h of sleep/night) and long sleep (≥ 10 h) compared to normal sleep (7–9 h) as the reference group.

Mediator

Physical activity. Physical activity was measured using the short form of the International Physical Activity Questionnaire (IPAQ), an internationally-validated (median $\rho = 30$ with accelerometer data) and reliable (test–retest Spearman's $\rho = .80$) measure of frequency and duration of walking and moderate and vigorous physical activity in the past week.³¹ Scores were created using IPAQ instruction for cleaning and processing data (available at <http://www.ipaq.ki.se/>). Data outliers indicating excessive and unlikely physical activity were removed (eg, >960 min/d). Total minute of walking, moderate and vigorous physical activity were added to create the total minute of physical activities per week. Log transformation was used to account for non-normal data.

Sedentary behavior. In the survey, participants were asked to report the average time per day over the past 30 days they spent sitting, watching TV or videos, using computer or playing computer games outside of school, such as "Over the past 30 days, on average how many hours per day did you sit and watch TV or videos?" and "Over the past 30 days, on average how many hours per day did you use a computer or play computer games outside of school?". To determine total screen time per day, the above two items were summed and treated as continuous. Questions assessing sedentary behaviors using various screen time-based items have demonstrated adequate reliability (eg, ICC's ranging from .71–.93), yet varied in validity due to underreporting sedentary behaviors.³²

Fruit and vegetable consumption (FV). FV intake was assessed with the NCI Five-A-Day fruit and vegetable questionnaire (excluding fried potatoes).³³ Participants were asked about the frequency of consumption of: 1) 100% orange juice or grapefruit juice; 2) other 100% fruit juices, not counting fruit drinks; 3) green salad, with or without other vegetables; 4) baked, boiled, or mashed potatoes; 5) vegetables, not counting salad or potatoes; and 6) fruit, not counting juices. Response options were: 0 = never, 1 = 1–3 times last month, 2 = 1–2 times a week, 3 = 3–4 times a week, 4 = 5–6 times a week, 5 = 1 time a day, 6 = 2 times a day, 7 = 3 times a day, 8 = 4 times a day, and 9 = 5 or more times a day. The frequency of daily FV consumption was calculated by summing responses of the 6 items after converting the responses to number of times per day.

This measure has demonstrated adequate validity³⁴ and has been used among African American church-based samples.³⁵

Red meat consumption (RM). RM items were based on the Dietary Screener Questionnaire³⁶ and were asked as follows "How often have you eaten: 1) salami, bologna, sausage, kielbasa, bacon, chorizo, deli meat, hot dogs, or similar processed meats (2 ounces, 2 small links, or 2 strips)?; 2) hamburgers?; 3) beef, ham, pork, or lamb in a sandwich or in a mixed dish, for example, in a stew, casserole, or lasagna?; and 4) 4–6 ounces of beef, ham, pork, or lamb as a main dish, for example, as a roast, steak or chops?" There were 6 responses for each item including: 1 = never, 2 = 1–3 times in four weeks, 3 = once a week, 4 = 2–4 times a week, 5 = 5–6 times a week, and 6 = once or more a day. Next, we converted the frequency of RM consumption per week to number of times per week (mid-point or the closest value was used if response option was not a single value), then adding these 4 RM items for weekly RM intake.

Sugar drink. Sugar drink was assessed using 2 items from the Dietary Screener Questionnaire.³⁶ Participants were asked about how often they drank: 1) fruit flavored drinks such as lemonade, Sunny Delight, or Kool-Aid, and 2) soda such as Coke or 7-Up, not counting diet drinks. Response options were similar to RM items. The frequency of sugar drink consumption was calculated by summing responses of the 2 items after converting the responses to number of times per day.

Fast food (FF). FF was accessed using a single item from the Dietary Screener Questionnaire ("How many time times did you eat fast food? Include fast food meals eaten at school or at home, or at a fast food restaurant, carryout, or drive thru").³⁶ Response options were similar to RM and sugar drink item. The frequency of eating FF was calculated by converting the responses to number of times per day.

Percent from fat (PF). PF was obtained from 2000 NHIS Multifactor Screener measure.³⁷ The Multifactor Screener was designed to assess approximate intakes of fruits and vegetables, percentage energy from fat, and fiber. The participants were asked to report how frequently they consume foods in 16 categories and the type of milk consumed. This measure was not an attempt to assess portion size or total diet. Score of PF was created using the process of scoring the individual response data described in Scoring Procedures (available at <http://healthcaredelivery.cancer.gov/nhis/multifactor/>).

Outcome

BMI. Weight and height were measured during participant's visit. BMI was calculated using the standard formula (kg/m^2) and was treated as continuous outcome.

Data Analysis

Preliminary data analyses included descriptive statistics for demographic characteristics and unadjusted ANOVA's examining health behaviors across sleep duration and quality categories. Additional sensitivity analyses were conducted to examine the bivariate relationship between health behaviors and different sleep duration cut-off scores (see Supplemental Table 1). Three sets of sleep duration categories were created: (1) 0–4 hours, 5–6 hours, 7–9 hours (reference), and 10+ hours; (2) 0–5 hours, 6 hours, 7–9 hours (reference), and 10+ hours; and (3) 0–6 hours, 7–9 hours (reference), and 10+ hours. The most parsimonious category was determined based on the pattern of scores and used in subsequent analyses. Sensitivity analyses were also conducted with sleep quality as continuous (see Supplemental Table 2). Hypotheses were tested using linear

regressions conducted in SPSS version 18 and path analyses conducted in Mplus version 8. First, two independent linear regressions were conducted with sleep duration (as categorical and continuous; see Supplemental Table 3 for continuous sleep duration results) and quality predicting BMI to test the first hypothesis. Models were conducted with and without demographic and health behaviors (ie, physical activity, sedentary behavior, sugary drinks, red meat, fast food, fruit and vegetables, and percentage from fat) as covariates. Second, the second hypothesis was tested using simple mediation models. If a health behavior was significantly related to sleep duration or quality and BMI, a mediation model was constructed whereby the significant sleep variable predicted the health behavior, which predicted BMI. Fig. 1 displays a path model with all study variables included. A joint significance test of paths a and b , and the 95% confidence intervals of the indirect effect ($a*b$) determined mediation based on previous recommendations.³⁸ Mediation was determined by calculating the indirect effect estimates based on 5000 non-parametric bootstrap samples and examining the 95% confidence intervals. Simple mediation models were adjusted for age, gender, income, education, and depressive symptoms. Depression was included as a covariate due to the high comorbidity between mood and sleep disturbances.

Results

Demographic descriptive statistics are presented in Table 1. The sample of African American adults (mean age = 48.18; SD = 13.70) was predominantly female (75.2%), married (42.4%), college educated (46.5%), and a majority reported incomes between \$40,000–79,999 (34.6%). Further sample characteristics showed that based on a 10-point cut-off for the CES-D, 18.6% of the sample ($n = 339$) are at risk for clinical levels of depression. The average sleep duration was 6.23 (SD = 1.53; skew = 1.37; kurtosis = 8.72). 61% of the sample reported short sleep (≤ 6 h/night), 35.8% reported normal sleep (7–9 h/night), and 1.6% reported long sleep (≥ 10 h/night). A majority of participants reported fairly or very good sleep quality (78.4%), and the average BMI was 31.95 (SD = 7.53).

Table 2 displays unadjusted bivariate relationships between sleep and health behaviors. Compared to “Very good/Fairly good” sleepers, on average “Very bad/fairly bad” reported greater sedentary behavior and less physical activity; greater sugary drink, red meat, fast food, and percentage from fat consumption; and greater BMI and depressive symptoms. Compared to normal sleepers (7–9 h/night), short sleepers (≤ 6 h/night) reported greater sedentary behavior, percentage from fat energy intake, BMI, and depressive symptoms; and

Table 1
Characteristics of participants ($n = 1827$)

	N (frequency %)/mean (SD)
<i>Demographic variables</i>	
Age (years)	48.18 (13.70)
Sex	
Male	454 (24.8)
Female	1373 (75.2)
Marital status	
Married	774 (42.4)
Never married/living with partner	521 (28.5)
Separated/divorced/widowed	527 (28.9)
Unknown	5 (0.2)
Education level	
High school or below	265 (14.5)
Some college, but no degree	470 (25.7)
Associate/vocational degree	242 (13.2)
College degree or above	850 (46.5)
Average annual household income	
<\$19,999	226 (12.4)
\$20,000–\$39,999	511 (18.8)
\$40,000–\$79,999	632 (34.6)
>\$80,000	578 (31.6)
Unknown	48 (2.6)
Depression (CES-D > 10)	339 (18.6)
BMI	31.96 (7.6)
Normal (18–25 kg/m ²)	199 (11.4)
Overweight (25–29 kg/m ²)	475 (27.2)
Obese (>30 kg/m ²)	1072 (58.7)
Unknown	81 (4.4)
Sleep duration: hours/night	6.23 (1.53)
Short (≤ 6)	1114 (61.0)
Normal (7–9)	654 (35.8)
Long (≥ 10)	30 (1.6)
Unknown	29 (1.6)
Sleep quality	
Very bad/fairly bad	388 (21.2)
Very good/fairly good	1433 (78.4)
Unknown	6 (0.3)

long sleepers (≥ 10 h) reported greater sugary drink intake and depressive symptoms.

Table 3 displays un-adjusted and adjusted results from a linear regression testing the associations between sleep and BMI (Hypothesis 1). Results partially supported this hypothesis. Specifically, short sleep was related to greater BMI. However, no effects were observed for long sleep or sleep quality. Furthermore, greater red meat consumption and sedentary behavior was related to greater BMI.

Based on the bivariate relationships between sleep and health behaviors, and linear regression models, one mediation model was constructed with sleep duration predicting sedentary behavior, which predicted BMI. Results partially supported the health behaviors

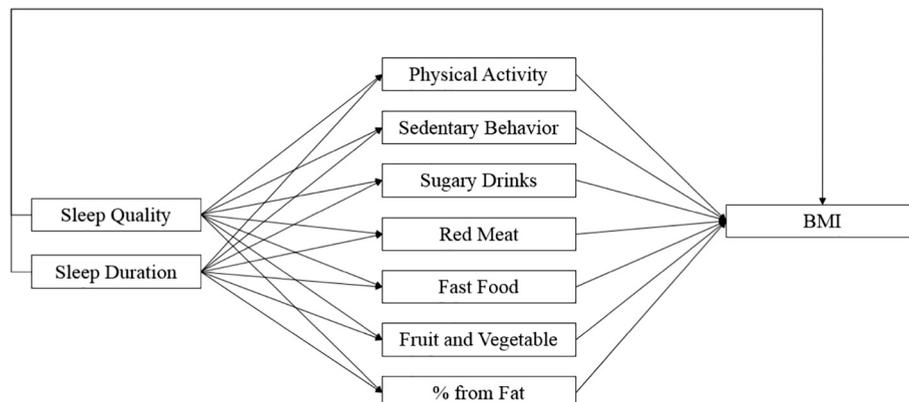


Fig. 1. Theoretical path model with all mediators.

Table 2
Unadjusted group differences in health behaviors

	Sleep Quality		F	P	Sleep Duration			F	P
	Very bad/fairly bad	Very good/fairly good			Short (≤6 h)	Normal (7–9 h)	Long (≥10 h)		
Physical activity	1.73 (3.18)	2.06 (2.65)	4.19	.04	1.99 (2.78)	2.08 (2.57)	1.30 (4.12)	1.26	.28
Sedentary behavior	5.67 (2.60)	5.22 (2.62)	8.82	.00	5.48 (2.61) ^a	5.03 (2.61) ^a	5.53 (2.80)	6.09	.00
Sugary drinks	1.00 (1.70)	0.66 (1.22)	19.43	.00	0.75 (1.34) ^a	0.64 (1.26) ^b	1.48 (2.11) ^{ab}	6.42	.00
Red meat	4.91 (4.07)	4.21 (3.89)	9.70	.00	4.42 (3.95)	4.16 (3.87)	5.60 (4.81)	2.47	.08
Fast food	0.35 (0.50)	0.27 (0.40)	10.12	.00	0.30 (0.43)	0.25 (0.42)	0.32 (0.41)	2.69	.07
Fruit and vegetable	2.96 (2.83)	3.23 (2.73)	2.86	.09	3.06 (2.61)	3.34 (2.96)	3.13 (2.38)	2.25	.11
Percentage from fat	34.55 (3.72)	34.11 (3.93)	1.94	.16	34.46 (4.10) ^a	33.77 (3.66) ^a	32.90 (1.51)	4.08	.02
BMI	33.30 (8.34)	31.59 (7.25)	15.57	.00	32.62 (7.56) ^a	30.91 (7.18) ^a	30.67 (9.08)	11.11	.00
Depression symptoms	10.11 (6.38)	4.38 (4.18)	445.69	.00	6.44 (5.60) ^a	4.04 (4.13) ^a	9.10 (7.52) ^a	51.54	.00

Note: Coefficients represent means and standard deviations in parentheses. F-statistics are results from unadjusted one-way ANOVA's. For sleep duration only, cells with similar superscripts denote Bonferroni corrected significance due to pairwise tests for the three groups.

mediating the relationship between sleep and BMI (Hypothesis 2). Specifically, short sleep was related to greater sedentary behavior, which was related to greater BMI (see Fig. 2). Further, the indirect effect was significant for short sleep (*Est.* = .08, *SE* = .04, *95% CI*: .02, .17), but not long sleep (*Est.* = .07, *SE* = .13, *95% CI*: −.16, .36).

Discussion

The primary objective of the current study was to examine the relationship between sleep (duration and quality) and BMI. We also tested health behaviors as mediators in the relationship between sleep and BMI among African Americans.^{39,40} Our results supported the link between sleep and BMI, and partially supported health behaviors as mediators. Specifically, we found that short sleep (<6 h/night) was related to greater BMI (Hypothesis 1), and sedentary behaviors mediated the relationship between short sleep and BMI (Hypothesis 2).

Table 3
Sleep and health behaviors predicting BMI

	<i>b</i>	<i>SE</i>	<i>P</i>	<i>b</i>	<i>SE</i>	<i>P</i>
Constant	27.41	1.26	.00	28.22	2.81	0.00
Gender	1.43	0.42	.00	1.44	0.57	0.01
Age	0.03	0.01	.05	0.03	0.02	0.08
Education	−0.16	0.17	.37	−0.17	0.23	0.46
Income	−0.14	0.28	.61	−0.18	0.38	0.63
Depression	0.14	0.04	.00	0.11	0.05	0.03
Short sleep	1.37	0.38	.00	1.31	0.51	0.01
Long sleep	−1.09	1.44	.45	−1.27	1.90	0.50
Red meat				0.17	0.07	0.01
Fast food				0.62	0.60	0.30
Fruit and vegetables				−0.06	0.09	0.46
Sugary drinks				−0.23	0.21	0.26
% Energy from fat				−0.07	0.07	0.28
Physical activity				−0.07	0.09	0.41
Sedentary behavior				0.23	0.09	0.02

	<i>b</i>	<i>SE</i>	<i>P</i>	<i>b</i>	<i>SE</i>	<i>P</i>
Constant	28.84	1.77	.00	29.16	2.88	.00
Gender	1.42	0.56	.01	1.44	0.57	.01
Age	0.03	0.02	.09	0.04	0.02	.05
Education	−0.14	0.23	.53	−0.17	0.23	.48
Income	−0.11	0.38	.76	−0.16	0.38	.67
Depression	0.13	0.05	.02	0.10	0.05	.07
Sleep quality	−1.07	0.65	.10	−1.04	0.65	.11
Red meat				0.17	0.07	.01
Fast food				0.68	0.61	.26
Fruit and vegetables				−0.07	0.09	.43
Sugary drinks				−0.25	0.21	.23
% Energy from fat				−0.06	0.07	.37
Physical activity				−0.06	0.09	.46
Sedentary behavior				0.24	0.09	.01

The current study contributes to the literature by examining and providing estimates of sleep duration among African American adults Houston, recruited in a faith-based setting. Our results found that sleep duration was worse in the current study compared to other studies. Specifically, 61% of the sample reported 6 or less hours of sleep/night compared to 54% found in other African American samples⁴¹; and the average sleep duration of the sample was 6.23 hours/night, compared to the national average of over 8 hours/night among the general population in 2016.³ It is possible that unique characteristics of the sample, such as the high proportion of women and college graduates, may account for the discrepancies. For example, women report greater sleep disturbances than men,⁴² and sleep disparities among Blacks and Whites are largest among those who hold professional occupations (eg, finance, education, administrative, management),⁴³ such that Blacks in these professions are more likely to report worse sleep compared to Whites in similar professions. Indeed, higher education levels were positively correlated to greater sleep quality (*r* = .10, *P* < .05), but not sleep duration. Although our estimates of short sleepers are higher than other studies, these are still likely downwardly biased as past research has shown that self-report measures overestimate objective measures by 1 hour of sleep/night.⁴⁴ The rate of short sleepers highlights important public health concerns for African Americans and potentially point to unique stressors African Americans experience. Past investigators have highlighted how stressors experienced at multiple socioecological levels interact to increase risk for health problems and perpetuate health disparities among minorities in the US.⁴⁵ Thus, it is possible that the high number of short sleepers may be a product of unique race-related stressors (eg, racial discrimination, microaggressions). Future studies, however, are needed to further explore this assertion.

Assessing the relationships between sleep, obesity, and health behaviors has important public health and clinical implications. First, the results contribute to the literature by replicating the link between short sleep with obesity^{6,8} among a predominantly obese sample of African Americans. Past large-scale observational research examining the relationship between sleep, health behaviors, and obesity have been conducted among predominantly non-obese samples^{20,21} limiting the generalizability to populations and racial/ethnic groups reporting high obesity rates. In addition to the high number of short sleepers in our sample, our study also revealed high obesity rates – 58.7% of our sample was within the obesity range, compared to the average 39.8% national figure between 2015 and 2016.⁴⁶ Indeed, short sleepers (*M*_{BMI} = 32.62) reported greater BMI than normal sleepers (*M*_{BMI} = 30.91). While much effort has been directed into studying behavioral interventions such as exercise and diet, our results provide support that inadequate sleep may be an important modifiable behavior in weight control.

Second, the pattern of results revealed significant relationships between poor sleep duration and quality with greater sugary drink,

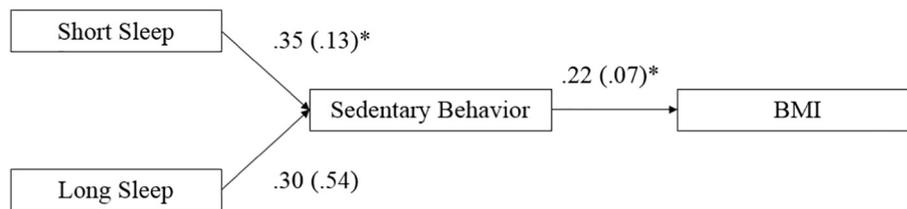


Fig. 2. Mediation results for sleep duration predicting BMI through sedentary behavior. Short and long sleep are dummy-coded variables with normal sleep as a reference. Coefficients displayed are unstandardized and standard errors are displayed in parentheses. * $P < .05$.

red meat, fast food, and percentage from fat energy consumption not found in other studies.²⁰ Specifically, higher quality sleep was related to greater physical activity and less sedentary behavior; less sugary drink, red meat, and fast food consumption; and lower BMI and depression symptoms. Further, short, compared to normal, sleepers reported greater sedentary behavior, percentage energy from fat intake, BMI and depressive symptoms. Multiple experimental studies have shown that sleep restriction is related to preferences for high-caloric foods^{10–12,47} due to dysregulation in neuroendocrinologic, neurologic, and metabolic processes. For example, sleep disturbances can increase HPA activation leading to a “comfort food” effect whereby individuals feed to self-soothe,⁴⁸ and sleep restriction can increase reward- and blunt inhibitory-related brain activity in the presence of food stimuli.⁴⁹ Further, short sleep can also alter metabolic processes such as increasing levels of ghrelin, decreasing levels of leptin, and increasing insulin resistance.⁵⁰ As a result, inadequate sleep can increase unhealthy food intake and total food consumption. Although our results did not suggest that increased fat consumption may account for the sleep and obesity link, this may be due to a social desirability bias in reporting diet or a ceiling effect given the high obesity rates.

The metabolic consequences of short sleep tap into culturally relevant diet practices among African Americans. For instance, recent investigations suggest that African Americans, compared to White/European Americans, are more likely to eat more carbohydrates, soft-drinks, and juices, and less protein after experimental sleep loss.²⁴ Thus, it is possible that poor sleep may undermine behavioral change efforts to reduce the unhealthy aspects of culturally-based home cooking (eg, high fat, salt, cholesterol).⁵¹ That is, decision-making around diet may be more difficult among African American short sleepers attempting to counter physiologically and culturally-based desires to eat less healthy foods.⁵²

We found that sleep quality was related to greater physical activity and less sedentary behavior, and short sleep was only related to greater sedentary behavior (see Table 2). The findings were inconsistent with experimental studies showing greater physical activity counts after sleep restriction,^{10,17,47} yet consistent with other studies showing that short sleep was related to greater sedentary behavior^{17,19,20} For example, a recent large-scale observational study from the Women’s Health Study showed that short sleep (<7 h/night) was related to greater accelerometer counts the next day, but also greater sedentary and light physical activity.⁵³ It is possible that individuals lack of energy following a night of short sleep, which may increase the likelihood of sedentary behaviors such as watch TV or using the computer at home.

The results from the mediation analyses may provide insight into the mechanisms of the sleep and obesity relationship that can be used to inform future weight management interventions for African Americans. In particular, sedentary behavior mediating the relationship between short sleep and BMI suggests that individuals with insufficient sleep are more likely to spend more time sitting watching TV or using the computer, which likely contributes to elevated BMI. Our results expand upon two large-scale observational studies that found that physical activity and dietary behaviors did not mediate

the relationship between sleep and obesity,^{20,21} but work-related sedentary behaviors did.²⁰ A recent review concluding that African Americans tend to lose less weight in standard behavioral treatments for obesity²⁷ opens opportunities to explore the role of sleep in this outcome. Our results suggest that targeting sleep as a way of increasing physical activity and decreasing sedentary behavior could potentially improve behavioral treatments for obesity, as standard behavioral treatments for obesity tend to focus on diet and physical activity, and often overlook sleep as a modifiable risk factor.²⁷ Thus, the results contribute to the growing literature as among the first to highlight the importance of sedentary behaviors in the link between sleep and BMI among a sample of predominantly obese/overweight African Americans.

Limitations and Future Directions

The findings are interpreted within the context of the following study limitations. First, the data are cross-sectional and we cannot determine causality or disentangle the temporal precedence in the bidirectional relationships between sleep and physical activity^{16,53} and sleep and obesity. Future longitudinal and intervention studies will help disentangle temporal precedence. Second, the number of long sleepers were too few to make meaningful interpretations. Future studies should examine the health behaviors among long sleepers given the increased risk of various health problems associated with long sleep duration. Third, the sleep measure was limited to single-item measures of sleep duration and quality. Because the study was based on secondary data analysis, we were unable to comprehensively measure sleep duration and quality, nap times, or assess sleep disorders highly comorbid with obesity such as obstructive sleep apnea, circadian rhythm disorders, or insomnia. Thus, future studies should consider circadian alignment, bedtimes and wake times, and sleep disorders. Fourth, self-report data are vulnerable to retrospective bias. A recent study found that self-reported, compared to objective, sleep among African Americans was overestimated by 58 minutes.⁴⁴ Thus, our results may underestimate the number of short sleepers as well as the relationships between short sleep, health behaviors, and BMI. Future studies should consider longitudinal assessments of both objective and subjective sleep. Lastly, generalizability is limited African Americans residing in urban areas. Although the sample was not intended to generalize to the national population of African Americans, our data collection method (ie, sampling from faith-based organizations) increased generalizability to a wide group of African Americans given that over 80% and 90% of African Americans attend religious services or engage in prayer at least once a month, respectively.⁵⁴

Disclosure Statement

The authors declare that they have no conflict of interests to report.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.sleh.2018.12.005>.

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