International Journal of EXERCISE SCIENCE

Original Research

Sleep and Risk for Metabolic Syndrome, Hypertension, Diabetes and Obesity Among Community-Dwelling Older Adults

PHILIP ZENDELS†[1], TRUDY MOORE-HARRISON‡[2], and JANE F. GAULTNEY‡[1]

[1]Health Psychology and Psychological Sciences, University of North Carolina at Charlotte, Charlotte, NC, USA; [2]Applied Physiology, Health and Clinical Sciences, University of North Carolina at Charlotte, Charlotte, NC, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 15(3): 88-102, 2022. Older adults often face a variety of health problems that are found less frequently in younger populations. Metabolic syndrome and other related diseases are common due to a variety of age and lifestyle factors. Sleep, often operationalized only as duration, quality, or apnea diagnosis, is associated with worse health outcomes across the lifespan. However, sleep is multi-faceted and may require a collection of measures in order to reflect this. This study examined a suite of self-reported sleep habits (risk for sleep apnea, night time duration, nap duration, quality, timing, and consistency of duration and timing) and physiological data in a sample of 144 older adults. Sleep-related variables as a group predicted risk for metabolic syndrome, hypertension, and diabetes but was not a clear predictor of obesity. Of the individual measures, risk for apnea and consistency of sleep duration throughout the week predicted risk for metabolic syndrome (apnea b = .64, p < .05; duration inconsistencies b = .22, p < .05). The findings of the study suggest that greater consistency in sleep schedules may benefit the health of older adult populations' risk for these disorders.

KEY WORDS: Metabolic syndrome, diabetes, hypertension, older adults, sleep, social jetlag

INTRODUCTION

Older adults may experience declines in cognition, emotional health, strength, and increases in hospitalization and impairments due to illness and injury (14). This may be partially explained by an increase in chronic health conditions, including obesity, hypertension, arthritis, cancer, diabetes, heart disease, and stroke (35), often resulting in impairments to activities of daily living (17, 28). With the population of older adults growing rapidly in the United States, measures to minimize factors that lower quality of life are important to reduce mortality and medical costs (34).

One particular condition increasing among adults globally is metabolic syndrome (MetS), a collection of abnormal symptoms related to metabolism and health (9). MetS is diagnosed using biomarkers of chronic health conditions, including high blood pressure, high triglyceride and

blood glucose concentration, low concentration of high-density lipoproteins (HDL), and body size, measured by high waist circumference or body mass index (BMI; 27). Older adults diagnosed with MetS are at greater risk for impaired activities of daily living and all-cause mortality than those without the diagnosis (28).

In turn, comorbid chronic conditions including hypertension, diabetes and obesity, as well as age (9) and lifestyle characteristics such as reduced physical activity, are associated with higher MetS diagnoses rates (47). Hypertension predicts higher rates of heart attack and lower cardiorespiratory health (25). Dyslipidemia and high blood glucose levels contribute to increased coronary artery disease and mortality (12). Blood glucose and triglyceride levels tend to increase with age, and HDL decreases, leading to unhealthier individuals and greater risk for MetS relative to the general population (49). Older adults are also more likely to have higher visceral fat and lower muscle mass relative to younger adults, leading to greater risk of other cardiometabolic diseases (29).

Other comorbid conditions and lifestyle behaviors also contribute tMetS. Insufficient, ineffective, or inconsistent sleep may also play a role in physical and mental well-being, and may also worsen with age. Prevalence of some sleep disorders that reflect or contribute to general health outcomes increase with age (31). Obstructive sleep apnea (OSA) is associated with a variety of health problems in older adults, such as hypertension and higher weight relative to those without the disorder (7). Symptoms of insomnia including longer sleep onset latency, frequent sleep disturbances, and reduced overall sleep quality, are strongly associated with MetS (24). Sleep problems such as increased latency of sleep onset and more frequent interruptions to sleep, increase with age (8). Older adults may receive less or more sleep than the recommended healthy range (36). Even in the absence of a diagnosable disorder,sleep quality tends to worsen with age because of delayed or advanced sleep onset or frequent awakenings, impacting daytime function and causing fatigue and daytime sleepiness (41, 42).

The value of daytime napping is unclear. Napping during daytime hours may reflect poor nocturnal sleep habits (53). Changes in nap schedules and/or excessive naps may signal poor health conditions (11, 13). However, other studies suggest protective benefits of naps in healthy older adults, helping reduce the risk for cardiovascular disease and improving immune system health (16, 46). Another possibility is that insufficient or inefficient sleep may be more a function of deteriorating physical and emotional health and medication use rather than age, per se (39). Timing, consistency, and consolidation of sleep may also be important for health. Inconsistent sleep patterns on weeknights and weekends, sometimes referred to as social jetlag (44), are associated with higher BMI (11), lower sleep quality and poorer health outcomes.

While studies have considered associations of sleep duration, quality, and risk for OSA with health, the present study operationalized sleep more broadly (19). It explored simultaneously-entered sleep characteristics (night duration, average night duration, average nap duration, sleep quality, difficulty initiating or maintaining sleep, sleep timing and consistency) as predictors of risk for MetS in an older adult population. This allowed examination of sleep indices as a group as well as the unique contribution of each component of sleep as predictors

of risk for metabolic syndrome. Analyses further explored the association by separately examining disorders relevant to metabolic syndrome (hypertension, diabetes, and obesity).

METHODS

Participants

Retired, older adults in Mecklenberg County were recruited by the Health Risk Assessment Program at the University of North Carolina at Charlotte. All participants were mobile, community dwelling, and voluntarily visited local senior adult community centers. Data on measures used to diagnose MetS were available for 144 of 304 participants, ranging from 55 to 92 years old (18% male, 65% African American/Black, 25% Caucasian, 2% Hispanic or Latino, 8% Other). A post hoc power analysis suggested a power of .96 given an effect size of .10 with our sample size and chosen analysis methods. See Table 1 for descriptive and bivariate correlational data. The study was approved by the local Institutional Review Board. Data were collected between 2018 and 2019. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (38).

Protocol

Data were collected from seven local community centers who had received advance notice of a free health screening opportunity. After giving signed consent, participants completed a survey asking socioeconomic status, demographic characteristics, medical conditions, and sleep habits. Following the survey, physiological measures were collected, including height and weight measurements, blood pressure, blood content for glucose, triglycerides, high-density lipoproteins, and heart rate. Participants were given a copy of their health screening, information about common diseases in older adults and preventative steps to discuss with a physician. Participants were offered snacks and small gifts in appreciation for their participation.

Apnea: The Berlin Apnea Questionnaire (40) queried the frequency and volume of snoring, daytime dysfunction, and physical health (BMI and blood pressure). If two of these categories are scored positive, an individual is considered at high-risk for OSA. Scores were dichotomized into high risk and low risk, with 65 (45%) individuals in the high-risk group. It should be noted that the apnea measure in the present study was based on self-reported data and did not constitute a diagnosis. Due to many questions being left blank (ex: "Has anyone noticed that you quit breathing during your sleep") our sample's reliability was weakened, but still showed moderate reliability (alpha = .59).

Difficulties Initiating and Maintaining Sleep: Difficulties initiating and maintaining sleep (DIMS) was the sum of two items from the Insomnia Severity Index (37). The calculated two-item variable ranged from 0 to 8, with higher scores indicating greater difficulty falling and staying asleep across the last two weeks. Our sample showed strong reliability for this measure (alpha = .80).

Other Sleep Measures: Seven questions asked typical time of falling asleep and awakening. Weeknight and weekend durations were asked separately to assess for variability in sleep duration and timing (operationalized as the midpoint between sleep onset and awakening; higher values indicated later sleep timing). Participants were asked how many days a week they napped and were asked the typical time of falling asleep and waking up for up to two naps per day.

Average sleep duration at night was calculated as a weighted average ((5*weeknight sleep+2*weekend sleep)/7, range 3.00-15.12 hours; 22). Midpoints were calculated by converting reported time to a fraction of time in the day, with times reported on following days being one point higher. Bedtimes were subtracted from wake times, and the final result was divided by 2 before being added to the bedtime to calculate midpoints. This score was also averaged across weekday and weekends. Inconsistencies in both duration and midpoint timing were calculated by taking the absolute value of weekend minus weeknight sleep. Nap duration was calculated by the total hours of naps multiplied by days spent napping across a week divided by seven, ranging from 0.00-4.57 hours.

Socio-economic Status: Socio-economic Status (SES) was measured using the McArthur Subjective Social Status Scale (2). Individuals are presented with an image of a ladder with 10 rungs and are asked to place themselves on a rung. The top of the ladder indicates individuals who are at the top of society in areas such as wealth, education, and jobs relative to others in the United States. Scores ranged from 1-10; higher scores represented higher perceived socioeconomic status compared to others.

Physiological Measures: Physiological data were collected by graduate students and a faculty member trained in using CardioCheck, EasyOne Plus Diagnostic System, Biolectrical Impedance Analysis for body composition, and bloodborne pathogens training. Participants visited stations set up around the center in order to measure their health and physiology. A vital signs station measured heart rate, body temperature, arterial oxygen saturation, resting systolic and resting diastolic blood pressure to assess for heart disease and risk of hypertension. Blood pressure readings were recorded three times after a five-minute wait before each, with the averages being used for data analyses. Height and weight measurements indicated body mass index. A finger prick station drew blood where participants' triglycerides, HDL, low-density lipoproteins (LDL), and total cholesterol are measured to assess risk of cardiovascular disease as well as fasting blood glucose and glycosylated hemoglobin (HbA1c) to measure risk of diabetes. A pulmonary function station tested individuals' lung function and risk for lung diseases by measuring their inhalation and exhalation speed and volume. Lastly, a fitness test measured their body strength, flexibility, and agility by having participants engage in basic exercises such as arm curls, sit-to-stand tests, walking tests, and back-scratching tests.

Statistical Analysis

Number of symptoms of MetS were calculated by dichotomizing each risk factor based on whether each met established thresholds for MetS (SBP > 130mmHG, DBP > 85 mmHg, fasting glucose > 100mg/dL, HDL < 40mg/dL, triglycerides > 150mg/dL, BMI > 29.4; 5). The

dichotomized variables were summed with higher scores indicating more symptoms of MetS (range 0-6). Diabetes risk was identified as 0 (glucose < 100 or HbA1c < 5.7), 1 (glucose 100-125 or HbA1c 5.7-6.4), or 2 (HbA1c ≥ 6.5; 26). Hypertension was scored as 0 (resting systolic blood pressure (SBP) ≤ 120 or resting diastolic blood pressure (DBP) < 90), 1 (SBP 120-140 or DBP 80-90), 2 (SBP 120-140 and DBP 80-90), 3 (SBP > 139 or DBP > 89), or 4 (SBP > 139 and DBP > 89; 3). Obesity scores were 0 (BMI < 25), 1 (BMI 25-29), 2 (BMI 30-39), or 3 (BMI ≥ 40; 6). In each case higher numbers indicated more risk factors for the disorder. These variables did not represent diagnoses, but rather a sum of risk factors.

Data were analyzed using four multiple regressions to examine the relationship between sleep and health variables related to risk for (1) metabolic syndrome, (2) hypertension, (3) diabetes and (4) obesity in a sample of older adults. Separate regressions were run in order to assess if sleep contributes to all factors of metabolic syndrome or only specific components of it. Each of these were run as a forward entry linear regression using SPSS 26 (IBM Corporation, Armonk NY, USA). Each analysis looked at a suite of sleep indices as predictors of the four health outcomes. In all analyses age, gender, SES and race were used as control variables. Following these controls, risk for apnea, nighttime duration, nap duration, DIMS, average midpoint, weeknight-weekend consistency of duration and consistency of midpoint were entered in a second step. This allowed consideration of unique variability explained by each sleep aspect. Missing data for hypertension, diabetes and obesity ranged from 2% to 13%, and were replaced using multiple imputation.

RESULTS

Preliminary analysis of descriptive and correlational data indicated expected directions in associations between sleep variables and between physiological measures. Results from these analyses are shown in Table 1. These retired adults averaged 8.30 hours of sleep at night, and napped an average of 20 minutes. The sleep midpoint was around 2:36 am. Relative to college-aged and working adults (44), this sample were fairly consistent in sleep duration and timing across the week. Physiological measures indicated that most individuals had one or more risk factors for MetS (91%), hypertension (77%), diabetes (65%) or obesity (70%).

Table 1. *Descriptive Statistics and Bivariate Correlations for All Variables in the Model*

	M (*SD*)	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Age	72.84 (7.72)												
2. SES	6.26 (1.86)	.02											
3. Apnea	.44 (.50)	-.10	.01										
4. DIMS	1.92 (2.02)	-.21*	-.11	.18*									
5. Night Duration (hrs)	8.30 (1.63)	.17*	.10	.02	-.19*								
6. Nap Duration (min)	19.87 (37.37)	-.01	-.18*	.01	.02	.04							
7. Midpoint (time, min)	2:36 (75.07)	.03	.04	.03	.03	.05	.08						
8. Duration Inconsistency (min)	40.07 (74.89)	-.11	.04	.21*	.22*	.15#	.06	.01					
9. Midpoint Inconsistency (time, min)	0:29 (49.44)	.15*	.03	.06*	.14*	-.10*	-.10*	-.13*	.01				
10. Risk Metabolic Syndrome	2.08 (1.27)	-.11	.06	.06	.04	.12	-.10	.27*	-.05	-.05*			
11. Risk Hypertension	1.68 (1.30)	-.03	.03	.29*	-.01	.16#	-.01	-.03	.02	-.05*	.58*		
12. Risk Diabetes	.78 (.67)	-.08	.09	.11	.20*	-.10	.01	-.09	-.16#	.02	.27*		
13. Risk Obesity	1.13 (.88)	-.16#	.01	.20	.03	.04	.10	.22*	-.05	-.13*	.40*	-.04	.08

*Note. N = 144. #p < .07 *p < .05.M* = Mean; SD = Standard Deviation. SES = Socioeconomic Status. Apnea = Score on Berlin Apnea Questionnaire. DIMS = difficulty initiating and maintaining sleep. Midpoint = middle of when an individual sleeps in percentage of the day. Duration Inconsistencies = absolute value of weekend-weeknight hours. Midpoint Inconsistencies = absolute value of weekend midpoint-weeknight midpoint.

The first regression analysis examined whether sleep variables could predict risk for metabolic syndrome (Table 2). The model accounted for about 19% of the variance overall, with the sleep block significantly accounting for 17%. Of the individual sleep variables, participants with more symptoms of sleep apnea and greater weeknight-weekend duration inconsistency were at greater risk for MetS.

Table 2. *Regression Analysis for Risk of Metabolic Syndrome (Analysis of Pooled Imputed Data)*

Model	R^2 Δ	*b*	*S.E.*	*95% C.I.*	
Controls	0.02				
	(Intercept)	3.20*	1.10	1.05	5.35
	Age	-0.01	0.01	-0.04	0.01
	Gender	0.06	0.28	-0.49	0.60
	SES	-0.01	0.06	-0.09	0.14
	Race	-0.05	0.22	-0.49	0.88
Sleep Variables	0.17*				
	(Intercept)	2.22	2.41	-2.50	6.95
	Age	-0.01	0.01	-0.04	0.02
	Gender	0.15	0.27	-0.37	0.68
	SES	-0.01	0.06	-0.12	0.11
	Race	0.08	0.22	-0.35	0.50
	Apnea	0.64*	0.21	0.23	1.06
	Night Duration	1.52	1.59	-1.60	4.64
	Nap Duration	-1.22	3.98	-9.02	6.57
	DIMS	-0.03	0.05	-0.12	0.078
	Midpoint	-0.28	1.97	-4.13	3.5
	Duration Inconsistencies	0.22*	0.09	0.05	0.39
	Midpoint Inconsistencies	-1.66	3.07	-7.67	4.36

Note. #$p < .07$. *$p < .05$ *b* = unstandardized regression coefficient; S.E. = standard error of the unstandardized coefficient; β = standardized regression coefficient. C.I. = confidence interval. Δ = change. SES = Socioeconomic Status. DIMS = Difficulty Initiating and Maintaining Sleep. Apnea = Score on Berlin Apnea Questionnaire. Midpoint = middle of when an individual sleeps in percentage of the day. Duration Inconsistencies = absolute value of weekend-weeknight hours. Midpoint Inconsistencies = absolute value of weekend midpoint-weeknight midpoint.

The next three analyses examined whether components of sleep predicted risk for each of three disorders that associate with metabolic syndrome: hypertension, diabetes, and obesity. The model for hypertension (Table 3) accounted for 17% of variability of which sleep factors explained a significant 15%. Higher risk for sleep apnea and less napping were significantly associated with increased risk for hypertension.

Table 3. *Regression Analysis of Risk for Hypertension (Analysis of Pooled Imputed Data)*

Model	R^2 Δ	*b*	*S.E.*	*95% C.I.*	
Controls	0.02				
	(Intercept)	2.82*	1.18	-0.06	2.26
	Age	-0.01	0.01	-0.02	0.01
	Gender	-0.20	0.29	-0.32	0.26
	SES	-0.06	0.06	-0.03	0.10
	Race	-0.15	0.23	-0.34	0.14
Sleep Variables	0.15*				
	(Intercept)	3.34	2.62	-0.13	5.06
	Age	-0.01	0.01	-0.02	0.01
	Gender	-0.14	0.28	0.34	0.24
	SES	-0.09	0.06	-0.02	0.11
	Race	0.17	0.23	-0.27	0.20
	Apnea	0.78*	0.22	0.17	0.29
	Night Duration	2.84#	1.67	-2.83	0.67
	Nap Duration	-8.55*	4.21	-3.68	4.87
	DIMS	-0.02	0.05	-0.02	0.09
	Midpoint	-1.47	2.10	-3.55	0.67
	Duration Inconsistencies	0.03*	0.05	0.02	0.21
	Midpoint Inconsistencies	-2.03	0.56	-3.95	2.68

Note. #$p < .07$. *$p < .05$ *b* = unstandardized regression coefficient; S.E. = standard error of the unstandardized coefficient; β = standardized regression coefficient. C.I. = confidence interval. Δ = change. SES = Socioeconomic Status. DIMS = Difficulty Initiating and Maintaining Sleep. Apnea = Score on Berlin Apnea Questionnaire. Midpoint = middle of when an individual sleeps in percentage of the day. Duration Inconsistencies = absolute value of weekend-weeknight hours. Midpoint Inconsistencies = absolute value of weekend midpoint-weeknight midpoint.

Table 4 shows the analysis of sleep for risk for diabetes. The total model accounted for 13% of the variability, of which 10% was associated for by the block including sleep variables (approached significance). Although the variability explained was low, greater weeknight-weekend inconsistency predicted greater risk for diabetes.

Table 4. *Regression Analysis of Risk for Diabetes (Analysis of Pooled Imputed Data)*

Model	R^2 Δ	*b*	*S.E.*	*95% C.I.*	
Controls	0.03				
	(Intercept)	1.10#	0.59	-0.06	2.26
	Age	-0.01	0.01	-0.02	0.01
	Gender	-0.03	0.15	-0.32	0.26
	SES	0.04	0.03	-0.03	0.10
	Race	-0.10	0.12	-0.34	0.14
Sleep Variables	0.10#				
	(Intercept)	2.46#	1.32	-0.13	5.06
	Age	-0.01	0.01	-0.02	0.01
	Gender	-0.05	0.15	-0.34	0.24
	SES	0.04	0.03	-0.02	0.11
	Race	-0.04	0.12	-0.27	0.20
	Apnea	0.06	0.12	-0.17	0.29
	Night Duration	-1.08	0.89	-2.83	0.67
	Nap Duration	0.59	2.18	-3.68	4.87
	DIMS	0.04	0.03	-0.02	0.09
	Midpoint	-1.44	1.08	-3.55	0.67
	Duration Inconsistencies	0.12*	0.05	0.02	0.21
	Midpoint Inconsistencies	-0.64	1.69	-3.95	2.67

Note. #$p < .07$. *$p < .05$ *b* = unstandardized regression coefficient; S.E. = standard error of the unstandardized coefficient; β = standardized regression coefficient. C.I. = confidence interval. Δ = change. SES = Socioeconomic Status. DIMS = Difficulty Initiating and Maintaining Sleep. Apnea = Score on Berlin Apnea Questionnaire. Midpoint = middle of when an individual sleeps in percentage of the day. Duration Inconsistencies = absolute value of weekend-weeknight hours. Midpoint Inconsistencies = absolute value of weekend midpoint-weeknight midpoint.

The model examining risk for obesity (Table 5) accounted for 14% of the variability, sleep explaining a nonsignificant 9%. The data indicated a trend in which greater inconsistency in weekend/weeknight bedtimes approached but did not reach significance.

Table 5. *Regression Analysis Risk for Obesity (Analysis of Pooled Imputed Data)*

Model	R^2 Δ	*b*	*S.E.*	*95% C.I.*	
Controls	0.05				
	(Intercept)	2.32*	0.86	0.63	4.01
	Age	-0.01	0.01	-0.03	0.01
	Gender	0.06	0.22	-0.38	0.49
	SES	-0.01	0.05	-0.11	0.09
	Race	-0.27	0.17	-0.61	0.07
Sleep Variables	0.09				
	(Intercept)	2.40	1.92	-1.37	6.17
	Age	-0.01	0.05	-0.03	0.02
	Gender	0.06	0.22	-0.38	0.49
	SES	-0.01	0.05	-0.10	0.09
	Race	-0.18	0.18	-0.53	0.16
	Apnea	0.17	0.18	-0.17	0.52
	Night Duration	-1.03	1.52	-4.05	1.99
	Nap Duration	2.44	3.33	-4.10	8.98
	DIMS	0.01	0.05	-0.09	0.11
	Midpoint	-0.42	1.55	-3.46	2.63
	Duration Inconsistencies	0.13#	0.07	-0.02	0.27
	Midpoint Inconsistencies	-3.34	2.54	-8.34	1.66

Note. N = 171. #$p \leq .08$. *$p < .05$, *b* = unstandardized regression coefficient; S.E. = standard error of the unstandardized coefficient; β = standardized regression coefficient. C.I. = confidence interval. Δ = change. SES = Socioeconomic Status. DIMS = Difficulty Initiating and Maintaining Sleep. Apnea = Score on Berlin Apnea Questionnaire. Midpoint = middle of when an individual sleeps in percentage of the day. Duration Inconsistencies = absolute value of weekend-weeknight hours. Midpoint Inconsistencies = absolute value of weekend midpoint-weeknight midpoint.

DISCUSSION

Sleep is likely multi-faceted; self-reported measures of duration, quality, disorders, timing and consistency were included in the model in order to operationalize sleep broadly. These data suggest that the significant association of sleep with MetS was primarily explained by risk for sleep apnea and inconsistent sleep duration throughout the week. Sleep also predicted related disorders of hypertension and diabetes (nonsignificant trend), but not obesity. Apnea predicted hypertension, while inconsistent duration predicted hypertension and diabetes. Night and nap sleep duration associated differentially with hypertension, in that people with higher blood pressure tended to sleep more at night and less during the day.

Higher night duration was marginally associated with greater hypertension risk, while more time spent napping predicted lower risk for hypertension. These patterns reflect the mixed findings in the literature about the contributions of night and day sleep duration. Both short and long sleep nighttime durations have been associated with increased risk for hypertension in most age groups (21). Daytime napping may predict several cognitive and emotional strengths, but, at least among older adults, other reports connect frequent napping with negative cognitive and health outcomes (32). For example, long daytime naps (> 1hr/day) associate with worse

health, possibly due to interrupted food metabolization, contributing to symptoms of MetS (52). Moderate naps (< 1hr/day) have been associated with better cognitive health and engagement with life outcomes among Chinese older adults (51). Since the average naps reported here were brief (~20 min), they likely reflected positive health, cognitive, or emotional status. Longer nighttime duration in the present sample may have simply been a marker of worse health. Wallace et al. (48) reported that heightened sleep propensity (longer duration, daytime sleepiness, more time in bed spent asleep) predicted all-cause mortality among a sample of older adults, which may explain some of our findings related to higher nighttime and nap duration.

The association of symptoms of OSA with risk for MetS and hypertension found here is supported by converging evidence linking apnea with health indices such as body size, metabolic disorders, and hypertension (15, 30). This finding, therefore, was expected. It was, nonetheless, of value to include it in the model to allow examination of unique contributions of covaried aspects of sleep disruption.

Given the importance of consistent sleep duration and timing for a variety of health indices such as lower BMI and healthier metabolic outcomes (11), it is surprising that sleep midpoint was not a significant predictor of the health outcomes reported here. Such an association has been reported in other literature, predicting lower subjective sleep quality, higher rates of diabetes, and higher fat-content foods and more alcohol consumption, possibly due to late night consumption (43, 45). However, the finding of a role of inconsistent duration, over and above variability explained by the other sleep measures, is worth notice. These findings agree with previous literature suggesting that social jetlag may accompany poor health (11, 18). The present data suggest that getting a consistent amount of sleep across the week may be an important and potentially modifiable health practice among older adults, as has been found with younger age groups (20).

As always, a study's strengths and weaknesses need to be acknowledged. A strength of the present study is the high representation of African American/Black older adults. Individuals of African descent are at elevated risk for sleep disorders, metabolic syndrome (50) as well as risk factors such as obesity and hypertension (1). Given that risk for these disorders and symptoms increase with age (4), it is important to include data on the convergence of risk factors, underlining the need for study of sleep and MetS in this population. Another strength of this study is the objective, biological measures used in data collection. The objective measures lend credibility to the assessment of health in this sample. While it would be desirable to also include objective measures of sleep, subjective sleep assessment nonetheless conveys useful information about health outcomes (33). Self-reported sleep may represent a different but still informative aspect of sleep relative to objective measures (23). Additionally, using a variety of measures for sleep may help capture the multifaceted nature of sleep.

Several limitations are noted. Even though inconsistent duration was a significant predictor, the time of week differences reported by the sample were modest. Participants reported an average sleep duration of 8.30 hours across a typical week, with 8.11 hours on weeknights and 8.78 hours on weekends. Midpoint differences across the week (indicating the consistency of timing) were

small. The sample may not be representative of older adult populations due to individuals being mobile and attending events at local senior adult community centers, therefore limiting generalizability. Participants who volunteered to take part in this study may have been particularly health conscious and may regularly engaged in physical activity, which associates both with health and sleep. Though data was collected about their general fitness, we did not collect data on the frequency of exercise. A replication using a sample with less mobility and community engagement may uncover greater variability of sleep measures. Another limitation was missing data. Although the original sample consisted of 304 participants, analyses were limited to the 144 participants for whom all indices of MetS were available. In addition, some participants did not know information requested, skipped pages of the survey, or did not wish to provide data. Therefore, it is again possible that the sample was not broadly representative, nor may the data reported here represent a true picture of their sleep. Future studies could ask the questions in a one-on-one setting, explaining the questions and measurements in order minimize missing data and attrition rates.

Future research could consider alternative measures of health, such as heartrate variability as an indicator of cardiac health. Although a widely utilized metric, BMI may be a flawed measure of obesity among older adults; other measures such as visceral fat, waist circumference, waist to hip ratio, neck circumference or physical fitness should be considered (10). Additionally, future studies could test more complex models, such as path analyses, to analyze potential mediators between sleep and health.

Consistent sleep throughout the week, while recognized as an important sleep health behavior, is usually studied in younger, employed populations. These data, while preliminary, raise the possibility that consistent sleep may also be a concern among older, mostly retired individuals. Their ability to control their sleep practices without the constraints of a rigid workweek schedule may allow easier implementation of such a healthy sleep behaviors.

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