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Short Communication

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Objectively-measured sedentary behavior with sleep duration and daytime sleepiness among US adults

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ABSTRACT

Background: Limited research has examined the association between sedentary behavior, sleep duration, and daytime sleepiness. Therefore, the purpose of this study was to examine these associations, and see if these associations were independent of physical activity (which is known to influence nighttime sleep and daytime tiredness). **Methods:** Data from 2005 to 2006 National Health and Nutrition Examination Survey were used. Sedentary behavior was measured through accelerometry with sleep-parameters measured through questionnaire. **Results:** After adjustments, and for every 60 min increase in sedentary behavior, participants were 16% more likely to *almost always* feel unrested during the day and 22% more likely to *almost always* feel overly sleepy during the day. Sedentary behavior was not associated with sleep duration at night ($\beta = -0.0002$; 95% confidence interval: -0.0008 to 0.0003; $P = 0.40$). **Conclusion:** To reduce perceptions of tiredness during the day, a sensible strategy may be to increase the frequency of sedentary breaks.

KEY WORDS: Accelerometry, energy, epidemiology, fatigue, sedentary behavior, sleep

INTRODUCTION

Inadequate sleep is one of the most prevalent problems in the United States (US) populace today. According to the Centers for Disease Control and Prevention, about 70 million adult Americans suffer from chronic sleep problems [1]. Among US adults, it is estimated that approximately 35-40% of the population has problems with falling asleep or daytime sleepiness [2]. Greater work demands, leading to increases in daily stress, have contributed to increases in sleep related disorders,[3] among other things. Inadequate or disrupted sleep has been linked to several modifiable negative health outcomes, including diabetes mellitus, obesity, depression, all-cause mortality, and cardiovascular disease [4].

While sleep problems are pervasive in American society, few cost-effective and natural protocols/remedies have been deemed medically reputable. Although medications have been developed to aid sleep (e.g. Ambien, Lunesta, and Rozerem), they are not without side-effects. Prescription sleep aids can be habit forming and carry risks such as nausea, drowsiness, and blurred vision, as well as other concerning side-effects [5]. Because of the known negative side-effects of hypnotic/sedative medications, other approaches to improve sleep must be sought. Another effective approach to improve sleep is cognitive behavioral therapy;[6] however, this approach may be costly and not feasible for all individuals. Physical activity (natural, cost-effective, and side-effect free) has been shown as a way to improve the quality and quantity of sleep, possibly occurring through physical activity-induced temperature down-regulation [7].

In addition to the established role of physical activity in improving sleep and other health outcomes, emerging research demonstrates that sedentary behavior is an independent predictor of health [8]. Although someone may be considered physically active by meeting physical activity guidelines, he or she may still be at risk for adverse health effects (e.g. cardiovascular disease and metabolic syndrome) if they remain sedentary for prolonged periods of time [9]. Little research has been conducted evaluating the relationship between sedentary behavior and sleep. One of the prevailing mechanisms through, which physical activity may improve sleep is from physical activity-induced temperature down-regulation [7]. Although speculative, prolonged sedentary behavior may also be associated with sleep through its inability to the down-regulate body temperature. To improve our understanding of the relationship of sedentary behavior, nighttime sleep, and daytime sleepiness, the purpose of this study was to examine the association of sedentary behavior with these sleep related parameters.

METHODS

Design

Data were obtained from 2005 to 2006 National Health and Nutrition Examination Survey (NHANES). Briefly, NHANES employs a representative sample of non-institutionalized US civilians, selected by a complex, multistage probability design. Participants were interviewed in their homes and subsequently examined in mobile examination centers (MEC) across numerous US geographic locations. Further details about NHANES can be found elsewhere [10]. The study was approved by the National Center for Health Statistics Ethics Review Board, with informed consent obtained from all participants prior to data collection.

Participants

In the 2005-2006 NHANES cycle, 5563 adults (18+ years) were enrolled. After excluding those who were pregnant or breast feeding a child, had missing sleep data or covariate data (i.e. age, gender, cotinine [marker of smoking status], depression, physical activity, race-ethnicity, health status, and body mass index), 4174 participant remained. Lastly, after excluding those who had insufficient accelerometry monitoring data (≥4 days of 10+ h/day of monitoring), 2758 participants remained, which constituted the analytic sample. When comparing the 1416 excluded participants to the analytical sample, excluded participants were less likely to be non-Hispanic white (45.7% vs. 51%, $P = 0.01$), were younger (41.0 years vs. 49.2 years, $P < 0.01$), had a higher cotinine level (73.9 ng/mL vs. 52.1 ng/mL, $P < 0.01$), and had a lower poverty income level (2.4 vs. 2.7, $P < 0.01$); these are unweighted estimates.

Measurement of Sedentary Behavior

At the MEC, participants were asked to wear an ActiGraph 7164 accelerometer on the right hip for 7 days following their examination. The ActiGraph 7164 accelerometer measures accelerations in the vertical axis using a piezoelectric plate. Additional information on the mechanics of the ActiGraph 7164 accelerometer can be found elsewhere [11]. Activity counts <100 were used to assess sedentary behavior, with time spent in sedentary behavior reported in 1 min bouts. To control for physical activity, activity ≥2020 were used to assess moderate-to-vigorous physical activity intensity. For the analyses described here, and to ensure habitual sedentary behavior patterns are represented, only those participants with at least 4 days with 10 or more hours/day of monitoring data were included in the analyses [12]. Non-wear was defined by a period of a minimum of 60 consecutive minutes of zero activity counts, with the allowance of 1-2 min of activity counts between 0 and 100 [12].

Measurement of Sleeping Variables

In the 2005-2006 NHANES sample, participants self-reported a variety of sleeping patterns and outcomes that were measured using the Functional Outcomes of Sleep Questionnaire [13]. In the present study, we examined the association of sedentary behavior with sleep duration (h/night), frequency of feeling overly sleepy during the day, and frequency of feeling unrested during the day. Response options for frequency of feeling overly sleepy and unrested during the day included *never, rarely, sometimes, often*, and *almost always*.

Measurement of Covariates

Various covariates were included in the analytic models based on previous research showing a relationship between these variables and sedentary behavior and/or sleep-related parameters [14-17]. Participants completed questionnaires assessing age, gender, race-ethnicity, health status (excellent, very good, good, fair, or poor), and depression. To assess depression symptoms, participants completed the Patient Health Questionnaire-9 (PHQ-9), with values ranging from 0 to 27 (higher values indicate greater depression symptoms). The PHQ-9 depression scale consists of the actual 9 criteria upon which the diagnosis of Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition depressive disorders is based. Body mass index (BMI) was calculated from measured weight and height (weight in kilograms divided by the square of height in meters). Physical activity levels were measured using the accelerometer with activity counts ≥2020 used to determine moderate-to-vigorous physical activity. As a marker of active smoking status or as an index of environmental exposure to tobacco (i.e. passive smoking), serum cotinine was measured. Serum cotinine was measured by an isotope dilution-high performance liquid chromatography/atmospheric pressure chemical ionization tandem mass spectrometry. Lastly, to exclude participants who were breast feeding or pregnant, which may influence their sleeping patterns, participants answered questions on whether they were pregnant or breast feeding.

Data Analysis

Analyses were performed in 2013 using procedures from a sample survey data (svy: commands) in STATA (version 12.0, College Station, TX, USA) to account for the complex survey design used in NHANES. To account for oversampling, non-response, non-coverage, and to provide nationally representative US estimates, all analyses included the use of the sample weights, clustering variables, and primary sampling units. In an effort to maintain nationally representative estimates, the sample weights for those with 4 or more days of valid accelerometry data were ratio-adjusted to maintain the age, sex, and race-ethnicity distribution of the full sample. Means and standard errors were calculated for continuous variables and proportions were calculated for categorical variables.

To examine the association between sedentary behavior (independent variable) and sleep duration (dependent variable), a multivariate linear regression analysis was performed. To examine the association between sedentary behavior (independent variable) and the categorical sleep-related variables, a multinomial logistic regression was employed, with 'never' serving as the referent group for each sleep-related variable. All models controlled for age, gender, race-ethnicity, cotinine, depression, moderate-to-vigorous physical activity, self-reported health status, and BMI. Statistical significance was established as a $P < 0.05$.

RESULTS

Demographic characteristics of the sample are displayed in Table 1. On an average, participants engaged in 487.7 (standard error [SE]: 2.0) min/day of sedentary behavior. The mean (SE) self-reported hours slept per night was 6.9 (0.03). After adjustments, multivariate linear regression analysis showed that sedentary behavior (independent variable) was not associated with sleep duration ($\beta = -0.0002$; 95% confidence interval [CI]: −0.0008 to 0.0003; $P = 0.40$). The multinomial logistic regression analyses showed that sedentary behavior (independent variable) was associated with *feeling unrested during the day* and *feeling overly sleep during the day* [Table 2]. Compared to those who report *never* feeling unrested during the day, for every 60 min increase in sedentary behavior, participants were 16% (odds ratio [OR]= 1.16; 95% CI: 1.01-1.32) more likely to *almost always* feel unrested during the day. Compared to those who report *never* feeling overly sleepy during the day, for every 60 min increase in sedentary behavior, participants were 22% (OR = 1.22; 95% CI: 1.07-1.38) more likely to *almost always* feel overly sleepy during the day. All models controlled for age, gender, race-ethnicity, cotinine, depression, moderate-to-vigorous physical activity, self-reported health status, and BMI. When adding sleep duration as a covariate to these models, the results were unchanged (data not shown).

Table 1: Weighted means and proportions (95% CI) for selected characteristics of the 2005-2006 NHANES sample

Variable	Mean/proportion (95% CI)
N	2758
Age (years)	46.2 (44.5-47.8)
% Male	49.9 (48.3-51.4)
BMI (kg/m^2)	28.4 (27.8-28.9)
Ethnicity	
% Mexican American	7.3 (5.3-9.4)
% Other Hispanic	3.5 (1.7-5.2)
% Non-Hispanic White	73.6 (67.8-79.4)
% Non-Hispanic Black	10.8 (6.6-15.0)
% Other race	4.6 (3.2-6.1)
Current health status	
% Excellent	11.5 (9.9-13.2)
% Very good	36.1 (32.7-39.4)
% Good	38.0 (34.8-41.1)
% Fair	12.7 (11.3-14.1)
% Poor	1.6 (0.9-2.2)
Cotinine (ng/mL)	57.4 (50.7-64.0)
Depression (range = 0-23)	2.4 (2.1-2.6)
Moderate-to-vigorous physical activity (min/day)	24.6 (23.1-26.0)
Sedentary behavior (min/day)	487.7 (483.6-491.8)
Hours slept per night	6.9 (6.8-7.0)

NHANES: National Health and Nutrition Examination Survey; BMI: Body mass index

DISCUSSION

Using a large US sample of adults, we attempted to determine if there were detectable associations of sedentary behavior with sleep duration and daytime sleepiness. Our analyses did not demonstrate an association between sedentary behavior and nighttime sleep duration, but did show that for every 60 min increase in sedentary behavior, participants were 16% more likely to almost always feel unrested during the day compared to never feeling unrested during the day. Similarly, for every 60 min increase in sedentary behavior, participants were 22% more likely to almost always feel overly sleepy during the day compared to never feeling overly sleepy during the day. It is difficult to explain the null association between accumulative sedentary behavior and sleep duration. However, future research examining the association between sedentary bout length and frequency of sedentary bouts on sleep duration may help to shed more light on this issue.

At the time of this writing, and to our knowledge, very few studies have examined the association between sedentary behavior and sleep-related parameters. Compared to other relevant studies in the literature, our findings are similar to the convenience sample ($n = 73$) employed by Ellingson *et al*.[18] who exhibited a comparable association between sedentary behavior and fatigue. Specifically, their findings indicated that women engaging in more sedentary behavior exhibited higher levels of fatigue, when compared with women who were less sedentary [18].

We were unable to locate other relevant studies; thus, future studies are needed to corroborate our findings. Our findings suggest that sedentary behavior may influence daytime energy levels, which is important because low energy levels may, in theory, influence work productivity and social interactions. While more physically active individuals have increased energy levels,[19] our findings were independent of physical activity. This suggests that prolonged sedentary behavior may still have an effect on perceptions of fatigue,

Table 2: Multinomial logistic regression examining the association between sedentary behavior and the two significant sleep-related variables, NHANES 2005-2006

Variable	Odds ratio (95% CI) for sedentary behavior†	*P* value
How often do you feel unrested during the day (*n*=2755)		
Never (*n*=895)	1.0	
Rarely (*n*=495)	1.04 (0.95-1.14)	0.33
Sometimes (*n*=756)	1.06 (0.99-1.14)	0.08
Often (*n*=394)	0.97 (0.90-1.05)	0.41
Almost always (*n*=215)	1.16 (1.01-1.32)	0.03
How often do you feel overly sleepy during the day (*n*=2755)		
Never (*n*=984)	1.0	
Rarely (*n*=641)	1.08 (0.99-1.18)	0.07
Sometimes (*n*=687)	1.04 (0.97-1.11)	0.15
Often (*n*=317)	1.03 (0.95-1.11)	0.32
Almost always (*n*=126)	1.22 (1.07-1.38)	0.004

†Odds ratio (95% CI) expressed as 60-unit changes. Models controlled for age, gender, race-ethnicity, cotinine, depression, moderate-to-vigorous physical activity, self-reported health status, and body mass index. NHANES: National Health and Nutrition Examination Survey; CI: Confidence interval

regardless of daily physical activity engagement. Therefore, based on our findings, we encourage adults to increase their frequency of sedentary breaks throughout the day, which is consistent with other research showing that frequency of sedentary breaks is associated with cardiovascular disease risk factors [20,21]. Small bouts of movement, such as walking to the water fountain or taking the stairs, can be great ways to minimize prolonged sedentary behavior. In addition, one could set prompts on his/her technological devices (e.g. smart phone) as a reminder to take small, frequent sedentary breaks. By increasing sedentary breaks, through the use of lifestyle physical activity breaks, one may, albeit speculatively, be able to increase his/her alertness and reduce fatigue. Of course, future studies will be needed to support this assertion as it is not certain whether reduced feelings of unrested and overly sleepy will translate into improved alertness and reduced fatigue.

A limitation of this study includes using a cross-sectional design as well as the subjective assessment of sleep. It is possible that perceptions of daily tiredness may have influenced sedentary behavior. Further, the majority of participants did not feel unrested or overly sleepy during the day; therefore, it is possible that this may have, in part, explained the null findings for some of the categories of these sleep-related variables. Additionally, other limitations include using data that is approximately 10-years old and limited to Americans, not examining whether the type of sedentary behavior (e.g. reading or watching television) has a differential association with sleep-related parameters, and the lack of reliability (e.g. test–retest reliability) assessment for the sleep-related variables in the study sample. Future studies may benefit by utilizing an objective measure of sleep-related parameters, employing a longitudinal or experimental study design to be able to accurately determine causality between psychological perception of alertness and prolonged sedentary activity, examining these associations in other populations, and investigating whether the type of sedentary behavior moderates the association between sedentary behavior and sleep-related parameters.

CONCLUSION

Our findings showed that, independent of physical activity, sedentary behavior was associated with *feeling overly sleepy* and *unrested* throughout the day. This suggests that prolonged sedentary behavior may promote increased perceptions of tiredness during the day. Minimizing daytime tiredness is important as excessive daytime tiredness may have numerous negative consequences in multiple domains. For example, Powell *et al* [22]. demonstrated that daytime sleepiness resulted in worse reaction time when compared to individuals with alcohol intoxication. This may be particularly concerning among certain occupations, such as long-haul drivers who report difficulty staying alert during at least 20% of their drives [23]. Further, daytime sleepiness may affect work or school-related performance as it leads to problems with concentration, memory, and mood [24].

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