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Relationships between Sleep, Sedentary Behavior, and Physical Activity in Young Adults

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ABSTRACT

Purpose
While there are some studies on sleep and physical activity, little is known regarding the associations between sleep and sedentary behavior. This study investigated the associations between sleep, sedentary behavior, and physical activity among young adults.

Methods
Cross-sectional data from 124 undergraduate students were included in the analysis (age=21±1 years). Both accelerometer-based and self-report assessments of sleep were included; physical activity and sedentary behavior were assessed by accelerometers. Participants were asked to fill out sleep questionnaires and wear accelerometers for 7 days. Pearson correlations, partial correlations, and analysis of covariance (ANCOVA) analyses were performed to investigate the relationships between sleep, sedentary behavior, and physical activity.

Results
After adjusting for age, gender, percent body fat, educational level, and monthly allowance, prolonged sedentary time was correlated with a shorter sleep onset latency ($r=-0.19$, $p=0.04$), shorter time in bed ($r=-0.43$, $p<0.001$), and shorter sleep duration ($r=-0.38$, $p<0.001$). Moderate-to-vigorous physical activity (MVPA) was positively correlated with sleep onset latency ($r=0.43$, $p<0.001$). Sedentary behavior and MVPA were not correlated with sleep quality or daytime sleepiness. After further categorizing sleep duration into three subgroups, individuals with ≤6 hours ($p<0.001$) of sleep spent more time being sedentary than did those with 6-7 hours ($p<0.001$) and ≥7 hours ($p=0.007$) of sleep. Individuals with 6-7 hours of sleep had a higher level of MVPA than did those with ≥7 hours of sleep.

Conclusion
Improving the duration of sleep may be a viable approach to help reduce sedentary behavior among young adults. Future studies with longitudinal designs are needed to further investigate the directionality of these associations and their potential mediators and moderators.

Keywords
Accelerometer; Sleep; Sedentary; Physical activity.

INTRODUCTION

Obesity is a significant public health issue that causes a high economic burden for society, in relation to both direct and indirect costs.[1] In Taiwan, the obesity rate has continually increased over the past two decades. According to nationally representative data from the Nutrition and Health Survey in Taiwan, the prevalence of obesity [body mass index (BMI)≥27 kg/m^2] was 22% in adults aged 19 years and above in 2014.[2] To prevent adverse health outcomes associated with obesity, intervention programs aimed at improving risk factors of obesity are needed. Three of the important modifiable behavioral factors that influence obesity-related disease risk are sleep, sedentary behavior, and physical activity.[3,4]

There is compelling evidence that physical activity is related to favorable sleep durations and sleep quality.[5] High school students who engaged in more than 3.5 hours of physical activity/week had better sleep quality than those who engaged in 3.5 hours or fewer hours of physical activity/week.[6] Another study showed that daily physical activity for ≥60 minutes is associated with sufficient sleep.[7] While sleep and physical activity have been widely studied, a much smaller amount of data are available regarding the associations between sleep and sedentary behavior. Moreover, findings on the relationships between sleep and sedentary behavior have been less conclusive. One study found that young individuals who watched 3 or more hours of television (TV)/day were at greater risk for sleep problems by early adulthood than those who watched fewer than 3 hours/day.[8] On the other hand, Chen et al[9] found that the number of hours during which Taiwanese adolescents watched TV on weekdays and the number of hours during which they used a computer for purposes other than schoolwork were not associated with insufficient sleep. It has been suggested that more studies are needed to understand how sedentary behavior is linked to different sleep problems, such as sleep onset latency, short sleep durations, and sleep efficiency.[10]

Another gap in the existing literature[8-10] regarding sleep and sedentary behavior is that most studies relied on subjective assessments which may be prone to self-reported bias. Accelerometers can be used to provide objective estimates of sleep, sedentary behavior, and physical activity simultaneously using the same monitors. Hence, the aim of this study is to evaluate the associations between accelerometer measures of sleep, sedentary behavior, and physical activity. To enrich the understanding of how sleep and sedentary behavior are related, subjective measures of sleep quality and daytime sleepiness is also included in the study.

MATERIALS AND METHODS

Participants

A total of 131 college students were recruited from a university in Taiwan. Participants were excluded from the study if they (1) were previously diagnosed with any major illnesses that could affect their physical abilities; or (2) took any medications that may influence body composition and sleep.

Procedures

Flyers were posted on the message boards in the university and interested students could sign up to be contacted. At the health promotion center on campus, trained study team members provided information about the study and obtained written consent from the students who agreed to participate. Eligible participants completed body composition measurements as well as the demographic and questionnaires on sleep quality and daytime sleepiness. Afterwards, participants were instructed to wear an accelerometer for 7 days, except during bathing and aquatic activities. In addition, participants were asked to keep a daily log of the times they wore and took off the activity devices during the 7 day period. During the seven days of data collection, participants were asked to maintain their current levels of physical activity and sleep schedules. The research staff contacted the participants *via* phone calls and text messages to ensure that the accelerometers were worn properly and later retrieved monitors. Institutional Review Board approval was obtained from the Kaohsiung Medical University Chung-Ho Memorial Hospital, Sanmin District, Kaohsiung, Taiwan.

Measurements

Sedentary behavior and physical activity by the accelerometers: The duration of sedentary behavior and physical activity were estimated using the Actigraph GT3X monitors (Actigraph LLC, Pensacola, FL, USA). The accelerometers were programmed to record in 1 minute epochs, and the data were processed using ActiLife® software (version 6.7.2). The periods during which the accelerometers were not worn were defined as 60 minutes of consecutive zero counts and were cross-validated by the participants' self-report logs. The mean minutes per day of sedentary behavior (<100 counts/min) and moderate-to-vigorous physical activity (MVPA; ≥3 metabolic equivalents (METs))[11,12] were calculated by summing the minutes spent daily on these activities and averaging across the 7 days of wear.

Sleep parameters by the accelerometers: The same wrist-worn Actigraph GT3X monitors were used to objectively measure nocturnal sleep and wakefulness. Sleep-wake times from participants' diary logs were entered to calculate summary sleep estimates using ActiLife® software (version 6.7.2). Six sleep parameters of nocturnal sleep were obtained from the accelerometer data, including sleep onset latency (the amount of time it takes to fall asleep), time in bed (the duration of laying in bed from the bedtime to wake-up time),[13] sleep duration (the number of 1 minute epochs in a sleep episode that were scored as 'sleep', excluding any times that were scored as 'wake'),[13] wake after sleep onset (the duration of wake time in a sleep episode after sleep has been initiated),[14] number of awakenings (the total number of awakenings during a sleep episode),[13] and sleep efficiency [(number of hours slept/number of hours spent in bed)×100=habitual sleep efficiency (%)].[15] All sleep variables estimated by accelerometers were computed as the mean of the 7 day accelerometer measurements.

Sleep quality: Sleep quality over the previous month was assessed using the 19-item validated Chinese version of the Pittsburgh sleep quality index (PSQI).[16,17] The PSQI items were categorized into 7 components (subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction) graded on a score ranging from 0 to 3 points. The global score was calculated by summing the 7 component scores, providing a continuous measure of sleep quality with high scores corresponding to poor sleep quality. A global score higher than 5 indicates a "poor sleeper", whereas a global score lower than 5 represents a "good sleeper".

Daytime sleepiness: The validated Chinese version of the Epworth sleepiness scale[18] was used to evaluate the degree of subjective daytime sleepiness. The scale asked the participants to rate how likely they were to fall asleep in different situations (e.g. sitting and reading, watching TV, in a car, while stopped for a few minutes in the traffic). The scale contained 8 items and each item was rated on a scale of 0 (would never doze) to 3 (high chance of dozing). The sum of all items was used to denote the level of daytime sleepiness; a higher score represented more daytime sleepiness. Participants were dichotomized into <11 (low risk for sleepiness) and ≥11 (high risk for sleepiness) groups based on the sum score.[19]

Body composition: Weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, using a beam medical scale and a wall-mounted stadiometer. The BMI was calculated as kg/m^2. The percent body fat was measured using a bioelectric impedance analyzer (X-SCAN Plus-II, iCare Co., Ltd, Korea). The measurement was performed in a standing position with the participant barefoot and wearing light clothing.

Demographic information: A questionnaire was used to assess demographic information such a sage (in years), sex, parental education level (highest level of mother or father), and average monthly allowance (in new Taiwanese dollars).

Statistical Analysis

Means and frequencies were calculated to describe the study sample. Data were assessed for normality using the Shapiro-Wilk tests. The relationships among sleep variables, sedentary behavior, and MPVA were examined using pearson correlation coefficients and partial correlation coefficients. Analysis of covariance (ANCOVA) with post-hoc analysis least significant difference (LSD) analysis was conducted to compare sedentary behavior and MVPA by sleep duration group (≤6 hours, 6-7 hours, and ≥7 hours), sleep quality (good sleepers and poor sleepers), and daytime sleepiness (low risk for sleepiness and high risk for sleepiness). Covariates included in the partial correlation analysis and ANCOVA models included age, gender, percent body fat, highest parental education level, and monthly allowance. All analyses were conducted using statistical package for the social sciences (SPSS) version 18.0 (IBM Corp., Armonk, NY, USA). The priori significance level was set at $p \leq 0.05$.

RESULTS

Table 1 presents the demographic information of the study sample. Of the 131 college students who completed the screening visit, 7 students was excluded were excluded due to missing data. A total of 124 students (mean age=21.1±1.2 years; females: 78.2%) were included in the current study. The participants' mean BMI was 22.1 kg/m^2; 21% (n=26) was classified as obese (≥27 kg/m^2)/overweight (≥24 kg/m^2), 64.5% (n=80) was classified as having normal weight, and 14.5% (n=18) was classified as underweight. The mean percent body fat was 18.8% among males and 24.2% among females. On average, participants spent 42.4 minutes in MVPA and 716.4 minutes in sedentary behavior. The mean sleep duration at night was 380.9 minutes and the mean sleep onset latency was 9.5 minutes.

Table 1. *Demographic Characteristics*

	N (%)	Mean	SD
Age (year)		21.12	1.20
Gender			
Female	97(78.2%)		
Male	27(21.8%)		
Percent Fat mass (%)			
Female		24.2	5.3
Male		18.8	7.8
Weight Status			
Underweight (BMI<18.5 kg/m^2)	18(14.5%)		
Normalweight (BMI 18.5-24 kg/m^2)	80(64.5%)		
Overweight (BMI24-27 kg/m^2)	12(9.7%)		
Obese (BMI≥27 kg/m^2)	14(11.3%)		
Parental Education (Highest of mother or father)			
Below high school	33(26.6%)		
High school	68(54.8%)		
College and above	23(18.6%)		
Monthly Allowancea			
≤4,999 NTD	41(33.1%)		
5,000-9,999 NTD	71(57.2%)		
≥10,000-14,999 NTD	12(9.7%)		
Sedentary behavior (minutes/day)		716.4	107.6
MVPA (minutes/day)		42.4	27.3
Sleep Parameters by Accelerometers			
Sleep onset latency (minutes)		9.5	8.5
Time in bed (minutes)		479.8	59.3
Sleep duration (minutes)		380.9	54.9
Wake after sleep onset (minutes)		89.4	38.5
Number of awakenings		4.7	2.1
Sleep efficiency (%)		79.4%	7.4%
Sleep Scales			
Sleep quality scale		7.2	2.4
Daytime sleepiness scale		6.6	3.0

Abbreviations: BMI: Body mass index,SD: Standard deviation, MVPA: Moderate-to-vigorous physical activity, NTD: New Taiwanese dollars. USD 1≈new Taiwanese dollars (NTD)30

Pearson correlations between sleep, sedentary behavior, and MVPA by measurement type are presented in Table 2. Based on the accelerometry data, sleep onset latency was inversely correlated with sedentary behavior (r=-0.19, p=0.03) and positively correlated with MVPA (r=0.45, p<0.001). Less time in bed was correlated with more time spent in sedentary behavior (r=-0.41, p<0.001). Sleep duration was negatively correlated with sedentary behavior (r=-0.34, p<0.001). The aforementioned significant correlations remained significant after adjustment for age, gender, percent body fat, highest parental education level, and monthly allowance. Sedentary behavior and MVPA were not significantly correlated with sleep quality or daytime sleepiness.

Table 2. *Pearson Correlations/Partial Correlations between Sleep and Physical Activity by Measurement Type*

	Sedentary Behavior		MVPA	
(a) Sleep and Physical Activity Data by Accelerometers				
	Pearson r	**Partial r[a]**	**Pearson r**	**Partial r[a]**
Sleep Parameters				
Sleep Onset Latency	-0.19*	-0.19*	0.45***	0.43***
Time in Bed	-0.41***	-0.43***	-0.12	-0.08
Sleep Duration	-0.34***	-0.38***	-0.18	-0.15
Wake after Sleep Onset	-0.10	-0.10	-0.03	-0.01
Number of Awakenings	0.03	0.03	-0.07	-0.02
Sleep Efficiency (%)	0.05	0.03	-0.12	-0.13
(b) *Sleep and Physical Activity Data by Questionnaires*				
	Sedentary Behavior		MVPA	
	Pearson r	**Partial r[a]**	**Pearson r**	**Partial r[a]**
Sleep Scales				
Sleep Quality	-0.07	-0.09	0.16	0.17
Daytime Sleepiness	-0.02	0.02	0.08	0.09

Results were based on pearson correlation and partial correlation analyses.
Abbreviations: MVPA: Moderate-to-vigorous physical activity
a. Parameters were adjusted for age, gender, percent body fat, highest parental education level, and monthly allowance.
**p≤0.05; ** p≤0.01; ***p≤0.001*

Table 3 shows the results of the comparisons of sleep variables, sedentary behavior, and MVPA. Daily sleep duration was associated with both sedentary behavior ($p<0.001$) and MVPA ($p=0.03$). When we further categorized sleep duration into three subgroups, adults with fewer than 6 hours of sleep/day spent more time in sedentary behavior than those with 6-7 hours of sleep/day (mean difference: 80.1 minutes/day, $p<0.001$) and those with more than 7 hours of sleep/day (mean difference: 100.1 minutes/day, $p<0.001$). In addition, adults who slept 6-7 hours/day spent 17.9 minutes/day more time in MVPA than those who had more than 7 hours of sleep/day ($p=0.007$). No significant differences were found between sleep quality, daytime sleepiness, sedentary behavior and MVPA.

DISCUSSION

One major study finding is that as an individual's sleep duration increases, he/she spends less time in sedentary behavior. In particular, individuals with fewer than 6 hours of sleep had a higher level of sedentary behavior, after adjusting for age, gender, percent body fat, highest parental education level, and monthly allowance. These results are consistent with those in previous literature. Based on the self-reported questionnaire data, higher amounts of sedentary time were found to be associated with higher odds of short sleep durations in postmenopausal women.[20] One possible explanation for this association is that an increase in sedentary be-

Table 3. *Comparisons of Physical Activityacross Sleep Variables*

	Sedentary Behavior			MVPA		
(a) Sleep and Physical Activity Data by Accelerometers						
	Mean (SD)	***p*-value[a]**	**Post-Hoc Comparisons[b]**	**Mean (SD)**	***p*-value[a]**	**Post-Hoc Comparisons[b]**
Sleep Duration		<0.001	"≤6 hours">"6-7 hours" "≤6 hours">"≥7 hours"		0.03	"6-7 hours">"≥7 hours"
≤6 hours (N=45)	771.03(97.44)			41.35(3.96)		
6-7 hours (N=54)	690.89(99.68)			48.55(3.61)		
≥7 hours (N=25)	670.10(107.98)			30.64(5.45)		
(b) *Sleep and Physical Activity Data by Questionnaires*						
	Sedentary Behavior			MVPA		
	Mean (SD)	***p*-value[a]**	**Post-Hoc Comparisons[b]**	**Mean (SD)**	***p*-value[a]**	**Post-Hoc Comparisons[b]**
Sleep Quality		0.89			0.99	
Good Sleepers (N=111)	716.41(114.00)			43.39(39.30)		
Poor Sleepers (N=13)	716.12(107.86)			42.32(26.02)		
Daytime Sleepiness		0.26			0.15	
Low Risk for Sleepiness (N=72)	720.31(113.14)			41.39(26.61)		
High Riskof Sleepiness (N=52)	716.15(107.98)			43.89(28.63)		

Results were based on Analysis of covariance (ANCOVA) with post hoc analysis.
Abbreviations: SD: Standard deviation, MVPA: Moderate-to-vigorous physical activity
a. Parameters were adjusted for age, gender, percent body fat, highest parental education level, and monthly allowance.
b. Only significant findings were shown.

havior is linked to an elevated risk of depression,[21,22] which often co-occurs with sleep problems such as insomnia and sleep disturbances.[23,24] In contrast, another study demonstrated that more sedentary time is associated with both short and long sleep durations among adults.[22] There appeared to be an inverse dose-response relationship between sleep duration and sedentary time in our study sample. Particularly, as the sleep duration decreased, more time spent in sedentary activities was recorded. It is alarming that the difference in sedentary time between those who slept fewer than 6 hours and those with 6-7 hours of sleep or more than 7 hours of sleep was approximately 80-100 minutes per day. Considering that sedentary behavior is widely recognized as a risk factor for developing obesity, cardiovascular disease, type 2 diabetes, and metabolic syndrome,[25,26] our findings highlight that improvements in sleep may be an alternative strategy for reducing the amount of time spent in sedentary behavior for young adults.

Sleep onset latency is the elapsed time between being fully awake and the beginning of sleep. The current study is one of the few studies that explored the association between sleep and onset latency. Two studies have shown that longer screen time not sitting time is related to a higher risk of long sleep latency.[27,28] The current study did not measure screen time and sitting time; instead, the total time spent in sedentary activities with small amounts of body movement was recorded by the accelerometers. We found that prolonged sedentary behavior is correlated with a shorter sleep onset latency while more time in MVPA is correlated with a longer sleep onset latency. It has been suggested that individuals with poor sleep spend a longer period of time being sedentary, as they feel a higher degree of fatigue.[29-31] It is likely that adults with more sedentary time feel a higher degree of tiredness and feel less restful during the day; as a result, they fall asleep quickly at night and have a shorter sleep latency. According to a review,[5] the effects of physical activity on sleep, regular exercise training showed beneficial effects on sleep onset latency (i.e., a shorter sleep onset latency). The observed positive correlation between MVPA and sleep onset latency does not necessarily imply that physical activity leads to an unfavorable sleep latency. We would like to note that the average time an individual took to fall asleep was 9 minutes among study participants, which is not considered a long period. Perhaps, when an individual spent more time in MVPA, they felt more energetic and did not fall asleep right away when they laid on the bed. In addition, prior studies did not investigate the roles that intensity, duration, and timing (24 hour clock time of physical activity)[32] of physical activity play in sleep onset latency. Future research is needed to understand whether the influences of physical activity and sleep latency differ by intensity, amount, and timing of physical activity.

Our findings that sedentary behavior was not significantly correlated with perceived daytime sleepiness are congruent with findings of a recent systematic review on sleep and sedentary behavior. Based on the meta-analysis of sixteen studies,[10] it was concluded that daytime sleepiness was not significantly associated with sedentary behavior. In contrast to prior literature in which more time spent performing sedentary activities was found to be related to poor self-reported sleep quality,[33] we did not find a correlation between sedentary behavior and self-reported sleep quality. The inconsistency may reflect the differences in measuring sedentary behavior. Kakinami et al[33] assessed sedentary behavior using the self-reported time spent watching TV and using computers while we estimated the total duration of sedentary behavior based on accelerometers, which captured the time spent in low energy expenditure activities throughout the day. It has been noted that light-emitting diode (LED)-backlit screen exposure can cause sleep disturbances by delaying the biological clock and suppressing the release of the sleep-inducing hormone melatonin.[34] The non-significant relationships between sleep quality and sedentary behavior observed in the present study may be due to the fact that we included a more general estimate of sedentary time. Additional research should examine whether the associations between sleep and sedentary behavior differ by the type of sedentary activity.

STRENGTHS AND LIMITATIONS

The main strength of the study is the inclusion of both subjective and objective measures of sleep. A combination of both approaches would enrich understanding of sleep behaviors. In addition, socioeconomic status factors known to influence sleep and activity levels were assessed and included as covariates to minimize possible confounding effects. This study has some limitations. First, the small sample size and the cross-sectional nature of the study impeded the generalizability of the findings and causal associations. Second, our data did not allow us to study the mechanisms associated with sleep, sedentary behavior, and physical activity. Third, only college students were included in the study and the findings may not be generalizable to other age groups as there may be age-related differences in sleep patterns and activity levels.[35] More studies are needed to identify whether or not the observed associations vary by age groups.

CONCLUSION

In conclusion, the study aids in identifying the cross-sectional relationships between sleep, sedentary behavior, and physical activity. Our findings imply that short sleep durations are associated with higher amounts of sedentary time in young adults. Promoting interventions that aim to reduce sedentary behavior may be an effective approach to enhance sleep for college students in Taiwan. School health education programs on healthy sleep duration are needed to reduce sedentary time for college students. Longitudinal studies with larger sample sizes are needed to clarify the causal inferences on sleep, sedentary behavior, and physical activity. Furthermore, future investigations are warranted to determine the potential moderators or mediators of the relationships between sleep and activity levels.

CONFLICTS OF INTEREST

The authors declare that they do not have any conflicts of interest.

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