ORIGINAL ARTICLE

Sleep duration and weight loss among overweight/obese women enrolled in a behavioral weight loss program

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OBJECTIVE: The purpose of this study was to examine whether baseline sleep duration predicts weight loss outcomes in a randomized controlled trial examining a behavioral weight loss (BWL) intervention among overweight and obese (OW/OB) women with urinary incontinence; and whether participation in the BWL intervention is associated with changes in sleep duration.

DESIGN: Longitudinal, clinical intervention study of a 6-month BWL program.

SUBJECTS: Three hundred sixteen OW/OB women, with urinary incontinence (age: 30–81 years, body mass index (BMI); 25–50 kg m⁻²) enrolled from July 2004–April 2006.

MEASUREMENTS: Measured height and weight, self-report measures of demographics, sleep and physical activity.

RESULTS: Neither self-reported total sleep time (TST) nor time in bed (TIB) at baseline significantly predicted weight loss outcomes among OW/OB women in a BWL treatment. BWL treatment was successful regardless of how much subjects reported sleeping at baseline, with an average weight loss of 8.19 kg for OW/OB women receiving BWL treatment, versus a weight loss of 1.44 kg in the control condition. Similarly, changes in weight, BMI and incontinence episodes did not significantly predict changes in sleep duration or TIB across the treatment period.

CONCLUSION: Although epidemiological and cross-sectional studies support a relationship between short sleep and increased BMI, the present study found no significant relationship between TST or TIB and weight loss for OW/OB women participating in a BWL treatment.

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INTRODUCTION

Over the past several decades, there has been a precipitous rise in the rates of obesity among adults,¹ as well as a concomitant decrease of 1–2 h per night in the average reported sleep duration.² Epidemiological and cross-sectional studies have reported an association between short sleep duration and higher body mass index (BMI).^{3–7} Prospective studies examining the relationship between sleep duration and weight are limited, with mixed results emerging from these studies.^{8–11}

There are few studies examining the relationship between sleep duration and outcomes from weight loss interventions. One recent study reported that baseline sleep duration significantly predicted success in a behavioral weight loss (BWL) program (defined as a weight loss of $\geq 10\%$) but did not predict amount of actual weight loss.¹² In contrast, in the Finnish Diabetes Prevention Study baseline sleep duration did not predict weight changes over 3 years.¹³

The Finnish DPP study,¹³ is the only study we are aware of that examined the effect of participation in a BWL program on sleep duration. Participants in the BWL group who reported sleeping 6.5 h or less at baseline had a significant increase in their self-reported sleep by 0.9 h at the 1-year follow-up compared with the group sleeping 7–8.5 h per night at baseline. Conversely, in the control group, at the 1-year follow-up those who reported sleeping 6.5 h or less at baseline had a significant decrease in

their self-reported sleep by 1.2 h, and those who reported sleeping 10 h or more at baseline had a significant increase in their self-reported sleep by 0.7 h compared with the group sleeping 7–8.5 h per night at baseline.

The purpose of this study is to extend these observations by examining: (1) whether baseline sleep duration predicts weight loss outcomes in a randomized controlled trial examining a BWL intervention among overweight and obese (OW/OB) women with urinary incontinence; and (2) whether there are changes in sleep duration among participants in a BWL intervention. The present study also assesses these questions separately for Caucasian and African-American women, as there are well-established differences between self-reported sleep duration among Caucasian and African-American populations (for example, Lauderdale *et al.*¹⁴). Investigation of participants' baseline characteristics across time in bed (TIB) categories presented previously,¹⁵ indicated that shorter TIB was associated with higher BMI and lower physical activity compared with the referent category of '>7–8 h,' after adjusting for covariates. The present analyses focus on longitudinal associations between sleep and weight loss in this sample.

SUBJECTS AND METHODS

Participants

Data reported in this manuscript were collected as part of a multi-site randomized controlled trial testing a BWL intervention among OW/OB

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women (BMI 25–50), age 30 or older, with urinary incontinence (PRIDE: Program to Reduce Incontinence by Diet and Exercise). The PRIDE study was conducted at Brown University in Providence, RI, and the University of Alabama at Birmingham. The final sample included 338 OW/OB women, enrolled from July 2004–April 2006. For the present analysis, 22 women were excluded from the original sample of 338 for the following reasons: 11 for indicating that their race was neither African-American nor Caucasian; 9 for suspected shift work or circadian disturbances, and 2 due to having extreme outlying values on the Block Food Frequency questionnaire.

Procedures

Details about the study design have been presented previously in Subak et al.¹⁶ Procedures during months 1–6 will be described briefly here. Eligible participants were randomly assigned in a 2:1 ratio to an intensive BWL program or to a control condition. During months 1–6, the BWL intervention had hour-long weekly meetings, where participants were provided with a calorie goal of 1200–1500 calories per day, a fat gram goal equal to $\leq 30\%$ of calories from fat, and physical activity goals to gradually increase physical activity to 200 min per week. Additionally, sample meal plans and vouchers for meal replacement products were provided to increase adherence. Finally, behavioral skills were taught to help participants make changes to their eating habits and physical activity levels. The control group consisted of four 1 h group sessions (at months 1, 2, 3 and 4), where structured information was provided about weight loss, physical activity and healthful eating habits. Sleep was measured, but not targeted, as part of the intervention. Participants in both groups completed a battery of measures at baseline and following the 6-month intervention period.

Anthropometrics

Height and weight were measured at baseline and 6 months. Participants were weighed in their clothes, without shoes, using a calibrated digital scale (Tanita BWB 800, Arlington Heights, IL, USA). Weight was measured to the nearest 0.5 kg. Height was measured to the nearest centimeter using a calibrated, wall-mounted stadiometer. Measured height and weight were used to calculate BMI (kg m^{-2}).

Demographics and health behaviors

Participants provided information about their age, race, education level and employment status, and completed the Beck Depression Inventory as a measure of depressive symptoms at baseline and 6 months.

Sleep

Self-reported sleep information was obtained using the Pittsburgh Sleep Quality Index (PSQI;¹⁷), a widely-used and well-validated measure of general sleep habits and quality over the past month. Two items assessing usual bedtime and usual rise time over the past month were used to calculate participants' TIB, which was categorized as follows: ≤ 6 h, > 6 to ≤ 7 h, > 7 to ≤ 8 h (referent category), > 8 to ≤ 9 h and > 9 h. The category of > 7 to ≤ 8 h was selected as the referent category because this amount of sleep has been associated with the lowest risk of obesity.^{9,18} Total sleep time (TST) was assessed from the following item on the PSQI, '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 spent in bed).' Self-reported TST was categorized as follows: < 6 h, ≥ 6 to < 7 h, ≥ 7 to < 8 h (referent category), ≥ 8 to < 9 h and ≥ 9 h. Sleep onset latency was assessed by a question asking participants how long it took them to fall asleep. Sleep efficiency was calculated as the percent of time spent asleep within the total TIB period. Additionally, frequency of snoring or coughing loudly was obtained from the PSQI as a marker for sleep disordered breathing.

Urinary incontinence

Participants completed a 7-day voiding diary. These are valid and reliable measures of urinary incontinence episodes,^{19,20} and diaries were reviewed by trained research staff. Total weekly incontinence episodes were used in the present analyses.

Statistical analysis

All analyses were conducted using PASW Statistics 18, Release 18.0.0 (SPSS, Inc., 2009, Chicago, IL, USA; www.spss.com). Descriptive analyses were conducted for demographic and weight-related variables at baseline and at 6 months. The urinary incontinence variable was skewed, therefore log-transformed values for this variable were used in the analyses. Reported TIB was categorized to examine relationships in comparison with a referent category of ' > 7 to 8 h' of sleep per night. Similarly, self-reported TST was categorized to examine relationships in comparison with a referent category of ' ≥ 7 to < 8 h' of sleep per night. One-way analyses of variance and χ^2 analyses were used to examine differences in demographic and clinical variables across TIB and TST groups ($P < 0.05$), or were considered to be of conceptual importance as related to sleep or weight, were included in the analyses as covariates. These included the following baseline variables: age, race, education, baseline weight, group assignment, depression scores, PSQI total score and total incontinence episodes. Linear regression analyses were conducted to examine whether baseline TIB or baseline TST predicted changes in weight during the 6-month BWL intervention. For each regression analysis, TIB or TST was entered in the first step, followed by the covariates listed above. Linear regression analyses were also conducted to examine whether changes in weight or BMI from baseline to 6 months predicted changes in self-reported TST across the 6-month study period. For each regression analysis, change in weight or change in BMI was entered in the first step, followed by the covariates listed above. Analyses examining the relationship between sleep and weight were also conducted separately for Caucasian and African-American women to examine potential racial/ethnic differences in these relationships. Quadratic contrasts were also conducted using Stata/SE 12.0 for Windows (StataCorp., 2011, College Station, TX, USA; www.stata.com), in order to examine weight change across TST groups.

RESULTS

Subject characteristics

On average, participants were 53 ± 11 years, with a BMI of 36 ± 6 , and had 24 ± 18 incontinence episodes per week. Approximately 78% of the sample was Caucasian and 19% of the sample was African-American. At baseline, participants in the BWL group slept for 6.60 ± 1.24 h, and participants in the control group slept for 6.44 ± 1.19 h ($P > 0.05$). Baseline sleep variables across the five TST categories are presented in Table 1.

Sleep duration and weight loss

Overall, participants in the BWL group had an average weight loss of 8.19 ± 6.11 kg ($8.41 \pm 6.10\%$) at 6 months, whereas the control participants had an average weight loss of 1.44 ± 3.96 kg ($1.53 \pm 4.05\%$; $P < 0.001$). Figure 1 shows the average weight losses for participants in each of the five TST groups. Although the figure suggests somewhat better weight losses in those with the recommended 7–8 h of sleep per night, none of the differences in weight loss among the five TST groups were close to being statistically significant. Moreover, in linear regression analyses, neither TIB nor TST at baseline significantly predicted weight loss following BWL treatment, before or after accounting for age, race, education, baseline weight, depression, sleep quality and total incontinence episodes (Tables 2a and b). Similarly, quadratic contrasts indicated that TST group did not predict weight loss in the BWL treatment. There was a small but significant correlation between reporting less difficulty falling asleep within 30 min at baseline and better subsequent weight loss ($r = 0.17$, $P < 0.05$). However, sleep efficiency at baseline did not predict subsequent weight loss.

Notably, African-American participants reported significantly shorter TST than Caucasian participants (5.70 (1.12) hours vs 6.74 (1.17) hours, respectively; $P < 0.001$). African-American participants also lost significantly less weight in the BWL group (5.61 kg vs 8.83 kg, respectively; $P < 0.01$) compared with Caucasian participants. However, linear regression analyses conducted separately for Caucasian women and African-American women indicated that

Table 1. Sleep variables across the 5 TST groups

Variables	Sleep categories					χ^2 or <i>F</i>
	<6 h (N = 60)	≥6 to <7 h (N = 91)	≥7 to <8 h (N = 93)	≥8 to <9 h (N = 61)	≥9 h (N = 11)	
TIB (hours)	6.80	7.55	7.84	8.53	9.58	27.56***
M (s.d.)	(1.48)	(1.09)	(0.92)	(0.90)	(0.99)	
TST (hours)	4.7	6.0	7.0	8.0	9.18	1944.75***
M (s.d.)	(0.53)	(0.00)	(0.00)	(0.00)	(0.40)	
SOL (min)	28.50	22.31	17.65	13.44	15.91	5.98***
M (s.d.)	(25.00)	(17.50)	(19.02)	(9.72)	(15.46)	
SE (%)	72.6%	81.3%	90.4%	94.8%	96.4%	29.40***

Abbreviations: SOL, sleep onset latency; TIB, time in bed; TST, total sleep time. *** $P < 0.001$. **Figure 1.** Weight loss (kg) for Program to Reduce Incontinence by Diet and Exercise (PRIDE) participants receiving behavioral weight loss (BWL) treatment.

there were no significant relationships between TIB or TST and weight loss for either of the two racial/ethnic groups in the BWL or control group.

Sleep following BWL treatment

On average, participants reported little change in their TST from baseline to 6 months (BWL: $M = +0.08$ h; control: $M = +0.07$ h). Additionally, there were no significant time effects, group effects or interactions for changes in TST or sleep disruptions due to needing to use the bathroom. Linear regression analyses indicated that neither changes in weight, changes in BMI nor changes in urinary incontinence episodes from baseline to 6 months predicted changes in self-reported TST, before or after accounting for age, race, education, group assignment, depression, sleep quality and total incontinence episodes. Separate analyses for African-American and Caucasian women, and for only those participants in the treatment group, again showed no effect of changes in weight, BMI or urinary incontinence on changes in TST. Short and long sleepers in both the BWL and control groups reported a more moderate TST at 6 months compared with their baseline TST, indicating a regression toward the mean (Figure 2). Sensitivity analyses were also conducted among only those participants who indicated infrequent coughing or loud snoring during sleep (that is, less than once per week; used as a proxy to assess for likelihood of sleep apnea). There were no changes in the

Table 2. TST (a) and TIB (b) as predictors of weight change (%) from baseline to 6 months following BWL treatment

	<i>B</i>	<i>SE</i>	<i>Beta</i>	<i>t</i>
(a) TST				
<i>Variables</i>				
Total sleep time (TST)	0.25	0.36	0.05	0.69
Ethnicity (AA/C)	−3.09	0.90	−0.19	−3.45**
Age	0.02	0.03	0.02	0.45
Education	−1.24	0.66	−0.10	−1.87
Baseline weight	−0.02	0.02	−0.06	−1.09
Total incontinence episodes ^a	−0.50	0.49	−0.05	−1.02
Beck depression score	0.14	0.07	0.12	2.05*
PSQI total score	0.04	0.12	0.03	0.36
Intervention group (treatment/control)	0.62	0.70	0.48	9.45***
(b) TIB				
<i>Variables</i>				
Time in bed (TIB)	0.00	0.00	0.01	0.24
Ethnicity (AA/C)	−2.96	0.89	−0.18	−3.34**
Age	0.01	0.03	0.02	0.44
Education	−1.18	0.66	−0.09	−1.80
Baseline weight	−0.02	0.02	−0.06	−1.12
Total incontinence episodes ^a	−0.51	0.49	−0.05	−1.04
Beck depression score	0.14	0.07	0.13	2.12*
PSQI total score	−0.01	0.10	−0.00	−0.07
Intervention group (treatment/control)	6.59	0.70	0.48	9.42***

Abbreviation: PSQI, Pittsburgh Sleep Quality Index. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. ^aThis variable was log-transformed due to being skewed.

preceding results when examined only among participants who were less likely to have sleep apnea.

DISCUSSION

The main finding of this study was that neither TIB nor TST at baseline predicted weight loss outcomes among OW/OB women in a BWL treatment. BWL treatment was successful regardless of how much subjects reported sleeping at baseline, with an average weight loss of 8.19 kg for women in the BWL group versus a weight loss of 1.44 kg in the control condition. Less sleep

Figure 2. Changes in self-reported total sleep time (in hours) from baseline (black bars) to 6 months (gray bars) in the behavioral weight loss (BWL) and control groups.

fragmentation at baseline was significantly, but modestly, correlated with better subsequent weight loss outcomes, whereas baseline sleep efficiency was not related to weight loss.

The present study is one of the first to examine the relationship between TIB and TST and weight loss outcomes among OW/OB individuals participating in a weight loss intervention. In contrast to the findings of Elder *et al.*,¹² but replicating data from the Finnish DPP study,¹³ the present findings suggest that self-reported TIB and self-reported TST do not significantly predict weight loss outcomes in a BWL treatment.

The other important finding was that the changes in weight, BMI and urinary incontinence that occurred over the 6-month weight loss program were not associated with changes in self-reported TST. Self-reported TST for both short and long sleepers in the BWL and control groups moved toward more moderate amounts across the 6-month treatment period, suggesting regression to the mean.

Similar to previous studies (for example, Vgontzas *et al.*²⁴), higher depression scores and poorer sleep quality were endorsed by participants reporting shorter TST. A considerable body of research has established an association between depression and impairments in sleep quality or quantity.^{25–27} However, elevated depression scores and impaired sleep quality were not found among long sleepers in the present sample. This may have been influenced by the small number of participants in the current sample, who reported sleeping 9 or more hours per night.

Results also showed that African-American women reported less sleep at baseline (5.70 h overall vs 6.74 h overall; $P < 0.001$) compared with Caucasian women and lost significantly less weight (5.61 kg vs 8.83 kg; $P < 0.01$) in the BWL group. This is consistent with existing literature reporting shorter self-reported and objectively measured sleep duration among African-American adults (for example, Lauderdale *et al.*¹⁴), as well as poorer weight loss outcomes (for example, Fitzgibbon *et al.*²⁸) compared with Caucasian adults. However, there was no relationship between TST and weight loss within either racial/ethnic group. In other words, even though the African-American women in this study lost less weight and obtained less sleep, there was no association between these two factors among this group of participants. African-Americans made up ~19% of the sample, so it is possible that this small number of African-American participants affected our ability to detect ethnic differences in this study.

Although this study had several strengths, including use of a randomized controlled design and longitudinal assessment, results should also be interpreted in relation to limitations. The present sample included OW/OB female participants with urinary incontinence. Incontinence is common among OW/OB adults²⁹ and was controlled for in all analyses. TST was based on

self-report, which is consistent with much of the existing epidemiological, cross-sectional and prospective literature. It is possible that use of an objective measure of sleep may have provided further insight into the relationships under study. In particular, given the relatively short period of study (that is, 6 months), it may be that individuals do not perceive changes in their sleep patterns, though subtle changes may be occurring. Use of objective measures of sleep would be beneficial to further investigate these relationships. Additionally, future studies should examine whether intervening to increase sleep duration or improve sleep quality has a beneficial impact on weight loss outcomes. A recent study by Chaput *et al.*³⁰ reported that short sleepers (defined as ≤ 6 h per day) who increased their sleep duration to 7–8 h per day over a 6-year period had a smaller increase in BMI and fat mass, compared with short sleepers who maintained their short sleep durations over the same period. This suggests that increasing sleep duration to a healthy duration of 7–8 h per day may be an important strategy for preventing weight gain. Additionally, little is known about the impact of maintaining weight loss on subsequent sleep habits. The present study examined the relationship between sleep and weight loss across a 6-month period. Future studies should examine whether maintaining a lower body weight following BWL treatment has a beneficial impact on sleep.

Though epidemiological and cross-sectional studies support a relationship between short sleep and increased BMI, this relationship is poorly understood. Limited prospective data have examined this relationship, and reports from these studies have provided conflicting results. After controlling for multiple potential confounding variables, including incontinence, the present study found that reported TIB and TST do not predict weight loss for OW/OB women participating in a BWL treatment. This highlights the complex relationship between sleep and weight and suggests that future studies need to examine this relationship more thoroughly using objective measures, longitudinal designs and interventions aimed at improving sleep.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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