Sleep duration and timing in the medium- to long-term post-bariatric surgery

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Abstract:

Sleep duration improves short-term following bariatric surgery; however, little is known about its association with bodyweight medium- to long-term post-surgery. The purpose of this study was to describe sleep duration and its relationship with BMI and body composition. Forty-nine individuals, with a BMI of 36.6 ± 9.8 kg/m^2, regained 26.4 ± 17.8% of their lost weight 9.5 ± 3.3 years post-surgery (range 3–16 years). Sleep logs and ActivPAL3 accelerometers were used to assess sleep duration. Participants averaged 7.9 ± 1.6 h/day and 8.5 ± 1.7 h/day of sleep for weekdays and weekends, respectively ($P < 0.01$). A positive association between delta weekend-weekday sleep timing midpoint with BMI (β = 0.03, 95% CI = 0.01, 0.06; $P = 0.01$) was noted in the multivariable-adjusted model. On average, this sample achieved recommended sleep durations medium- to long-term post-surgery. Having an earlier sleep timing midpoint during the weekend may be associated with lower BMI.

Keywords: Gastric bypass | RYGB | Obesity | Accelerometry | Sleep length | Sleep timing midpoint

Article:

Introduction

Obesity affects one third of the North American population and is a risk factor for the metabolic syndrome, cardiovascular disease, and respiratory disorders such as obstructive sleep apnea [1, 2]. Shorter (< 7 h of sleep/night) and/or longer (> 9 h of sleep/night) sleep durations have been associated with weight gain, as well as increases in waist circumference and body fat percentage [3].

Bariatric surgery effectively manages obesity while eliminating or significantly reducing obstructive sleep apnea in most patients [4]. One study reported that pre-surgery bariatric patients have shorter sleep durations and a greater frequency of sleep disruptions than individuals without obesity [5]. Shortly following surgery, or dramatic weight loss, marked improvements in both sleep duration and quality have been noted [4, 5]. One study also reported that having an evening chronotype, or a greater propensity to go to bed later during the night, was associated with higher pre-surgery body mass index (BMI) and greater weight regain post-surgery compared with having a morning chronotype (i.e., a greater propensity to wake earlier in the morning) [6]. This suggests that sleep timing may also be associated with obesity parameters in this population. Furthermore, cross-sectional studies have shown inverse associations between sleep duration with BMI [7] and risk of hypertension [8]; however, "catch-up sleep" during the weekend (versus weekdays) was also associated with a lower BMI [7] and reduced risk of hypertension [8]. Additional studies concerning the sleep patterns on weekdays and weekends and its association with obesity in the medium- to long-term follow-up period in bariatric surgery patients are needed to complement these initial findings. Therefore, the purpose of this study was 1) to describe weekday and weekend sleep durations in individuals who are at least 3 years post-bariatric surgery and 2) to explore the relationship between sleep duration with BMI and body composition in these individuals.

Materials and Methods

Fifty-eight individuals who had previously undergone bariatric surgery (3 to 16 years prior to this study's assessments) were recruited by telephone. Only ambulatory participants aged 25–70 who did not use walking aids were included in this study. Nine participants had incomplete sleep logs; hence, 49 participants were included in the present analyses. This study was approved by the University Medical Ethics Review Board (A04-M35-11A). Written informed consent was obtained from all participants. No participants reported being diagnosed with sleep apnea or using sleep aids at the time of data collection.

During the in-laboratory assessment, participant height was measured to the nearest centimeter (Seca 216 stadiometer) and weight was assessed to the nearest tenth kilogram (Seca 635 bariatric scale) (Seca, Hamburg, Germany). Body mass index was calculated as body weight/height^2 (kg/m^2). Body composition, including fat mass and fat-free mass (kg), was assessed with a Dual-energy X-ray absorptiometry (DXA) scanner (GE health care, Chicago, USA). Lightweight clothing and no footwear were worn during body weight and body composition assessments.

For the in-laboratory assessment, a self-report sleep log was combined with an ActivPAL3 accelerometer (PAL Technologies Ltd., Glasgow, UK) and given to participants to wear for 7 consecutive days. This device can be used to identify participants' movements, including sitting/lying time. This device was placed in a latex sleeve and was attached to the participant's mid-thigh using a clear Tegaderm adhesive patch. Accelerometer data were extracted using ActivPAL software version 17.18.1. Since the ActivPAL accelerometer only captures movements (sitting/lying, standing, and walking/steps), the participants' sleep logs were used to confirm bed- and wake-times measured with the accelerometer based on the beginning of an extended period of non-movement (sedentary/lying) and the end of an extended period of non-movement (sedentary/lying time) coupled with the beginning of movement (steps), respectively.

Sleep timing midpoint (wake-time–½ of total sleep duration) on weekdays and weekend days was also calculated for each participant since this variable is a valid indicator of sleep chronotype [9].

Descriptive values were reported as means ± standard deviations for continuous variables and as counts and percentages for categorical variables. Descriptive data for sleep duration and sleep timing midpoint were reported as continuous and categorical variables. The following categories were used for sleep duration based on previous evidence of a U-shape association between sleep duration and obesity [3, 10]: < 7 h/day (short duration sleep), 7–9 h/day (recommended sleep duration), and > 9 h/day (long sleep duration). The groupings used to define sleep timing midpoint were as follows: ≤ 4 h00 vs. > 4 h00 given previous population-based evidence [9] identifying 4 h00 as the 50th percentile for sleep timing midpoint. Differences in descriptive sleep data between weekdays and weekend days were assessed using an analysis of variance test for continuous variables and a chi-square test for categorical variables. Linear regression models estimated multivariable-adjusted beta coefficients (β) and 95% confidence intervals (95% CIs) between sleep duration (hours/day) and sleep timing midpoint (clock time), as well as differences between weekday and weekend sleep duration and sleep timing midpoint (calculated as weekend–weekday sleep values) with in-lab measurements of BMI, fat mass, and fat free mass. Multivariable-adjusted models included the following covariates: age at the time of assessments, sex, pre-surgery BMI (reported by the surgeon), elapsed time since surgery, and steps/day as a proxy for physical activity participation. Sleep duration and delta sleep duration between weekdays and weekend days were also added as covariates to the sleep timing midpoint models.

Effect modification was first assessed by adding the interaction terms for weekday sleep duration and sleep timing midpoint by covariate (age, sex, pre-surgery BMI, elapsed time since surgery, and steps/day) to the multivariable-adjusted regression models. Stratified analyses were conducted if the interaction term reached statistical significance ($P < 0.05$). All statistical tests were performed using IBM's SPSS v25, and statistical significance was set at $P < 0.05$.

Results

Participant characteristics and descriptive data for sleep and obesity assessments at least 3 years post-surgery are presented in Table 1. The mean elapsed time since surgery in this sample was 9.5 ± 3.3 years, and the mean reduction in BMI from pre-surgery to the time of study assessments was − 18.0 ± 7.3 kg/m^2 (32.7 ± 11.6% weight loss). All participants had a BMI ≥ 30 kg/m^2 pre-surgery; however, one third of participants had a BMI < 30 kg/m^2 at the time of study assessments. Mean sleep durations on weekdays and weekend days were within recommended guidelines; however, sleep durations were significantly longer during weekend days vs. weekdays. Sleep timing midpoint was also significantly later during weekend days vs. weekdays, with a greater proportion of participants having a sleep timing midpoint > 4 h00 on weekend days compared with weekdays.

A significant positive association was noted between sleep duration on weekdays with fat mass in the unadjusted, but not the multivariable-adjusted models (Table 2). A significant positive association between delta weekend-weekday sleep timing midpoint with BMI was also noted in the multivariable-adjusted model only (Table 3). There was evidence of effect modification by elapsed time since surgery on the sleep duration-BMI association (P for interaction = 0.01). Stratified analyses revealed no significant differences in BMI related to sleep duration between participants with < 10 years since surgery ($n = 26$, β = 1.47, 95% CI = − 0.59, 3.53; $P = 0.15$) versus ≥ 10 years since surgery ($n = 23$, β = 0.05, 95% CI = − 1.08, 1.19; $P = 0.92$). No other evidence of effect modification was noted (results not shown).

Table 1. Participant characteristics and descriptive data for sleep and obesity assessments post-surgery

Participant characteristics		Mean ± SD	
Pre-surgery BMI (kg/m^2); mean ± SD		54.6 ± 12.2	
Age post-surgery* (years); mean ± SD		51.0 ± 9.1	
Elapsed time since surgery (years); mean ± SD		9.5 ± 3.3	
Steps/day on weekdays; mean ± SD		6470 ± 3200	
Steps/day on weekend days; mean ± SD		5926 ± 2737	
Sex			
Male; *n (%)*		14 (28.6%)	
Female; *n (%)*		35 (71.4%)	
Employment status			
Unemployed; *n (%)*		25 (51.0%)	
Employed; *n (%)*		24 (49.0%)	
Obesity assessments post-surgery*		Mean ± SD	
BMI (kg/m^2); mean ± *SD*		36.6 ± 9.8	
BMI category			
< 30 kg/m^2; *n (%)*		16 (32.7%)	
≥ 30 kg/m^2; *n (%)*		33 (67.3%)	
Fat mass (kg); mean ± SD		43.5 ± 12.8	
Fat free mass (kg); mean ± SD		53.1 ± 11.9	
Sleep assessments post-surgery*	Mean ± SD (weekdays)	Mean ± SD (weekend days)	*P* value**
Sleep duration (hours/day); mean ± SD	7.9 ± 1.6	8.5 ± 1.7	*0.01*
Sleep duration category			
< 7 h/day; *n (%)*	15 (30.6%)	4 (8.2%)	0.06
7–9 h/day; *n (%)*	27 (55.1%)	26 (53.1%)	0.64
> 9 h/day; *n (%)*	7 (14.3%)	19 (38.8%)	0.25
Sleep timing midpoint (clock time); mean ± SD	3 h14 ± 1 h12	3 h47 ± 1 h20	*0.001*
Sleep timing midpoint category			
≤ 4 h00; *n (%)*	38 (77.6%)	31 (63.3%)	*0.02*
> 4 h00; *n (%)*	11 (22.4%)	18 (36.7%)	*< 0.0001*

*Assessments took place ≥ 3 years following bariatric surgery

***P* values for the differences in descriptive sleep data between weekdays and weekend days. The *P* value is italicized if ≤ 0.05

BMI body mass index

Table 2. Strength of the associations between sleep duration and sleep timing midpoint during weekdays and weekend days with BMI, fat mass and fat free mass assessed post-bariatric surgery

Outcome: BMI (kg/m^2)	Unadjusted linear regression model results, β (95% CI); *P* value	Multivariable-adjusted* linear regression model results, β (95% CI); *P* value
Sleep duration during weekdays (hours/day)	0.47 (− 1.33, 2.27); 0.60	0.90 (− 0.19, 1.99); 0.10
Sleep duration during weekend days (hours/day)	0.44 (− 1.29, 2.17); 0.61	0.37 (− 0.67, 1.41); 0.48
Sleep timing midpoint during weekdays (hours/day past 12:00 AM)§	1.28 (− 1.08, 3.64); 0.28	0.27 (− 1.24, 1.77); 0.72
Sleep timing midpoint during weekend days (hours/day past 12:00 AM)§	0.82 (− 1.32, 3.00); 0.44	0.67 (− 0.67, 2.01); 0.32
Outcome: Fat mass (kg)	**Unadjusted linear regression model results, β (95% CI); *P* value**	**Multivariable-adjusted* linear regression model results, β (95% CI); *P* value**
Sleep duration during weekdays (hours/day)	*2.62* (*0.37*, *4.86*); *0.02*	1.82 (− 0.12, 3.77); 0.07
Sleep duration during weekend days (hours/day)	1.03 (− 1.22, 3.29); 0.36	0.53 (− 1.46, 2.52); 0.59
Sleep timing midpoint during weekdays (hours/day past 12:00 AM)§	2.25 (− 0.81, 5.32); 0.15	1.74 (− 0.90, 4.38); 0.19
Sleep timing midpoint during weekend days (hours/day past 12:00 AM)§	1.00 (− 1.81, 3.82); 0.48	1.79 (− 0.73, 4.32); 0.16
Outcome: Fat free mass	**Unadjusted linear regression model results, β (95% CI); *P* value**	**Multivariable-adjusted* linear regression model results, β (95% CI); *P* value**
Sleep duration during weekdays (hours/day)	− 1.09 (− 3.25, 1.09); 0.32	− 0.04 (− 1.29, 1.21); 0.95
Sleep duration during weekend days (hours/day)	− 0.37 (− 2.47, 1.73); 0.73	0.11 (− 1.05, 1.27); 0.85
Sleep timing midpoint during weekdays (hours/day past 12:00 AM)§	0.84 (− 2.05, 3.73); 0.56	− 0.28 (− 2.01, 1.45); 0.75
Sleep timing midpoint during weekend days (hours/day past 12:00 AM)§	0.09 (− 2.53, 2.71); 0.95	− 0.73 (− 2.22, 0.76); 0.33

*These results are adjusted for the following covariates: age, sex employment status, pre-surgery BMI, elapsed time since surgery, steps/day on weekdays/weekend days. Sleep duration on weekdays/weekend days was also added to the sleep timing midpoint models

The estimates and *P* values are italicized if ≤ 0.05

BMI body mass index

§A positive value indicates a later sleep timing midpoint

Table 3. Strength of the associations between differences in sleep duration and sleep timing midpoint between weekdays and weekend days with BMI, fat mass and fat free mass assessed post-bariatric surgery

Outcome: BMI (kg/m^2)	Unadjusted linear regression model results, β (95% CI); *P* value	Multivariable-adjusted* linear regression model results, β (95% CI); *P* value
Delta sleep duration (hours/day)**	0.01 (− 1.90, 1.92); 0.99	− 0.47 (− 1.64, 0.71); 0.43
Delta sleep timing midpoint (minutes/day)§	0.03 (− 0.01, 0.07); 0.18	*0.03* (*0.01*, *0.06*); *0.01*
Outcome: Fat mass (kg)	Unadjusted linear regression model results, β (95% CI); *P* value	Multivariable-adjusted* linear regression model results, β (95% CI); *P* value
Delta sleep duration (hours/day)**	− 1.67 (− 4.13, 0.79); 0.18	− 1.46 (− 3.66, 0.75); 0.19
Delta sleep timing midpoint (minutes/day)§	0.02 (− 0.04, 0.08); 0.52	0.04 (− 0.01, 0.09); 0.11
Outcome: Fat free mass	Unadjusted linear regression model results, β (95% CI); *P* value	Multivariable-adjusted* linear regression model results, β (95% CI); *P* value
Delta sleep duration (hours/day)**	0.77 (− 1.54, 3.08); 0.51	0.06 (− 1.25, 1.37); 0.92
Delta sleep timing midpoint (minutes/day)§	0.03 (− 0.02, 0.08); 0.26	0.01 (− 0.02, 0.04); 0.50

*These results are adjusted for the following covariates: age, sex employment status, pre-surgery BMI, elapsed time since surgery, delta steps/day (weekend steps/day–weekday steps/day). Delta sleep duration (weekend sleep duration–weekday sleep duration) was also added to the delta sleep timing midpoint models

The estimates and *P* values are italicized if ≤ 0.05

**Delta sleep duration was calculated as weekend sleep duration–weekday sleep duration. A positive value indicates greater sleep duration during weekend days vs. weekdays

BMI body mass index

§Delta sleep timing midpoint was calculated as weekend sleep timing midpoint–weekday sleep timing midpoint. A positive value indicates a delayed sleep timing midpoint

Conclusion

The majority of participants in our sample slept the recommended 7–9 h/night [10] and had a sleep timing midpoint ≤ 4 h00 on weekdays and weekend days. One study reported that the majority of patients (71%) slept < 7 h/day before surgery, but that only 34% of them reported sleeping < 7 h/day during the year following surgery [5]. Our results are comparable, but only for weekday sleep durations. We observed that few participants (8%) in our sample slept < 7 h/day during weekend days (versus 31% during weekdays), suggesting that “catch-up sleep” during the weekend may have occurred in some participants.

We did not observe statistically significant associations between changes in sleep duration from weekdays to weekend days with BMI and body composition in this sample, which does not corroborate previous findings [7]. However, a recent experimental study [11] reported similar weight gains and decreases in insulin sensitivity following 5 days of imposed sleep restriction coupled with 2 days of recovery sleep versus 7 days of sustained sleep restriction, suggesting that weekend sleep recovery was not sufficient to prevent weight gain and insulin dysregulation associated with sleep debt.

Differences between weekend and weekday sleep timing midpoint were positively associated with BMI, suggesting that having a later sleep timing midpoint during the weekend (vs. weekday) was associated with a higher BMI in this sample. Having a later sleep timing midpoint has been previously associated with a higher BMI [12] and an increased risk of insulin resistance [13]. Furthermore, having an evening chronotype has been associated with a higher pre-surgery BMI and greater weight regain post-surgery compared with having a morning chronotype [6].

The biologic mechanisms underlying sleep timing with obesity and metabolic health are not well understood [13]. However, it may be hypothesized that circadian disruptions may occur when the timing of waking behaviors (e.g., eating and physical activity participation) occur when the endogenous circadian environment facilitates sleeping. Indeed, an experimental study that imposed circadian misalignment by having participants eat and sleep ~ 12 h out of phase reported increases in postprandial glucose and insulin levels, in addition to decreases in leptin and sleep efficiency [14].

This study has several strengths, including the use of DXA for body composition assessment and using both objective and self-reported measurements of sleep duration. Moreover, our analyses focused on the medium-to-long-term post-surgery timeframe and changes in sleep patterns from weekdays to weekend days, which have been seldom discussed in the literature. Limitations include the relatively small sample size, which may have limited our effect modification analyses. The measurement of sleep at only one time point limits our ability to assess associations between longitudinal changes in sleep with weight outcomes. Lastly, ActivPAL is unable to detect awake-time while lying down, limiting our ability to assess sleep efficiency.

These results suggest that many of the participants in our sample achieve recommended sleep durations when assessed medium- to long-term post-surgery. Furthermore, having an earlier sleep timing midpoint during the weekend (vs. weekday) may be associated with a lower BMI. Further research is needed to confirm our results and assess sleep quality in this population.

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Contributions

Ryan E. R. Reid and Jessica McNeil contributed equally to this work.

RERR contributed to the conception and design, data acquisition, data processing, and manuscript preparation. JM contributed to the conception of the manuscript research questions, statistical analysis, and manuscript preparation. GR and TGRR contributed to data processing. TEC contributed to data acquisition. REA contributed to the conception and design and provided expert knowledge on the topic, as well as gave approval for the final version of the manuscript to be published.

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