Accepted manuscript

Associations of Subjective Sleep patterns and Social Jet Lag with Weight Loss and Dietary Intake in Bariatric Surgery Patients: A One-Year Follow-Up Study

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Short title: Sleep and Social Jet Lag Associations with Bariatric Surgery Outcomes**.**

This peer-reviewed article has been accepted for publication but not yet copyedited or typeset, and so may be subject to change during the production process. The article is considered published and may be cited using its DOI
10.1017/S0007114525000352
The British Journal of Nutrition is published by Cambridge University Press on behalf of The Nutrition Society

ABSTRACT

Current literature has shown that poor sleep patterns and social jet lag (SJL) are associated with obesity and weight gain. However, this area remains underexplored in patients who have undergone bariatric surgery. We hypothesized that higher levels of SJL and poorer sleep patterns are associated with lower weight loss, greater caloric/nutrient intake, and poorer metabolic outcomes following surgery. This study aims to assess the associations of SJL and subjective sleep with anthropometric, metabolic, and dietary parameters during the first year following bariatric surgery. SJL, sleep quality, and daytime sleepiness were measured in 122 patients (77% women; median age 33.0 [28.0 – 41.7]). SJL was estimated by the absolute difference between the midpoint of sleep and wake times on weekdays and weekends. Daytime sleepiness and sleep quality were evaluated using the Epworth Sleepiness Scale (Epworth) and the Pittsburgh Sleep Quality Index (PSQI), respectively. Multiple linear regressions were employed to evaluate the associations of SJL, sleep quality, and daytime sleepiness with weight loss, metabolic, and dietary outcomes. Independent variables were negatively associated with weight loss after surgery: SJL at 6 months and one year; sleep quality at all time points; and sleepiness after one year ($p < 0.05$). SJL was positively associated with calorie and protein intake after one-year post-surgery ($p < 0.05$). Our results show that higher SJL and poorer sleep patterns are associated with worse anthropometric, metabolic, and dietary outcomes after bariatric surgery. These findings reinforce the importance of addressing variables related to biological rhythms to optimize post-surgical outcomes in bariatric patients.

Key words: Bariatric Surgery, Social jetlag, Weight loss, Sleep patterns

https://doi.org/10.1017/S0007114525000352 Published online by Cambridge University Press

Introduction

Circadian rhythms are regulated by the central clock located in the suprachiasmatic nucleus [1]. The central clock interacts with peripheral clocks in various organs, including liver [2], intestines [3], pancreas [4], adipose tissue [5], and cardiovascular system [6]. Together, they constitute the circadian timing system, which responds to external cues such as light and lifestyle factors like physical activity and meal timing. This synchronization between the central and peripheral clocks influences the sleep-wake cycle, hormone release, and organ activity at distinct times of the day [7].

Circadian misalignment occurs when there is a failure in the synchronization between endogenous factors (central and peripheral clocks) and environmental signals, leading to alterations in the physiological circadian rhythm and the sleep-wake pattern [1]. Social jet lag (SJL) addresses the difference between sleep midpoint during weekdays and weekends and has been a widely used measure of circadian misalignment [8, 9]. This measure has been associated with unhealthy habits, such as poor dietary patterns [10, 11], metabolic diseases [12,13,14], and poorer lifestyle habits [15,16,17]. Similar to SJL, studies also show that a worse sleep pattern is associated with greater energy consumption, leading to weight gain - thus indicating a bidirectional relationship between sleep and obesity [18].

Bariatric surgery is considered the most effective treatment for obesity, and a multidisciplinary team is very important to manage the weight loss [19]. Furthermore, bariatric surgery has shown that an improvement in sleep patterns is associated with better surgical outcomes [20]. In a previous study with bariatric patients, we demonstrated that the group with greater SJL had lower weight loss, worse metabolic outcomes, and poorer dietary pattern after six months of bariatric surgery compared to the group with less SJL [21]. However, there is currently limited evidence regarding the influence of chronobiological issues - such as SJL and poor sleep patterns - on the weight loss process in patients undergoing bariatric surgery during first-year post-surgery. Given that bariatric surgery is widely performed worldwide and is regarded as a promising treatment for obesity [19], albeit with associated challenges such as weight regain, understanding the variables that may impact patient outcomes is essential for optimizing long-term clinical results.

Based on the points presented, it is plausible that improved sleep patterns and reduced circadian misalignment could be associated with more favorable surgical outcomes. This study aims to examine the relationship between circadian misalignment and sleep patterns and the progression of anthropometric, metabolic, and dietary parameters during the first year following bariatric surgery. We hypothesized that individuals experiencing higher levels of social jet lag, poorer sleep quality, and increased daytime sleepiness during the first year after bariatric surgery would exhibit lower weight loss, higher intake of calories and macronutrients, as well as worse metabolic outcomes.

Methods

Participants

This study received approval from the Research Ethics Committee of the Federal University of Uberlândia (66023717.8.0000.5152). The clinical trials number is NCT03485352 (URL: https://clinicaltrials.gov/ct2/show/NCT03485352). All participants were informed about the study objectives and provided signed informed consent. Further details regarding the methodology can be found in a previous study [21]. This prospective cohort study included 122 patients (77% women, median age 33 years) undergoing bariatric surgery (Roux-en-Y gastric bypass (79.5%) or vertical gastrectomy (20.5%)) at a private clinic in Uberlândia, Minas Gerais, between June 2017 and October 2018. Inclusion criteria were patients in the preoperative period of bariatric surgery, aged 18 to 59 years, with a body mass index (BMI) ≥ 35 kg/m² associated with two comorbidities or BMI > 40 kg/m² regardless of comorbidities [19]. The exclusion criterion was the performance of revisional surgery.

All participants were interviewed in person for all study evaluations on the day of their routine clinic appointment by a trained nutritionist from our research group.

Social Jet Lag (SJL)

SJL was calculated as the absolute difference between the midpoint of sleep on free days/weekends (mid-sleep on free days - MSF) and the midpoint of sleep on workdays/weekdays (mid-sleep on workdays - MSW) [8,9]. This evaluation was conducted in person at four assessment points (baseline, 3 months, 6 months, and 1 year post-surgery) by a team experienced in sleep pattern research, using the following questions: “What time do you usually go to sleep during the week?”, “How long (min) do you stay up in bed before sleep onset (after turning off the lights) during the week?”, “What time do you usually wake up during the week?”, “What time do you usually go to sleep on weekends?”, “How long (minutes) do you stay up in bed before sleep onset (after turning off the lights) on weekends?” and “What time do you usually wake up on weekends?”.

https://doi.org/10.1017/S0007114525000352 Published online by Cambridge University Press

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Sleep Patterns

Sleep patterns were assessed by evaluating daytime sleepiness and sleep quality at four time points (baseline, 3 months, 6 months, and 1 year) during in-person appointments on the day of their routine clinic visit. Sleep quality was evaluated using the Pittsburgh Sleep Quality Index (PSQI) questionnaire, adapted for Portuguese [22]. This questionnaire, which has been used in other Brazilian studies [22,23], comprises 19 questions regarding sleep quality and disturbances over the past month, with scores above 5 indicating poor sleep quality. The Epworth Sleepiness Scale questionnaire assessed daytime sleepiness, with scores above 9 indicating high daytime sleepiness [24]. All questionnaires were administered at four assessment time points: preoperative, 3 months, 6 months, and one year after bariatric surgery.

Anthropometric Variables

Weight and height were measured using standardized methods at all four follow-up appointments [25]. Body mass index (BMI) was calculated as kg/m². In accordance with WHO guidelines (2000) for adults, a BMI of ≥ 25 kg/m² was classified as overweight, and > 29.9 kg/m² as obesity [25].

Metabolic Parameters

Fasting levels of glucose, insulin, total cholesterol (TC), high-density lipoprotein (HDL), low-density lipoprotein (LDL), very-low-density lipoprotein (VLDL), and triglycerides (TG), along with the HOMA-IR estimate, were established preoperatively, at 6 months, and one-year post-surgery. Blood samples were collected at a laboratory with rigorous adherence to high-quality standards, affiliated with the patient's insurance, after a 12-hour fast. Blood samples were collected and processed on-site by a nurse under optimal conditions, adhering to widely established and standardized protocols. All analyses were conducted using methodologies have been validated in the literature [26, 27].

Dietary Intake

Dietary intake was assessed by administering two 24-hour dietary recalls (24HRs) at each of the four assessment time points. All recalls were conducted by a trained nutritionist using the Multiple Pass Method [28]. At each time point, two recalls were completed: one during a weekday and the other on a weekend. The first 24-hour dietary recall was conducted in person on the day of the routine clinic visit, while the second recall was conducted via telephone, ensuring the reliability of the method [28]. The Multiple Pass Method stipulates that, at the beginning of the assessment, a general listing of all foods consumed in the past 24 hours is made, followed by additional details about each item, including preparation, ingredients, and any potentially forgotten foods, as well as the time and location of meals. Subsequently, the quantities consumed are estimated, and the list is reviewed to ensure accuracy. A final check confirms that all foods and beverages have been included. Macronutrients, calories, and fiber were evaluated using DietPro Clínico 5.0 software. A total of eight 24HRs were collected, and the averages for weekdays and weekends were calculated for each of the four assessment time points.

Statistical Analysis

The Kolmogorov-Smirnov test was used to analyze the normality of the data. Student's t-test was employed for variables with a normal distribution, while the Mann-Whitney test was used for non-normally distributed variables. The Chi-square test was applied to analyze proportion variables.

Multiple linear regressions were used to assess the association between SJL exposure mean, sleep quality, daytime sleepiness level, and weight loss, metabolic outcomes, and dietary intake at 3 months, 6 months, and one year after surgery.

Logistic regression was used to evaluate the likelihood of weight loss one year after surgery in groups more or less exposed to SJL, higher levels of daytime sleepiness, and poorer sleep quality with one year. The mean for each exposure variable was estimated across the four assessment periods, and the sample was subsequently divided into two categorical groups according to the median of each parameter: more exposed (mean > median) and less exposed (mean < median).

Analyses of linear regression with metabolic outcomes were adjusted for potential confounders that, according to the literature, could influence the outcomes, including surgical technique, shift work, gender, age, family income, sleep medication use, diabetes diagnosis, exercise practice, BMI, and daily caloric intake. Analyses of linear and logistic regression with anthropometric and dietary intake-related outcomes were adjusted for all variables mentioned above, except for BMI and caloric intake, respectively.

To address missing data, we used mean imputation, replacing missing values with the mean of observed values for each variable. This approach assumes that the data are Missing Completely at Random (MCAR) and was chosen to maintain the dataset's overall structure

https://doi.org/10.1017/S0007114525000352 Published online by Cambridge University Press

and comparability across analyses. By imputing missing values, we ensured that the analyses remained robust while minimizing potential biases introduced by data loss.

Statistical analysis was performed using SPSS version 20 (SPSS, Inc., Chicago, IL, USA), and $p < 0.05$ was considered statistically significant.

Results

Table 1 provides information on sociodemographic characteristics, surgical techniques, physical activity, sleep parameters (Epworth score, PSQI score and sleep duration) and SJL at baseline, and at 3, 6 months, and 1 year of treatment. We observed that the majority of participants were female (77%), underwent Roux-en-Y gastric bypass surgery (79.5%), and were married (66.4%). Both sleep quality and daytime sleepiness significantly improved over the follow-up period after one year of bariatric surgery ($p < 0.001$).

Table 1

Table 2 presents the results of the linear regression analysis assessing the association between the mean exposure to SJL, sleep quality, and daytime sleepiness with weight loss in kilograms (kg), percentage of weight loss, and reduction in BMI at 3 months, 6 months, and one year after bariatric surgery. We observed negative associations between SJL and weight loss (kg) (β = -0.14, p = 0.03; β = -0.24, p = 0.03), percentage of weight loss (β = -0.21, p = 0.02; β = -0.29, p= 0.03), and reduction in BMI (β = -0.18, p = 0.02; β = -0.25, p = 0.03) at 6 months and one year after bariatric surgery, respectively. Negative associations were also found between sleep quality and weight loss in kilograms (kg) (β = -0.22, p = 0.001; β = -0.33, $p < 0.001$; β = -0.33, p = 0.002), percentage of weight loss (β = -0.24, p = 0.005; β = -0.37, $p < 0.001$; β = -0.37, p = 0.004), and reduction in BMI (β = -0.26, p = 0.001; β = -0.34, $p < 0.001$; β = -0.42, p = 0.001) at 3 months, 6 months, and one year after bariatric surgery, respectively. Additionally, a negative association was found between the average daytime sleepiness level and weight loss in kilograms (kg) (β = -0.28, p = 0.009), percentage of weight loss (β = -0.37, p= 0.002), and reduction in BMI (β = -0.35, p = 0.002) one year after bariatric surgery.

Table 2

Table 3 shows the results of the logistic regression analysis, evaluating the association of SJL exposure, sleep quality, and daytime sleepiness with weight loss one year after bariatric surgery. The group with greater exposure to SJL (p = 0.038; Odds Ratio = 3.76 [1.07–13.18]) and those with higher levels of daytime sleepiness (p = 0.04; Odds Ratio = 3.13

[1.01–9.65]) had an increased risk of experiencing less weight loss during the first year following bariatric surgery. No significant results were found for sleep quality ($p = 0.10$).

Table 3

Table 4 presents the results of the linear regression analysis assessing the association between food consumption and mean exposure to SJL, daytime sleepiness, sleep quality, at 3 months, 6 months, and one year after surgery. The results showed a positive association between the average SJL and calorie intake ($\beta = 0.35$, $p = 0.01$) and protein intake ($\beta = 0.30$, $p = 0.03$) one year after bariatric surgery. No significant results were found for the other analyzed variables.

Table 4

Supplementary Table 1 shows the results of the linear regression analysis on the delta difference of metabolic parameters and the mean exposure to SJL, PSQI score, and daytime sleepiness at one year after surgery. The results showed a negative association between the reduction in cholesterol ($\beta = -0.55$, $p = 0.002$) and triglycerides ($\beta = -0.44$, $p = 0.02$) and the mean of SJL. Negative associations were found between the reduction in insulin ($\beta = -0.47$, $p = 0.02$) and the mean PSQI score (a higher PSQI score show worse the sleep quality), as well as between the reduction in insulin ($\beta = -0.57$, $p = 0.01$), low-density cholesterol ($\beta = 0.45$, $p = 0.006$), and HOMA-IR ($\beta = -0.53$, $p = 0.04$) and the mean of daytime sleepiness (the higher score show greater the daytime sleepiness).

Supplementary Table 1

Supplementary Table 2 shows the results of linear regression analysis assessing the association between SJL exposure with the mean of sleep quality, daytime sleepiness, and time of sleep at each moment (3 months, 6 months, and 1 year). The results show a positive association of SJL with daytime sleepiness at 1 year after surgery and a negative association of SJL with sleep duration at 3 and 6 months after surgery.

Supplementary Table 2

We used G*Power to determine the sample size for the multiple linear regression analysis. The test was conducted post hoc. The parameters used for the calculation were as follows: Effect size (f^2): 0.22, based on previous findings [21]; alpha level (α): 0.05; sample size: 60; number of predictors: 1. The result showed a power ($1-\beta$) of 0.95.

Figure 1 shows the flowchart detailing the evolution of the number of patients during the 1-year follow-up study. A study cohort of 138 eligible patients was identified. However, 11 individuals opted not to participate, and 5 were scheduled for revisional surgery, meeting the exclusion criteria. This resulted in 122 participants undergoing baseline assessments. Subsequently, at the 3-month evaluation, 5 participants were missing follow-up compared to the baseline number, totaling 117 participants in this assessment. By the 6-month assessment, 9 participants were missing follow-up and 5 participants missed the 3-month assessment but attended the 6-month assessment, bringing the total to 113 participants in this assessment. Finally, at the one-year evaluation, 62 participants were missing follow-up, resulting in a total of 60 participants for this assessment. Participants who missed the 3-month, 6-month, and 1-year routine consultations at the clinic did not complete the evaluations during these periods.

Figure 1

Figure 2 shows the effects of time on PSQI score, sleep duration, SJL and Epworth score during first year after bariatric surgery. The results show a significant effect of time on PSQI ($p < 0.001$) and Epworth ($p < 0.001$) score during the first year following bariatric surgery.

Figure 2

The regression analyses conducted with the imputed data demonstrated that the results were consistent and reproducible with those obtained from the observed data (data not shown).

Discussion

This study assessed the impact of sleep patterns and social jet lag (SJL) on anthropometric, metabolic, and dietary outcomes during the first year following bariatric surgery. Our hypothesis was confirmed, as linear regression results demonstrated that greater exposure to SJL was associated with smaller weight loss and less reduction in BMI at both 6 months and 1-year post-surgery. Additionally, lower sleep quality was linked to decreased weight loss in kilograms and a reduction in the percentage of weight loss and BMI at 3, 6, and 12 months post-surgery. Elevated levels of daytime sleepiness were associated with reduced weight loss in kilograms, percentage of weight loss, and BMI reduction one-year post-surgery. In terms of dietary consumption, we observed a positive association between SJL and calorie as well as protein intake after one year of bariatric surgery.

Circadian misalignment appears to impact various metabolic processes, including alterations in gut microbiota [29], hunger and satiety hormones [30, 31], and suppression of melatonin secretion [32]. Existing literature demonstrates the negative effects of SJL on obesity across different populations [33, 34, 35], as well as on obesity-related chronic diseases such as type II diabetes mellitus [36] and systemic arterial hypertension [13]. Furthermore, it has been associated with certain types of cancer, including colorectal [37], hepatic [38], and thyroid cancer [39]. A systematic review with meta-analysis of 68 studies confirmed that SJL is linked to a higher risk of increased BMI and waist circumference [13]. However, the relationship between obesity and SJL in individuals who have undergone bariatric surgery remains poorly understood. Our previous study [21] demonstrated a negative association between SJL and anthropometric, metabolic, and dietary outcomes six months after bariatric surgery. In this study, we extend those findings over a longer follow-up period, revealing that individuals more exposed to SJL had less weight loss compared to those with lower exposure to SJL during the first-year post-surgery. This difference may become more evident and could be associated with obesity recurrence, a phenomenon frequently observed among individuals undergoing bariatric surgery [40].

Our study establishes an association between SJL and sleep patterns, illustrating the intricate interconnection of these impairments [41]. Similar to SJL, impaired sleep patterns are also linked to unfavorable outcomes in bariatric surgery. We observed a negative statistical impact of sleep quality and daytime sleepiness on weight loss in bariatric patients during the first-year post-surgery. Importantly, sleep duration plays a pivotal role in evaluating sleep quality and has been identified as a crucial factor influencing body weight [42]. Sleep restriction is associated with disruptions in the neuroendocrine mechanism that control appetite, leading to increased ghrelin levels and decreased leptin levels, thereby impacting energy consumption and, subsequently, body weight gain [43, 44]. A small study with 14 participants who underwent bariatric surgery emphasized the significance of sleep patterns in long-term weight loss maintenance at the 6 and 9-year post-surgery marks [45]. This study revealed an inverse relationship between sleep duration and BMI at the 6-year follow-up, implying that shorter sleep was associated with greater weight regain post-bariatric surgery. Inadequate sleep not only elevates the risk of obesity development but also influences the outcomes of weight loss interventions [46]. Therefore, it is crucial to assess both the quantity and quality of sleep, emphasizing sleep hygiene practices to optimize positive outcomes during the weight loss process in patients undergoing bariatric surgery [47, 48].

Our results indicate a negative association between SJL and both calorie and protein intake throughout the first-year post-bariatric surgery (Table 4). Consistent with our findings, previous studies in the literature involving other populations have demonstrated a negative impact of circadian misalignment on dietary patterns [10, 49, 35]. In our previous study with 792 individuals, a higher SJL was associated with increased intake of total calories, protein, total fat, saturated fat, cholesterol, and servings of meat, eggs, and sweets compared to those with SJL of up to 1 hour [11]. Individuals with SJL are more likely to experience sleep deprivation, particularly during the week, which may result in hormonal alterations related to hunger and satiety, leading to increased caloric intake and body weight gain. Several studies have also associated sleep deprivation with poorer dietary patterns [50, 51, 52]. These findings highlight the importance of assessing sleep patterns during the nutritional monitoring of bariatric patients, particularly concerning the quantity and quality of food intake, as well as meal timing.

Based on all that has been discussed, it is possible to consider that the future of clinical practice for patients who have undergone bariatric surgery may include regular screening for sleep problems and the implementation of sleep hygiene measures. To minimize circadian misalignment and its significant negative impact, appropriate time-related interventions - such as optimizing exposure to the light-dark cycle and aligning meal times - should be tested in the nutritional and clinical management of these patients. This proactive approach may help mitigate the effects of these factors on eating habits and overall health, ultimately enhancing the efficacy of bariatric treatments and supporting long-term success.

Concerning metabolic data (Supplementary Table 1), our study revealed that greater SJL was associated with lower reduction in cholesterol and triglyceride levels during the first-year post-bariatric surgery. Additionally, higher Daytime sleepiness was associated with lower reduction in insulin, low-density lipoprotein, HOMA-IR, while poor sleep quality was associated with lower reduction of insulin one year after surgery. Previous studies in the general population have also shown this negative effect of SJL on serum cholesterol levels [11,14] and triglycerides, along with alterations in glycemic metabolism such as insulin, fasting glucose [53], and glycated hemoglobin [13]. A recent study demonstrated a correlation between sleep quality and glycated hemoglobin as well as HOMA-IR [54], while another associated daytime sleepiness with hypertriglyceridemia and low high-density lipoprotein cholesterol [55]. Our findings highlight the clinical significance of addressing social jet lag and sleep patterns in bariatric patients, as these factors negatively impact metabolic outcomes. The observed associations align with previous research linking sleep patterns and circadian misalignment to metabolic disturbances, emphasizing the need for comprehensive management strategies that incorporate sleep quality improvements to optimize long-term metabolic health post-surgery. The literature on the influence of sleep patterns on metabolic outcomes in bariatric patients is still limited, highlighting the need for further research to better understand these findings and their potential association with weight regain in this population.

Despite the valuable insights gained from this study, it is essential to acknowledge its limitations. The use of questionnaires that depend on participants' memory and subjective reporting introduces potential bias. Additionally, the small sample size, which only included patients undergoing two surgical techniques (bypass and vertical gastrectomy) in a private bariatric surgery service, limits the generalizability to patients undergoing other procedures at public health institutions. Regarding sleep evaluation, the absence of objective parameters such as polysomnography and actigraphy could impact the accuracy of sleep pattern measurements as sleep latency and the exact sleep time and our interpretation of results related to sleep quality and daytime sleepiness. Nevertheless, we employed validated questionnaires widely used in studies with similar objectives and methodologies.

Additionally, the loss to follow-up of 60 patients represents a significant factor that may have influenced the results, potentially introducing both selection bias and attrition bias. Despite the efforts made to reach these individuals, this loss underscores the considerable challenge of maintaining continuity in follow-up within this population, a challenge that may also arise in clinical practice. To address this limitation, we performed sensitivity analyses using imputed data for the missing cases, which confirmed that the results remained robust and consistent. It is also essential to highlight the strengths of our study. This one-year follow-up research focuses on patients undergoing the post-bariatric surgery process, evaluating sleep and chrononutrition patterns - factors that have been relatively understudied in this context. By exploring these chronobiological elements, our study aims to shed light on their potential impact on treatment outcomes for obesity. If these findings are corroborated by future research, they could serve as crucial components in optimizing obesity treatment strategies.

https://doi.org/10.1017/S0007114525000352 Published online by Cambridge University Press

https://doi.org/10.1017/S0007114525000352 Published online by Cambridge University Press

Conclusion

Our study highlights the negative associations of SJL, daytime sleepiness, and poorer sleep quality on weight loss during the first year following bariatric surgery. Additionally, SJL was linked to higher calorie and protein intake. Longer-term studies utilizing objective sleep data are needed to provide a more comprehensive understanding of these outcomes in bariatric patients.

Acknowledgements

We would like to thank all the patients and the LEV Clinic who participated in this research. We also thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq; CAC is CNPq fellow: #308466/2023-3).

Financial support

This research didn´t receive any specific grant from any funding agency, commercial or non-profit sectors. All tests used in the research were already part of the patients' routine clinic assessments as requested by the medical doctor at baseline, 6 months, and 1 year after surgery.

Conflict of Interest

Aline Cunha Carvalho (ACC) works at LEV Clinic, is a PhD student, and is part of the Chrononutrition Research Group at the Federal University of Uberlândia. She does not declare any conflicts of interest.

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Author contributions

ACC participated in the planning, data collect, interpretation of results, performed the statistical analysis and writing of the manuscript

LPM participated in the interpretation of results and writing of the manuscript.

LAM participated in the interpretation of results and writing of the manuscript.

JAG participated in the interpretation of results and writing of the manuscript.

ACT participated in the interpretation of results and writing of the manuscript.

CTCA participated in performed of data collect, interpretation of results and writing of the manuscript.

MCM participated in the interpretation of results and writing of the manuscript.

CAC participated in the planning, interpretation of results, support on the statistical analysis and writing of the manuscript.

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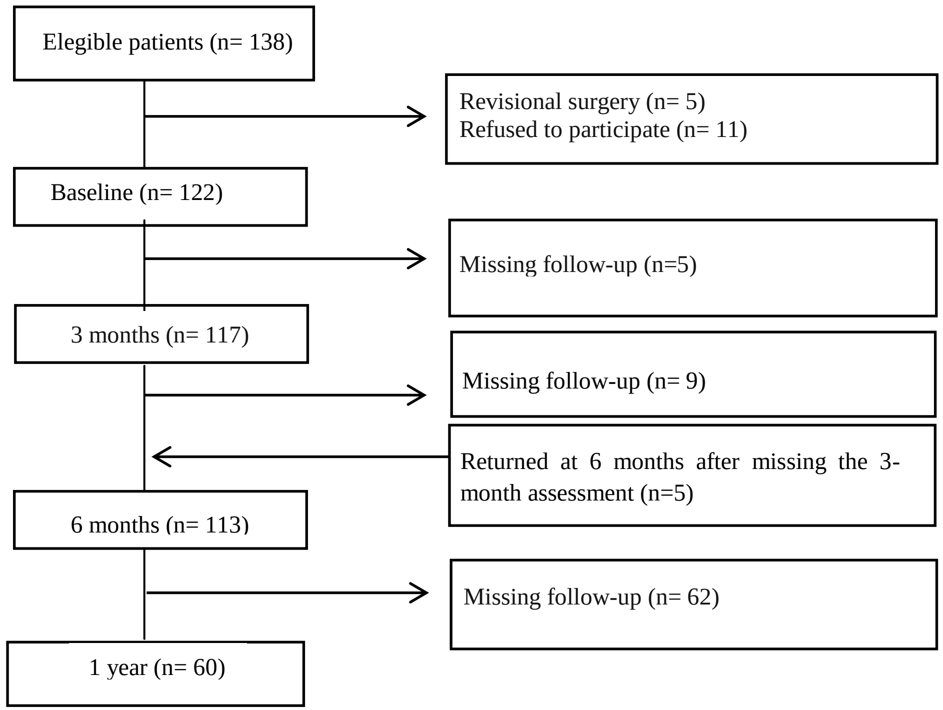

Figure 1. Flowchart of Participants in Baseline, 3-Month, 6-Month, and 1-Year Evaluations after Bariatric Surgery.

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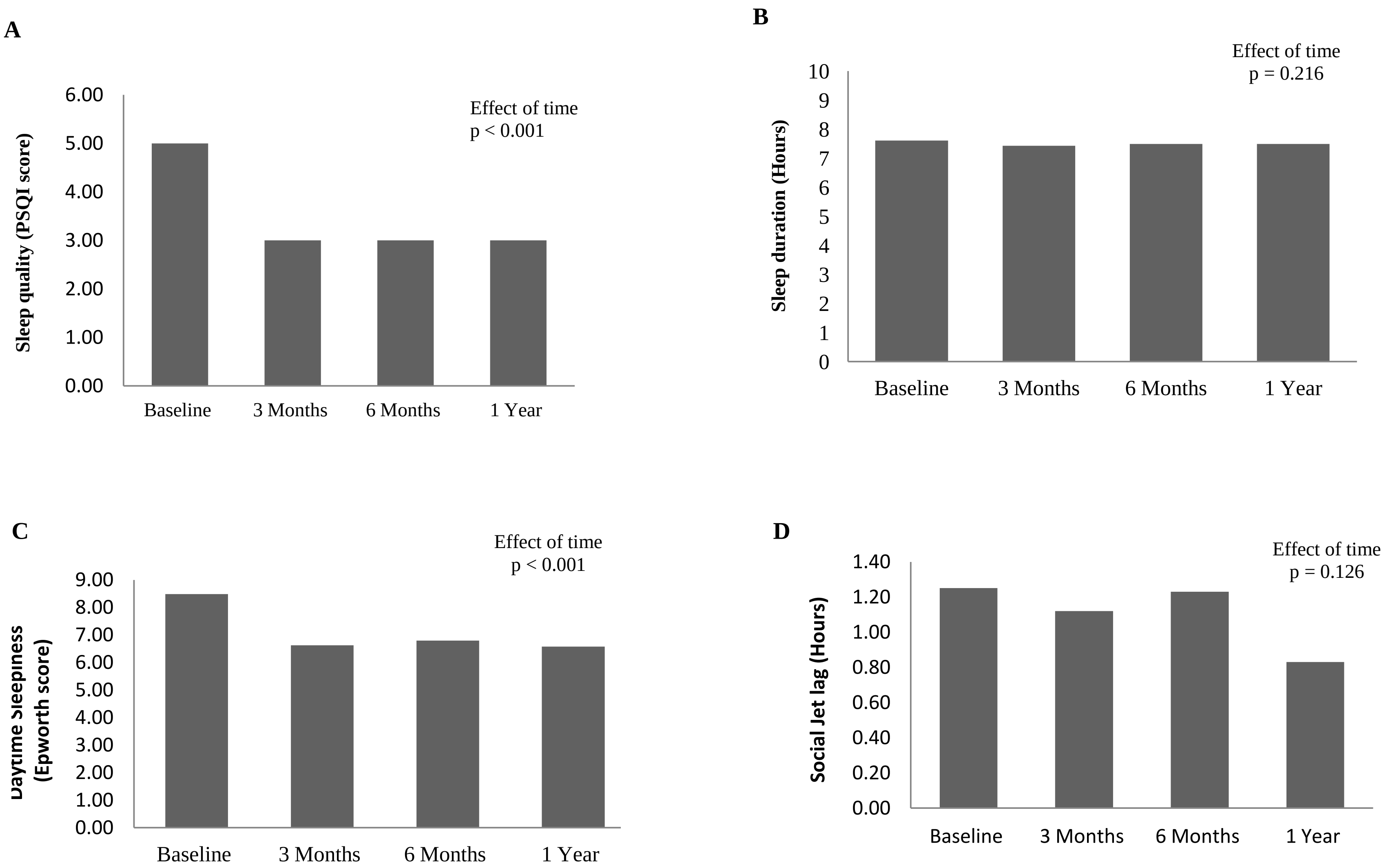

Figure 2. Effects of time on PSQI score (A), sleep duration (B), Epworth score (C) and SJL (D) during the first year of bariatric surgery.

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Table 1. Sociodemographic characteristicals, surgical techniques, physical activity, sleep parameters and chronotype in 1-year follow-up.

Variables	All (n= 122)	Mean or % or Median	SD or Interval interquatil
Gender			
Female (%)	94	77.0	
Male (%)	28	23.0	
Age (Years)	122	33.0	[28.0 – 41.7]
Surgical Technique			
Roux-en-Y gastric bypass (%)	97	79.5	
Sleeve gastrectomy (%)	25	20.5	
Family Income			
3 - 6 minimum wage (%)	20	16.3	
6 - 9 minimum wage (%)	38	31.1	
Above 10 minimum wage (%)	31	25.4	
Education			
Elementary school (%)	5	8.3	
High school (%)	26	43.3	
University degree (%)	21	35.0	
Post-graduation (%)	8	13.3	
Marital status			
Married (%)	81	66.4	
Single (%)	40	32.8	
Physical activity (Yes)			
Baseline (%)	34	27.8	
3 months (%)	104	88.8	
6 months (%)	84	73.6	
1 year (%)	44	73.3	
Sleep quality (PSQI score)			
Baseline [ ]	122	5.0	[1.0 – 14.0]
3 months [ ]	117	3.0	[0.0 – 9.0]
6 months [ ]	113	3.0	[0.0 – 10.0]
1 year [ ]	60	3.0	[0.0 – 13.0]
Mean Daytime Sleepiness (Epworth score)			
Baseline (SD)	122	8.48	4.56
3 months (SD)	117	6.62	3.96
6 months (SD)	113	6.79	4.03
1 year (SD)	60	6.58	4.63
Mean Sleep Duration (Hours)			
Baseline (SD)	122	7.61	1.07
3 months (SD)	117	7.43	1.10
6 months (SD)	113	7.49	1.13
1 year (SD)	60	7.49	1.30
Social Jet lag (Hours)			
Baseline [ ]	122	1.25	[0.0 – 6.41]
3 months [ ]	117	1.12	[0.0 – 5.87]
6 months [ ]	113	1.23	[0.0 – 6.25]
1 year [ ]	60	0.83	[0.0 – 6.0]

Note: Values are presented as mean and standard deviation for normally distributed data or as median [interquartile range] for non-normally distributed data or as percentage. Participants in each evaluation moments: Baseline (n= 122), 3 months (n= 117), 6 months (n= 113) and 1 year (n= 60).

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Table 2 Associations between changes in anthropometric parameters and mean exposure to social jet lag, sleep quality, and daytime sleepiness at 3 months (n = 117), 6 months (n = 113), and 1-year follow-up (n = 60).

	Variables	Coefficient (β)	P value	R^2 adjusted
	Social jet lag			
3 months	Total weight loss (Kg)	-0.11	0.07	0.53
	Total weight loss (%)	-0.15	0.07	0.18
	BMI (Kg/m²)	-0.13	0.07	0.37
6 months	Total weight loss (Kg)	-0.14	**0.03**	0.51
	Total weight loss (%)	-0.21	**0.02**	0.16
	BMI (Kg/m²)	-0.18	**0.02**	0.35
1 year	Total weight loss (Kg)	-0.24	**0.03**	0.33
	Total weight loss (%)	-0.29	**0.03**	0.14
	BMI (Kg/m²)	-0.25	**0.03**	0.24
	Sleep quality (PSQI Score)			
3 months	Total weight loss (Kg)	-0.22	**0.001**	0.56
	Total weight loss (%)	-0.24	**0.005**	0.21
	BMI (Kg/m²)	-0.26	**0.001**	0.39
6 months	Total weight loss (Kg)	-0.33	**< 0.001**	0.58
	Total weight loss (%)	-0.37	**< 0.001**	0.22
	BMI (Kg/m²)	-0.34	**< 0.001**	0.41
1 year	Total weight loss (Kg)	-0.33	**0.002**	0.37
	Total weight loss (%)	-0.37	**0.004**	0.17
	BMI (Kg/m²)	-0.42	**0.001**	0.33
	Daytime sleepiness (Epworth score)			
3 months	Total weight loss (Kg)	-0.02	0.70	0.52
	Total weight loss (%)	0.03	0.67	0.15
	BMI (Kg/m²)	-0.03	0.62	0.34
6 months	Total weight loss (Kg)	0.004	0.55	0.47
	Total weight loss (%)	0.10	0.25	0.09
	BMI (Kg/m²)	0.04	0.61	0.30
1 year	Total weight loss (Kg)	-0.28	**0.009**	0.34
	Total weight loss (%)	-0.37	**0.002**	0.20
	BMI (Kg/m²)	-0.35	**0.002**	0.30

Note: Mean of social jet lag, sleep quality and daytime sleepiness were evaluated during three moments of evaluation each variable (3 and 6 months and one year). Linear regression was adjusted for sex, age, family income, type II diabetes, surgical technique, shift work, physical activity and energy intake and $p < 0.05$ was considered significant. Participants in each evaluation moments: Baseline (n= 122), 3 months (n= 117), 6 months (n= 113) and 1 year (n= 60).

Table 3. Odds ratio (OR) evaluating the association for weight loss below the median after 1 year based on exposure to social jet lag, daytime sleepiness, and sleep quality (less versus more exposed; below or above the group median).

Sleep patterns variables (n=60)	**Odds Ratio [CI 95%]**	**P**
Social jetlag	3.76 [1.07 – 13.18]	**0.03**
Sleep quality (PSQI score)	2.52 [0.81 – 7.78]	0.10
Daytime Sleepiness (Epworth score)	3.13 [1.01 – 9.65]	**0.04**

Note: Values was calculated by logistic regression related median of weight loss percentage after 1 year (Median 34.6 %) and presented as odds ratio for weight loss according mean of each variable (SJL, PSQI and EPWORTH score) with 1 year.
We performed two categorical groups according to the mean of each parameter: more exposed (mean > median) and less exposed (mean < median).
$P < 0.05$ was considered significant.
Logistic regression analyses were adjusted for gender, age, surgical technique, physical activity, shift work, and energy intake.

Table 4. Association between food consumption and mean of exposure social jet lag, daytime sleepiness and sleep quality after 3 months (n= 117), 6 months (n= 113) and 1-year (n= 60) follow-up.

Variables	Social jet lag (Hours)		Daytime sleepiness (Epworth score)		Sleep quality (PSQI score)	
3 months (n= 117)	**Coefficient (β)**	**P value**	**Coefficient (β)**	**P value**	**Coefficient (β)**	**P value**
Calories (Kcal/day)	-0.02	0.80	- 0.05	0.52	0.05	0.56
Proteins (g/day)	-0.09	0.31	- 0.12	0.17	0.005	0.95
Carbohydrate (g/day)	0.15	0.08	0.17	0.05	0.08	0.38
Total fat (g/day)	-0.07	0.42	-0.10	0.25	0.01	0.84
Monounsaturated fat (g/day)	0.13	0.16	0.102	0.28	0.04	0.68
Polyunsaturated fat (g/day)	-0.09	0.32	-0.14	0.10	-0.08	0.34
Saturated fat (g/day)	0.14	0.15	0.12	0.19	0.06	0.54
Fibre (g/day)	0.07	0.43	0.02	0.75	-0.004	0.96
6 months (n= 113)						
Calories (Kcal/day)	0.13	0.16	-0.03	0.72	0.07	0.42
Proteins (g/day)	0.02	0.82	-0.002	0.98	0.02	0.81
Carbohydrate (g/day)	0.20	0.06	-0.05	0.59	-0.004	0.97
Total fat (g/day)	0.04	0.64	-0.01	0.90	0.05	0.59
Monounsaturated fat (g/day)	0.19	0.05	0.16	0.06	0.14	0.12
Polyunsaturated fat (g/day)	0.05	0.63	-0.07	0.41	-0.01	0.90
Saturated fat (g/day)	0.05	0.57	0.12	0.18	0.12	0.21
Fibre (g/day)	0.12	0.23	-0.02	0.84	-0.05	0.62
1 year (n= 60)						
Calories (Kcal/day)	0.35	**0.01**	0.11	0.40	-0.23	0.09
Proteins (g/day)	0.30	**0.03**	0.02	0.84	-0.06	0.66
Carbohydrate (g/day)	0.26	0.06	0.04	0.75	-0.09	0.49
Total fat (g/day)	0.09	0.49	0.14	0.33	-0.23	0.09
Monounsaturated fat (g/day)	0.08	0.60	0.20	0.12	-0.16	0.23
Polyunsaturated fat (g/day)	0.20	0.13	0.08	0.49	-0.24	0.09
Saturated fat (g/day)	0.08	0.54	0.14	0.30	-0.26	0.06
Fibre (g/day)	0.14	0.34	-0.09	0.52	-0.23	0.08

Note: Mean of social jet lag, daytime sleepiness and sleep quality was evaluated by three assessment periods (3 months, 6 months and one year). Linear regression was adjusted for sex, age, family income, type II diabetes, surgical technique, shift work, physical activity and BMI. Analysis of food consumption variables were evaluated according 24-hour dietary recall questionnaire at the three assessment moments and $p < 0.05$ was considered significant. Participants in each evaluation moments: Baseline (n= 122), 3 months (n= 117), 6 months (n= 113) and 1 year (n= 60).

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Supplementary Table 1. Associations between the delta difference of metabolic parameters and the mean of exposure to social Jet lag, sleep quality and daytime sleepiness with 1-year follow-up (n= 60)

Metabolic variables	Coefficient β / (Exp β)	P value	R2 adjusted
Social jet lag			
Fasting glucose (mg/dl) *	0.02	0.92	0.33
Insulin (µIU/ml) *	-0.04	0.89	-0.29
Cholesterol (mg/dl)	-0,55	**0.002**	0.34
LDL (mg/dl)	0.12	0.55	0.20
HDL (mg/dl)	0.09	0.74	0.36
VLDL (mg/dl) *	0.11	0.69	0.17
Triglycerides (mg/dl)	-0.44	**0.02**	0.43
HOMA IR *	-0.01	0.97	-0.21
Sleep quality (PSQI score)			
Fasting glucose (mg/dl) *	0.05	0.75	0.68
Insulin (µIU/ml) *	-0.47	**0.02**	0.30
Cholesterol (mg/dl)	0.10	0.65	0.53
LDL (mg/dl)	0.29	0.07	0.49
HDL (mg/dl)	0.05	0.85	0.54
VLDL (mg/dl) *	0.19	0.28	0.57
Triglycerides (mg/dl)	0.03	0.92	0.59
HOMA IR *	-0.33	0.07	0.39
Daytime Sleepines (Epworth score)			
Fasting glucose (mg/dl) *	0.008	0.97	0.68
Insulin (µIU/ml) *	-0.57	**0.01**	0.37
Cholesterol (mg/dl)	0.02	0.93	0.52
LDL (mg/dl)	0.45	**0.006**	0.60
HDL (mg/dl)	0.24	0.36	0.57
VLDL (mg/dl) *	0.0001	1.00	0.57
Triglycerides (mg/dl)	0.05	0.86	0.59
HOMA IR *	-0.53	**0.04**	0.50

Note: Linear regression adjusted for sex, age, family income, type II diabetes, surgical technique, shift work, use of medication to sleep, activity, energy intake and BMI. The variables fasting glucose, insulin, HOMA-IR, and VLDL did not exhibited normal distribution, so we performed a log transformation to facilitate linear regression, which resulted in the presentation of Exp (β); $p < 0.05$ was considered significant. The other variables (cholesterol, LDL, HDL and triglycerides) exhibited a normal distribution, so we have coefficient β.

* Variables which were transformed using the common log transformation (Exp β)

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Supplementary table 2. Association between exposure of social jet lag with mean of sleep quality, daytime sleepiness and time of sleep in each moment (3 months (n= 113), 6 months (n= 117) and 1 year (n= 60)).

Variables	Coefficient (β)	P value	R2 adjusted
Sleep Quality (PSQI score)			
3 months	0.09	0.34	0.06
6 months	0.04	0.64	0.04
1 year	0.11	0.46	0.03
Daytime Sleepiness (Epworth score)			
3 months	0.10	0.28	-0.002
6 months	0.16	0.08	0.03
1 year	0.37	**0.02**	0.07
Sleep duration (Hours)			
3 months	-0.24	**0.007**	0.18
6 months	-0.26	**0.006**	0.24
1 year	-0.12	0.45	-0.002

Note: Linear regression adjusted for sex, age, family income, type II diabetes, surgical technique, shift work, use of medication to sleep, physical activity, energy intake and BMI and $p < 0.05$ was considered significant. Participants in each evaluation moment: Baseline (n = 122), 3 months (n = 117), 6 months (n = 113), and 1 year (n = 60).