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ORIGINAL ARTICLE

The relationship between sleep- and circadian rhythm-related parameters with dietary practices and food intake of sedentary adults: a cross-sectional study

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Abstract

We aimed to explore the link between sleep-related parameters and dietary practices. This cross-sectional exploratory study includes sedentary individuals between 20 and 59 years of age. We applied exigent inclusion and exclusion criteria, such as weight stability and without humor- or sleep-related diseases. Also, shift workers were not included. We evaluated sleep quality (by Pittsburg Sleep Quality Index; PSQI), sleepiness (by Epworth Sleepiness Scale), chronotype (by Morningness Eveningness Questionnaire; MEQ), and social jetlag from sleep dairy. Moreover, Food Practices Measurement Scale was used to assess dietary practices. Food intake estimates (i. e., energy, eating window, and late-night dinner eating) were derived from two 24-h food recalls (R24h). For analysis, dietary practices and energy intake from R24h were considered dependent variables, while PSQI, ESS, MEQ, STJ, EW, and LNDE were considered independent variables. Our sample comprises 42 adults (21 women and 21 men; 35.4 (12.5) y; 25.6 (5.21) kg/m^2 BMI; 26.5 (7.97) % body fat). We verified that persons with poor sleep quality showed lower dietary practice scores (MD − 6.68; p = 0.021). Besides, in regression analysis, chronotype (β = 0.266; p = 0.039) was positively associated with dietary practices, and eating window was positively associated with energy intake (β = 267 kcal; p = 0.023). In contrast to our hypothesis, other sleep- and circadian-related variables were not associated with dietary practices or energy intake. In summary, we conclude that morning chronotype appears to be related to better dietary practices from the Food Guide for the Brazilian Population guide and that higher eating window was positively associated with energy intake.

Keywords Poor sleep · Social jetlag · Circadian misalignment · Dietary practices · Energy intake

Introduction

Negative sleep-associated parameters and circadian misalignment may affect energy balance leading to weight gain, obesity, and several metabolic disorders (i.e., insulin resistance and poor lipid profile) [1, 2]. In recent decades, observational and sleep-restriction intervention studies showed that sleep-associated parameters are linked with poor health outcomes [3, 4]. For instance, Che et al. [1] found that short sleep duration increased the risk of metabolic syndrome by 15% and obesity by 14%. Moreover, short sleep duration increases the risk of hypertension by 16% and high blood glucose by 12% [1].

However, it is unclear if these poor outcomes are from poor sleep-, diet-associated factors, or both [5] because the sleep-diet interaction is complex. Multiple sleep-associated

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variables can affect food intake, quality, and behavior (i. e., sleep duration, sleep quality, sleep pattern, bedtime, sleep midpoint, wake-up time, etc.) [5]. These factors may favor more inadequate meal choices, especially rich in saturated fatty acids, sugar, and ultra-processed foods (e. g., according to the NOVA classification, 'formulations of ingredients, mostly for industrial use only, derived from a series of industrial processes) accompanied by a lower intake of healthy food and nutrients (i. e., whole grains, fiber, polyunsaturated lipids, etc.). The higher intake of ultra-processed foods coincides with a higher incidence and prevalence of obesity and non-communicable chronic diseases [2, 6–9].

Thus, short sleep duration could be critical in mediating poor meal choices and conduct several adverse health outcomes. For instance, short sleep duration favors hormonal disturbance (i. e., lower levels of leptin and higher levels of cortisol and ghrelin) [10, 11]. These hormone changes were related to food cravings, hedonic food stimuli, homeostatic disruption and were predictors of weight loss [12, 13]. Bogh et al. [14] showed that after a weight loss-diet, participants with short sleep duration and poor sleep quality regained more weight than normal and good quality sleepers after one-year.

Still, sleep curtailment increases eating time or eating window, leading to higher energy intake. Likewise, short sleep duration could be associated with late-night dinner eating (after 8 pm and just one hour before bedtime), which per se may be associated with metabolic disorders [15–17]. Moreover, circadian misalignment can lead to higher energy intake, poor diet quality, and disorganization of the eating routine. In previous studies, vespertine chronotype and social jetlag have been associated with poorer food intake [18, 19].

Hence, sleep- and circadian-associated factors may mediate dietary practices and energy intake. Thus, a plethora of pathways could explain the complex sleep-diet interaction and its effect on health outcomes. We believe that poor sleep quality, sleepiness, higher social jetlag, longer eating window, and late dinner night eating will be associated with poor dietary practices and higher energy intake in sedentary adults living with overweight and obesity. As such, we aimed to explore the link between sleep- and circadian-related parameters with dietary practices and energy intake of sedentary adults living with overweight and obesity.

Materials and methods

Type of study and data collection

This cross-sectional exploratory study consists of two face-to-face meetings, with 15-day interval between visits. The interviews, questionnaires, anthropometry, and other tests occurred between April and September 2021 at the Centro Universitário São Camilo teaching clinic, known as PROMOVE (Center for Promotion and Rehabilitation in Health and Social Integration) located in the district of Ipiranga, São Paulo, Brazil.

Ethical procedures

The study was approved by the Research Ethics Committee of the Federal University of São Paulo (protocol #0910/2020). All the principles described in the International Ethical Guidelines for Research Involving Human Beings, Geneva (1993) and the precepts described in the latest update of the Helsinki Declaration (1964) proposed by the 64 th general assembly of the World Medical Association held in October 2013 were respected [20].

Study population

Eligible males and females were aged 20–59 years, sedentary or irregularly active A and B according to the physical activity level classification of the International Physical Activity Questionnaire (IPAQ) [21]. We included persons that have not shown sleep-related diseases (i.e., obstructive sleep apnea, insomnia, bruxism, restless legs syndrome, etc.). Body mass index, ethnicity, schooling level, or monthly income were not exclusion criteria.

We excluded pregnant women, and recent mothers or fathers due to poor sleep-related condition [22, 23]. Moreover, we excluded individuals on weight loss treatment (i.e., because people on weight loss intervention increased their diet quality) [24] or using antidepressant medications, especially drugs of the serotonin receptor, as well as in chronic or acute use of hypnotics of the barbiturate class, benzodiazepines, z-drugs, and wakefulness promoters, such as modafinil, and regularly consuming products such as melatonin. These medicines can affect sleep-related parameters [25–27]. Finally, shift or night workers were also excluded [28]. Therefore, these criteria were established to ensure that the people evaluated did not have sleep problems.

The sample size was not calculated a priori. However, to avoid type I and II errors, the statistical analysis was carried out cautiously, and, in case of a positive association between the independent variables and the outcomes, the calculation of sample power was performed a posteriori [29].

Assessments

In the first meeting, all the research procedures were explained, and the Informed Consent was handed out to be read and signed by the participants. Subsequently, an interview was applied with open and closed questions about personal-, socioeconomic-, clinical-, and lifestyle-related information. Still, validated questionnaires and a 24-h food recall were applied. Moreover, participants were instructed to complete the sleep- and dietary-diary during two consecutive weeks. Participants were instructed to maintain their routine and lifestyle habits, especially dietary, sleep, and physical activity level.

Interview

It was composed of open and closed questions about personal-, social-, educational-, and cultural-related factors (i. e., age, family income, educational and socioeconomic status, smoking and medications). After that, we collected data on sleep, chronotype, eating practices and food consumption. The interview was conducted in a closed room with only one researcher so that the answers offered were not underestimated or overestimated. In addition, the main researcher was trained to apply the questionnaires, reducing random and systematic biases related to the application of questionnaires [30].

Sleep quality

To assess sleep quality, we used the Pittsburg Sleep Quality Index (PSQI) validated and translated into Portuguese [31]. The PSQI information allows estimation of the sleep quality in the last month. The 19 items are grouped into seven components, including (1) sleep duration, (2) sleep disturbance, (3) sleep latency, (4) daytime dysfunction due to sleepiness, (5) sleep efficiency, (6) overall sleep quality, and (7) sleep medication use. The overall PSQI scores range from 0 to 21 points, according to the test's authors. A PSQI score ≤ 5 indicates good quality sleep, while a PSQI > 5 score denotes poor sleep quality in discerning good and poor sleepers, a global PSQI score > 5 shows a sensitivity of 89.6% and a specificity of 86.5% [32].

Sleepiness

The Epworth Sleepiness Scale (ESS) assessed daytime sleepiness, validated for the Portuguese language [33]. The ESS is composed of eight multiple-choice questions, and the score ranges from 0 to 24. A higher score indicates higher daytime sleepiness.

Chronotype

The chronotype was evaluated using the Morningness Eveningness Questionnaire (MEQ), validated in Portuguese [34]. The MEQ comprises 19 multiple-choice questions with four answer options. The MEQ assesses subjective daily preferences and results in a Morningness-Eveningness score. These preferences are established when people prefer to be active (i.e., to do physical exercise) or to rest. The final score allows us to determine which chronotype the person being evaluated belongs to, among matutine, indifferent, and vespertine.

Sleep pattern and social jetlag

According to Carney et al. [35], the sleep pattern was assessed using a sleep diary for 14 days. The sleep diary has several advantages, especially concerning the variability of sleep-related parameters [36, 37]. Still, from the sleep diary, we calculated SJL according to Wittmann et al. [38], being the absolute difference between midsleep on free days (MSF) and midsleep on workdays (MSW) as follows:

$$SJL = (MSF - MSW)$$

Also, we applied the SJL equation correction proposed by Jankowski [39]. Thus, a sleep-corrected formula for SJL is proposed (SJLsc): MSFsc = sleep onset on free days + half of the average weekly sleep duration; MSWsc = sleep onset on workdays + half of the average weekly sleep duration.

$$SJLsc = MSFsc - MSWsc$$

Assessment of dietary practices and food intake

The Food Practices Measurement Scale was used to assess dietary practices in agreement or disagreement with the recommendations of the Food Guide for the Brazilian Population [40, 41]. The Food Practices Measurement Scale is a self-administered scale with 24 four-point Likert-type items ("never," "rarely," "often," "always"), comprising four dimensions of good and healthy eating addressed in the guide: food choice, modes of eating, planning, and household organization. The score values from 0 to 3 range from 0 to 72 as the maximum value. The higher score suggests better dietary practices. According to previous data, the scale's score was associated with higher consumption of fresh and minimally processed foods and inversely associated with consumption of ultra-processed foods [42].

Dietary intake estimates were derived from two 24-h food recalls (R24h), collected on non-consecutive days at the interviews (first and second meeting). The data were collected by an interviewer (senior nutrition undergraduate student) experienced in dietary data collection. Only one evaluator reduces intra-individual variations. Moreover, we applied the Multiple-Pass Method. The Multiple-Pass Method has been widely recommended to assess dietary intake and reduce random and systematic errors [43]. The Multiple-Pass Method comprises five steps: (i) a quick listing of foods and beverages consumed, (ii) commonly forgotten foods, (iii) time and occasion of consumption, (iv) detailing cycle, and (v) a final review [43].

The collection was done in a private place, to avoid distractions, and the appointments for each R24h were made according to the participant's availability. A photographed food catalog from the Brazilian version of Globo Diet was used to determine more details [44]. The analysis was carried out in detail, considering social and cultural aspects [45]. Then, the total calories ingested, macro and micronutrients, were calculated with Web Diet® software. After that, the web-based statistical modelling technique Multiple Source Method (MSM; https://msm.dife.de/tps/en), proposed by the European Prospective Investigation into Cancer and Nutrition (EPIC), was used to estimate the usual dietary intake from two-24 h recall [46]. The MSM was developed in 2006 and it provides usual food intake distributions from individual short-term estimates by combining the probability and the amount of consumption with the incorporation of covariates into the modeling part [47]. We did not use the mean to reflect habitual dietary intake. Means obtained from several repeated measurements show greater variance, which may lead to estimation errors present in a subset of the population who report intakes other than true under-report or over-report [48, 49].

Eating window and late-night dinner eating

In the second meeting, the 24-h food recall was applied again. The eating window was defined as the time (in hours) between the first and last meal. Consequently, we categorize this variable to 12 h. For instance, people whose interval between the first and last meal was greater than 12 h were considered to have a longer eating window. In contrast, people whose interval between the first and last meal was shorter than or equal to 12 h were considered to have a short eating window [50]. The determination of the late-night dinner eating varies between studies [51, 52], although it is most determined after 8 pm. We considered the median of our sample (8:30 pm) to determine the late-night dinner eating. Thus, people who consumed their dinners > 8:30 pm were considered late-night dinner eating.

Energy balance

From IPAQ data, we calculated the non-resting energy expenditure (i.e., Vigorous physical activity MET = 8; Moderate physical activity MET = 4; Walking MET = 3.3) [53–55]. Hence, we summed the resting energy expenditure from indirect calorimetry, non-resting energy expenditure, and thermic effect of food (10% of energy intake) to calculate the total daily energy expenditure [56, 57]. Finally, the energy balance was obtained by subtracting total daily energy expenditure from energy intake.

Anthropometric parameters

The height was measured using a vertical stadiometer with an accuracy of 1 mm. We assessed body mass with both feet on a weight balance with 0.1 g precision; all participants were instructed not to wear excessive clothing and they were barefoot at the very moment. The average of three measurements was used to calculate the participant's Body Mass Index (BMI) (weight [kg] / height [m] [2]). Still, the waist, hip, neck, and abdominal circumferences were measured with a flexible, inelastic tape measure accurate to 0.1 cm as follows: (i) waist circumference at the midpoint between the costal margin and the iliac crest is two cm above the navel; (ii) hip circumference over the point of the greatest posterior gluteal region in an erect position; (iii) neck circumference below the laryngeal prominence, perpendicular to the neck axis; finally, (iv) abdominal circumference over the umbilical scar [58, 59].

Body composition was estimated by model-310 electrical bioimpedance Biodynamics® (Model A, Biodynamics Corp., Seattle, USA). The resting energy expenditure was also evaluated by Fitmate equipment (Cosmed®). Participants fasted for ≥ 5 h and rested on a horizontal plane for 15 min [60]. We measured REE for 20 min, discarding the first 5 min.

Statistical analyses

Continuous data are described in mean and standard deviation, while frequencies in absolute and percentage values. After normality analysis to verify the distribution of the variables, we used Independent t tests or Mann–Whitney U test were performed for comparisons between groups, which could be (i) sex, (ii) PSQI score, (iii) eating window; (iv) social jetlag; (v) late-night dinner eating. One-way analysis of variance (ANOVA) was also performed to compare chronotypes (matutine, indifferent, and vespertine). To verify the differences between energy expenditure by sex and age, we applied an age-controlled analysis of variance (ANCOVA). In these case, Bonferroni post hoc was applied.

Concerning the data distribution, we designed a linear regression model, considering dietary practice's score from The Food Practices Measurement Scale and energy intake from two 24 h-recall as the dependent variables. To create the regression models, we considered the following steps: first, insert the independent variable of interest; second, insert potentially confounding variables, such as sex [61, 62] and socioeconomic level [63]. Thus, only three variables were inserted for each regression model. Thus, one regression model was created for each independent variable (i.e., sleep quality by PSQI, sleep duration, eating window, late dinner night eating, social jetlag with and without correct, and MEQ). For sleep quality from PSQI and MEQ, we insert continuous score. For eating window (> 12h00 vs. < 12h00), late dinner night eating (> 8:30 pm vs. < 8:30 pm), and social jetlag (> 1h00 vs. < 1h00) with and without correct, we insert a dichotomous variable. These analyses were performed to avoid type I and II errors, considering the sample size obtained. We assumed significant associations only when the effect size was 0.33 (R^2) or more, alpha of 5%, and power of 0.80, regarding the G*Power a posteriori sample size calculation. The insertion of variables in the model considered biological plausibility criterion; still, tolerance of independent variables, Akaike Information Criterion (AIC) and R^2 were checked to determine the best-fitting model as recommended by Jenkins and Quintana-Ascencio [64] for regression analyzes for small samples. We used JAMOVI 2.3 version software.

Results

Fifty-five participants were recruited. Three were not included because they did not meet all the inclusion criteria. Fifty-two were included in the study. However, ten were excluded because they did not follow the second visit. Therefore, forty-two were analyzed (21 women and 21 men). Table 1 displays our sample characteristics. Continuous data are described as mean and standard deviation, while frequency data are expressed in absolute and relative values.

The mean age and BMI were 34.5 ± 12.5 years, and 25.6 ± 5.21 kg/m2 [2], respectively. Both, age (p = 0.224), and BMI (p = 0.214) did not differ between sex. Considering the BMI, our sample has predominantly 22 (52.4%) people with normal weight (10 women; 12 men), followed by 13 (31%) people living with obesity (5 women; 8 men), five (11.9%) people living with overweight (4 women; 1 man), and two (4.8%) people living with underweight (2 women).

Concerning body composition-related parameters, the mean body fat was 26.5 ± 7.97% for the whole sample, 31.56 ± 5.28 for women, and 21.09 ± 6.71 for men ($p < 0.001$). However, the fat mass in absolute value (kg) did not differ between groups (p = 0.422). Regarding lean mass, the whole sample showed 53.1 ± 13.5 kg, women 42.91 ± 7.34 kg, and men 63.87 ± 9.48 kg. As expected, men's lean mass was higher than women ($p < 0.001$).

The energy intake (kcal) and dietary practice scores were 2178 (390) kcal and 37.2 (9.28), respectively. Both energy intake (MD 175.46 kcal; p = 0.147) and dietary practice's score (MD 3.05; p = 0.293) did not differ between sex. Moreover, we verified the thermic effect of food, resting energy expenditure, non-resting energy expenditure, total daily energy expenditure, and energy balance. Women's non-resting energy expenditure (MD 269.9 kcal; p = 0.036), total daily energy expenditure (MD 602.5 kcal; p = 0.001), and energy balance (MD − 427.5 kcal; p = 0.004) were lower than men. The IPAQ categories were shown as absolute and relative values. We observed that 23 (54.8%), 8 (19%), and 11 (26.25) were sedentary, type A and B irregularly active, respectively. Distribution was similar between sex (p = 0.204).

Regarding sleep-related parameters, PSQI score, sleep duration from PSQI, week-sleep duration from sleep dairy, weekend-sleep duration from sleep dairy, sleep efficiency, and Epworth score were 6.79 (3.01), 6.64 (1.23) h, 6.61 (0.98) h, 7.79 (1.30) h, 88.4 (10.6) %, 9.62 (5.07), respectively. Similarly, PSQI score (MD 1.38; p = 0.139), sleep duration from PSQI (MD 0.73; p = 0.050), week-sleep duration from sleep dairy (MD 0.56; p = 0.067), weekend-sleep duration from sleep dairy (MD 0.01; p = 0.975), sleep efficiency (MD 2.71; p = 0.412), and Epworth (MD 1.04; p = 0.509) score does not differ between sex.

Our sample comprised 62% (n = 26) of people with poor sleep quality, while chronotype distribution followed 47.6% (n = 20) of indifferent, 40.5% (n = 17) of matutine, and 11.9% (n = 5) of vespertine. Assessing dinner moment, 41.5% (n = 17) showed late-night dinner eating (dinner after 8:30 pm). Concerning the eating window, 62% (n = 26) have > 12 h eating window. Also, 21 (51.2%), and 12 (29.3%) showed higher social jetlag and social $\text{jetlag}_{\text{sc}}$, respectively.

Table 2 exhibits comparisons between sleep- and circadian-related parameters. It was observed that only poor sleepers showed lower dietary practice scores than good sleepers (MD—6.68; p = 0.021). Considering non-statistically significant results, poor sleepers (PSWQI score > 5) have a higher daily energy intake than good sleepers (MD 118.52 kcal; p = 0.345). Likewise, those who have short sleep duration (< 7 h) showed a higher daily energy consumption (MD 52.3 kcal; p = 0.692). Moreover, those with a longer eating window (> 12 h) had a higher energy intake than the shorter eating window (MD = 151.1 kcal; p = 0.227). Further, energy intake was higher in people with social jetlag (> 1 h) (MD = 124.79 kcal; p = 0.309). In contrast, late-night dinner eating (> 8:30 pm) showed lower energy intake than non-late-night dinner eating (MD 161.47 kcal; p = 0.189). Interestingly, neither non-exercise energy expenditure (p = 0.557) nor total daily energy expenditure (p = 0.482) differs between late-night dinner eating. Notably, energy balance did not differ between late dinner night eating and non-late-night dinner eating (p = 0.835) (data not shown).

Table 3 exhibits linear regression considering dietary practice as a dependent variable. For the PSQI as continuous independent variable ($F_{(36,5)} = 1.44$; p = 0.232; $R^2 = 0.167$), eating window ($F_{(36,5)} = 1.50$; p = 0.213; $R^2 = 0.173$), late-night dinner eating ($F_{(36,5)} = 1.39$; p = 0.641; $R^2 = 0.166$), sleep duration ($F_{(36,5)} = 1.05$; p = 0.407; $R^2 = 0.130$), social jetlag ($F_{(36,5)} = 1.31$; p = 0.283; $R^2 = 0.157$), and adjusted social jetlag ($F_{(36,5)} = 1.04$; p = 0.411; $R^2 = 0.129$) we did not verify association with dietary practices. For the chronotype,

Table 1 Baseline characteristics

Variables	Whole sample (n = 42)	Women (n = 21)	Men (n = 21)	p value
Age (years)	34.5 ± 12.5	32.14 ± 12.51	36.86 ± 12.23	0.224
Body mass (kg)	73.2 ± 18.5	63.21 ± 12.87	83.11 ± 18.04	**< 0.001**
BMI (kg/m^2)	25.6 ± 5.21	24.64 ± 4.62	26.66 ± 5.65	0.214
Neck circumference (cm)	36.0 ± 4.49	32.65 ± 2.70	39.32 ± 3.26	**< 0.001**
Waist circumference (cm)	83.4 ± 14.6	76.90 ± 11.0	89.86 ± 15.11	**0.003**
Abdominal circumference (cm)	88.8 ± 16.2	86.15 ± 13.86	96/21 ± 17.19	0.043
Hip circumference (cm)	102.0 ± 10.3	100.20 ± 9.63	104.39 ± 10.67	0.189
Body fat (%)	26.5 ± 7.97	31.56 ± 5.28	21.09 ± 6.71	**< 0.001**
Body fat (kg)	19.3 ± 8.06	20.34 ± 6.9	18.29 ± 9.18	0.422
Lean mass (kg)	53.1 ± 13.5	42.91 ± 7.34	63.87 ± 9.48	**< 0.001**
Resting metabolic rate (kcal)	1414 ± 275	1282 ± 233.26	1596 ± 341.79	**0.001**
< 30 years	1441 ± 386	1259 ± 276	1704 ± 382	0.185*
≥ 30 years	1446 ± 264	1210 ± 129	1516 ± 300	
NREE (kcal/day)	1516 ± 415	1378 ± 460	1648 ± 326	**0.036**
TDEE (kcal/day)	3177 ± 133	3045 ± 721	3345 ± 734	**0.001**
Energy balance (kcal/day)	− 997 ± 656	− 778 ± 524	− 1205 ± 711	**0.004**
Dietary practices score, energy, macronutrient intake, eating window, and late-night dinner eating				
Dietary practices score	37.2 ± 9.28	38.76 ± 10.86	35.71 ± 7.32	0.293
24-h recall (kcal per day)	2178 ± 390	2090 ± 349	2266 ± 417	0.147
Thermic effect of food (kcal per day)	218 ± 39	209 ± 34.9	227 ± 41.7	0.147
Carbohydrate (g per day)	269 ± 93.9	265.9 ± 77.89	282.1 ± 97.04	0.555
Protein (g per day)	86.5 ± 26.6	78.8 ± 21.69	92.6 ± 30.91	0.101
Lipids (g per day)	84.3 ± 24.9	82.0 ± 28.11	86.2 ± 21.68	0.587
Saturated Fatty Acids (g per day)	30.8 ± 14.6	27.9 ± 10.66	34.2 ± 17.16	0.159
Monounsaturated fatty acids (g per day)	23.9 ± 6.08	22.6 ± 5.87	24.8 ± 6.33	0.251
Polyunsaturated fatty acids (g per day)	17.7 ± 7.20	16.9 ± 7.88	18.7 ± 6.46	0.429
Cholesterol (mg per day)	338 ± 196	323.9 ± 154.35	370.4 ± 217.48	0.437
Eating window (> 12 h)	26 (61.9)	12 (57.1)	14 (66.7)	0.525
Late-night dinner eating > 8:30 pm	17 (41.5)	10 (47.6)	7 (35)	0.412
Physical activity level				
Sedentary	23 (54.8)	14 (66.7)	9 (42.9)	0.204
Type A irregularly active	8 (19)	2 (9.5)	6 (28.6)	
Type B irregularly active	11 (26.2)	5 (23.8)	6 (28.6)	
Sleep- and circadian-related parameters				
PSQI score	6.79 ± 3.01	6.10 ± 2.70	7.48 ± 3.20	0.139
Poor sleep quality (> 5 PSQI score)	26 (62)	11 (52.4)	15 ± 71.4)	0.204
Sleep duration from PSQI (h)	6.64 ± 1.23	7.01 ± 1.33	6.27 ± 1.02	**0.050**
Mean week sleep duration (h)	6.61 ± 0.98	6.88 ± 1.11	6.32 ± 0.75	0.068
Mean weekend sleep duration (h)	7.79 ± 1.30	7.78 ± 1.47	7.79 ± 1.14	0.971
Sleep efficiency (%)	88.4 ± 10.6	89.76 ± 8.70	87.05 ± 12.21	0.412
Epworth score	9.62 ± 5.07	10.14 ± 5.42	9.10 ± 4.75	0.509
SJL (> 1 h)	21 (51.2)	10 (47.6)	11 (55)	0.636
SJL$_{sc}$ (> 1 h)	12 (29.3)	7 (33.3)	5 (25)	0.558
MEQ score	53 ± 10.9	56.38 ± 9.89	49.57 ± 10.97	**0.041**
Matutine	17 (40.5)	12 (57.1)	5 (23.9)	0.064
Indifferent	20 (47.6)	8 (38.1)	12 (57.1)	
Vespertine	5 (11.9)	1 (4.8)	4 (19)	
Smoking habits, medications, income, and educational status				
Smoking	2 (4)	0 (0)	2 (9.5)	0.147
Medications	17 (21)	10 (47.6)	7 (33.3)	0.346

Table 1 (continued)

Variables	Whole sample (n = 42)	Women (n = 21)	Men (n = 21)	p value
Up to 2 minimum wages per month	2 (4)	2 (9.5)	0 (0)	0.104
Between 2 and 4 minimum wages per month	11 (26)	6 (28.6)	5 (23.8)	
Between 4 and 10 minimum wages per month	19 (45)	11 (52.4)	8 (38.1)	
Above 10 minimum wages per month	10 (23)	2 (9.5)	8 (38.1)	
Until high school	21 (50)	11 (52.4)	10 (47.6)	0.758
College or higher	21 (50)	10 (47.6)	11 (52.4)	

Continuous data are described in mean ± standard deviation, while frequencies in absolute (percentage) values. T student independent test was performed; Bold = p value ≤ 0.05. *p value for interaction between age, sex, and 30 year-old cutoff (ANCOVA analysis was performed)

n sample size, *kg* kilograms, *mg* milligrams, *cm* centimeters, m^2 squared meters, *kcal* kilocalories, *h* hours, *BMI* body mass index, *PSQI* Pittsburg sleep quality index, *MEQ* Morningness-Eveningness questionnaire, *NREE* non-resting energy expenditure, *TDEE* total daily energy expenditure, > greater than

Table 2 Comparisons of dietary practices and habitual energy intake according to sleep and circadian rhythm parameters

Comparison	Dietary practice (mean; SD)		MD (95% CI)	p value	Energy intake (mean; SD)		MD (95% CI)	p value
Sleep quality	**> 5 PSQI score**	**≤ 5 PSQI score**			**> 5 PSQI score**	**≤ 5 PSQI score**		
	34.7 ± 8.03	**41.4 ± 9.91**	**− 6.68 (1.04–12.3)**	**0.021**	2223.2 ± 416.36	2104.6 ± 341.9	118.52 (− 369.04 to 132)	0.345
Sleep duration	**< 7 h**	**≥ 7**			**< 7 h**	**≥ 7**		
	37.9 ± 9.6	37.1 ± 7.97	0.81 (− 5.38 to 7.02)	0.792	2182.8 ± 428.41	2130.5 ± 289.82	52.30 (− 213.1 to 317.7)	0.692
Eating window	**> 12 h**	**< 12 h**			**> 12 h**	**< 12 h**		
	37.8 ± 9.36	36.3 ± 9.36	1.6 (− 7.61 to 4.41)	0.594	2235.6 ± 375.09	2160.6 ± 406.85	151.1 (− 399.82 to 97.6)	0.227
Late-night dinner eating	**> 8:30 pm**	**< 8:30 pm**			**> 8:30 pm**	**< 8:30 pm**		
	36.5 ± 9.28	38.0 ± 9.53	− 1.57 (− 4.47 to 7.62)	0.602	2097 ± 403.7	2258 ± 363.93	− 161.47 (− 82.66 to 405.6)	0.189
Social Jetlag	**> 1 h**	**≤ 1 h**			**> 1 h**	**≤ 1 h**		
	36.7 ± 8.10	38.6 ± 10.0	− 1.98 (− 3.76 to 7.73)	0.489	2227 ± 475	2102 ± 263.1	120.78 (− 369.1 to 119.5)	0.308
Chronotype	**Matutine**	**Indifferent**			**Matutine**	**Indifferent**		
	39.1 ± 10.0	36.5 ± 9.13	2.61 (− 3.79 to 9.01)	0.414	2216 ± 422	2186 ± 385	30.22 (− 239.2 to 299.73)	0.821
	Vespertine				**Vespertine**			
	34.2 ± 7.36		− 2.25 (− 6.90 to 11.4)	0.616	2019 ± 318		− 167.0 (− 220.39 to 554.5)	0.382

Comparisons were made using an independent t test. Bolded are comparisons whose p value is less than or equal to 0.05

PSQI Pittsburg sleep quality index, < lower than, > greater than, *MD* mean difference, *SD* standard deviation

we observed positive association with dietary practices ($F_{(36,5)} = 2.43$; $p = 0.054$; $R^2 = 0.252$). However, by the effect size ($R^2 = 0.252$), 42 people and 4 independent variables, the power was 0.681.

Table 4 exhibits linear regression considering energy intake as a dependent variable. For the PSQI as a continuous independent variable ($F_{(36,5)} = 3.02$; $p = 0.022$; $R^2 = 0.296$), late-night dinner eating ($F_{(36,5)} = 4.75$; $p = 0.002$; $R^2 = 0.404$), sleep duration ($F_{(36,5)} = 3.41$; $p = 0.013$; $R^2 = 0.327$), social jetlag ($F_{(36,5)} = 2.78$; $p = 0.032$; $R^2 = 0.284$), adjusted social jet lag ($F_{(36,5)} = 3.11$; $p = 0.020$; $R^2 = 0.307$), and chronotype ($F_{(36,5)} = 3.13$; $p = 0.019$; $R^2 = 0.303$) we did not verify association with energy intake from 24-h food recall. In contrast, eating window ($F_{(36,5)} = 4.18$; $p = 0.004$; $R^2 = 0.368$)

Table 3 Regression model assuming dietary pattern as a dependent variable

Independent variables	Dietary Practices (mean; 95% CI)		R^2	t	p value
	ß	95% CI			
PSQI score	− 0.099	− 1.16 to 0.961	0.167	− 0.190	0.850
Sleep duration (h)	0.395	− 2.93 to 3.72	0.130	0.241	0.811
Late-night dinner eating > 8:30 pm vs < 8:30 pm	1.379	− 4.57 to 7.32	0.166	0.470	0.641
Eating window > 12h00 vs < 12h00	1.640	− 4.534 to 7.81	0.173	0.538	0.593
Social Jetlag > 1h00 vs < 1h00	− 3.250	− 9.27 to 2.77	0.157	− 1.096	0.281
Social Jetlagsc	0.495	− 5.91 to 6.90	0.129	0.157	0.876
Chronotype (MEQ)	0.266	6.22e−4 to 0.531	0.252	2.032	**0.049**

For each independent variable, a multiple linear regression model was performed and controlled by sex and socioeconomic factors. We created the multiple linear regression with JAMOVI software. Data are depicted as mean and 95% confidence interval, accompanied by r^2 and p value. In bold, significant results (p value < 0.05)

PSQI Pittsburg sleep quality index, *MEQ* Morningness-Eveningness questionnaire, > greater than, < lower than, ≤ lower than or equal

Table 4 Regression model assuming sleep quality, LNDE, EW, SJL, and chronotype as independent variables and energy intake as a dependent variable

Independent variables	Energy intake (mean; 95% CI)		R^2	t	p value
	ß	95% CI			
PSQI score	24.1	− 16.8 to 65.1	0.296	1.196	0.186
Sleep duration (h)	− 113	− 238 to 12.8	0.327	− 1.82	0.077
Late-night dinner eating > 8:30 pm vs < 8:30 pm	− 168	− 375 to 38.6	0.404	− 1.65	0.108
Eating window > 12h00 vs < 12h00	**267**	**39.8–493.3**	**0.368**	**2.38**	**0.023**
Social Jetlag > 1h00 vs < 1h00	118	− 120 to 356.2	0.284	1.01	0.320
Social Jetlagsc	− 180	− 425 to 64.8	0.307	− 1.49	0.144
Chronotype (MEQ)	7.18	− 3.57 to 17.9	0.303	1.36	0.184

For each independent variable, a multiple linear regression model was performed and controlled by sex and socioeconomic factors. We created the multiple linear regression with JAMOVI software. Data are depicted as mean and 95% confidence interval, accompanied by r^2 and p value. In bold, significant results (p value < 0.05)

PSQI Pittsburg sleep quality index, < lower, > higher, *MEQ* Morningness-Eveningness questionnaire, > greater than, < lower than, ≤ lower than or equal

was positively associated with energy intake. As described in the statistical analysis section, an effect size equal to or greater than 0.33 has a sample power of at least 80%.

Discussion

We aimed to verify whether sleep-related parameters and circadian rhythm factors were associated with the dietary practice from the Brazilian Food Guide and 24-h food recall energy intake. We hypothesized that poor sleep quality, short sleep duration, higher eating window, social jetlag, late-night dinner eating, and vespertine chronotype would be associated with poorer dietary practices and higher energy intake.

Our sample consisted of 18 people (42.9%) living with overweight or obesity. The prevalence of people living with overweight and obesity in the Brazilian population is 57.2%, including aged people, which we did not assess in this study [65]. The mean score of dietary practices in our sample was similar to that exhibited in the Brazilian population (37.2 vs. 36.4) [41]. However, compared to the 2018 epidemiological data, the energy intake of our sample is approximately 313–430 kcal higher than the Brazilian population's intake [66, 67].

We verified that only people living with poor sleep quality by PSQI showed lower dietary practice scores, indicating poor dietary-related habits or poor dietary-related choices. Our sample comprised 62% (n = 26) of people with poor sleep quality. It was verified that in a sample of 2.635 people, 1.727 (65.5%) showed poor sleep quality evaluated with PSQI, according to epidemiology data of the Brazilian general population [68].

Poor sleep quality, regardless of the sleep duration, appear to promote negative changes in dietary intake [2]. These changes may come from increased ghrelin and decreased leptin levels [69] or increased drive to the hedonic-associated food intake [70], especially by the endocannabinoid system, a critical domain of the hedonic food pathway [71–73].

Although we have found that people with high PSQI scores present higher energy intake (~ 118.52 kcal) than those with (not significantly) lower PSQI scores, previous studies suggest that insufficient sleep favors a higher energy intake of approximately 150 kcal/day, leading to more elevated positive energy balance and weight gain [74]. Several studies that have applied the PSQI to assess sleep quality have identified that poor sleep quality was associated with poorer dietary-related parameters (i.e., high intake of processed food or lower quality food and high energy intake) [75–79]. These studies assessed the individual food groups through dietary recalls, food frequency questionnaires, or validated dietary intake questionnaires.

Questions inserted in the dietary practice's questionnaire consider trading meals for quick snacks. Previous studies showed that poorer sleep quality increases fatigue, stress, and more impoverished dietary choices, which can lead to more accessible food (i.e., ultra-processed foods) preferences [80, 81]. Poor sleep quality could trigger negative emotions and favor excessive consumption of hyper-palatable energy-dense foods, which can increase body weight and BMI. More recently, González et al. [82] deeply discuss this relationship. The dietary practices questionnaire asks about the consumption of candy, chocolates, other sweets, industrialized juices, fast food, soft drinks, switching lunch to pizza or sandwiches, and skipping meals. Thus, the dietary practices questionnaire displays another unhealthy dietary pattern with a high intake of red and processed meat, high-fat dairy, and refined carbohydrates or sweets. Our data, at least in part, follow Souza's study. They observed that adolescents' poor sleep quality was positively associated with ultra-processed foods intake [83].

In a Brazilian study, Castro et al. [81] found that short sleepers had the highest energy and nutrient intakes in snacks (especially in the afternoon and evening) than adequate and long sleepers. In Castro's study, total snacking contributed to about 23% of total energy intake among short sleepers (equal to the contribution of dinner, 22%) and provided the highest amounts of total and added sugar compared with the other food occasions [81]. In the regression model, however, we did not verify that the PSQI score was associated with the dietary practice score.

We only observed a positive association between MEQ continuous score with dietary practices. Higher MEQ values indicate morning chronotype. Thus, this positive association indicated that matutine subjects could exhibit better dietary practices. Other studies did not conduct any similar analysis with dietary practices questionnaire; thus, our data are the first to demonstrate this relationship. Rosi et al. [84] showed that matutine subjects reported a smaller intake of sweets and sweeteners and a reduced intake of ultra-processed fats [84]. Still, skipping meals, another aspect evaluated in the dietary practice's questionnaire can also impact health. Phoi et al. [85], in a scoping review, reinforce that evening chronotypes tend to skip breakfast, lunch, and dinner at a greater frequency than other chronotypes [85]. More recently, some reviews support that evening-related chronotypes negatively affect dietary-related habits [86, 87].

Moreover, we observed a higher eating window positively associated with a 24-h food recall energy intake. It is known that the living scenario affects the way we eat. People who wake up earlier and need to sleep later (i.e., because of work activity) extend the eating window, which can increase daily energy intake [88]. On the other hand, especially those with less active jobs (i.e., who need to sit all day) end up favoring a positive energy balance [89]. We did not verify that our sample was in a positive energy balance. Nevertheless, the 24-h food recall is problematic and can lead to underestimations that make it difficult to understand the energy balance [90].

Despite limited data, some studies suggested that time-restricting feed can positively affect health-related parameters, passing through decreased energy intake to improve weight loss [91]. Manipulating the eating pattern by circadian rhythm could increase the daily fasting period. This implies restricting daily food intake to 8–12 h to extend the period spent in a fasting state. However, so far, there is not enough strength of recommendation to encourage this eating practice [91]. Our samples' mean eating window duration was 12 h 18 min. Despite not being significant, those with an eating window greater than 12 h intake more than 151 kcal. Twenty-six (61.9%) of the sample showed a higher eating window (> 12 h). Therefore, it is possible that more extended eating windows positively impact energy intake.

Our study has some advantages. For example, the careful examination of different sleep and circadian rhythm parameters and the investigation of dietary practices innovates the nutrition- and diet-evaluating manner. Several studies evaluate dietary intake with only a 24-h recall or use the mean value, which may imply high variance [92–94]. More recently, it was demonstrated that the reliability for estimating mealtimes is better when the 24-h recall is repeated [95]. Besides, the inclusion and exclusion criteria of several studies can generate varied estimates because there is no control for several factors that are known to affect sleep [94]. Therefore, although small, our sample's quality is a fundamental element for the estimates shown here. Finally, throughout the writing, we avoided undue extrapolations and speculations to avoid the practice of Spin [96].

Nevertheless, our study has significant limitations, such as the sample size, the evaluation by subjective questionnaires, and the cross-sectional model, which do not allow causal inference. Furthermore, in future analyses, evaluating the food literacy is critical to broaden the understanding of the results. This factor seems to be associated with chronotype, sex, and BMI [97].

In summary, we conclude that morning chronotype appears to be related to better dietary practices from the Food Guide for the Brazilian Population and that higher eating window was positively associated with energy intake. Nevertheless, it is vital to reinforce the need for studies that evaluate this relationship in depth since poorer sleep quality and chronotype related problems are increasingly common.

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Author contributions ACOM, CGM, MVLdSQ, and RVT-S: drafted the study. ACOM and GAL: collected the data. MVLdSQ audited the database and conducted the statistical analysis. FPN: reviewed the English and collaborated with the writing. ACOM, CGM, MVLdSQ, and RVT-S: wrote the article.

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Declarations

Conflict of interest The authors have no conflict of interest.

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