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A putative association between food intake, meal timing and sleep parameters among overweight nursing professionals working night shifts

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A R T I C L E I N F O

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A B S T R A C T

Studies have suggested that dietary composition and meal timing of night workers differs from day workers, and it may be associated with sleep disturbances. The aim of the present study was to assess the relationship of macronutrient intake and meal timing during work-days and days-off with objective and subjective parameters of sleep among overweight nurses working night shifts. This study drew on baseline data from a phase II, randomized, double-blind, crossover, controlled clinical trial. The sample comprised 39 female nursing professionals. Dietary composition was determined by food diaries for one work-day and one day-off. Sleep data was obtained by actigraphy and the Pittsburgh Sleep Quality Index. Mean age was 38.2 years (SE 1 year) and mean time working the night shift was 5.8 years (SE 0.6 years). Around three-quarters of participants had sleep duration <7 h and poor quality sleep (74.4% and 79.5%, respectively). Individuals who slept <7 h had higher mean intake of animal protein on days off than those who had sleep duration ≥7 h. Total carbohydrate intake was greater on the day-off compared to the work-day, with the greatest intakes occurring between 00:00 to 05:59 and 18:00 to 23:59.

1. Introduction

Overweight is a public health problem and is more prevalent among night workers than day workers [1]. According to Liu et al. [2], night-shift workers had a 25% higher risk of overweight and 17% a higher risk of obesity than day workers. The high overweight and obesity rates seen in shift workers may stem from disturbances in the wake-sleep cycle or in eating habits [3–9]. In addition, night workers generally experience sleep restrictions and sleep problems, which in turn can impact diet composition and hence increase the risk of obesity [10–12].

Night workers often arrange meals or snacks during their shifts as a strategy to stay awake, preferring foods that are rich in fats and simple carbohydrates [13,10]. According to Coelho et al. [14] and Santos et al. [15], these foods are the most harmful for health, particularly in promoting cardiometabolic diseases. Working night shifts also negatively impacts the regularity and timing of meals, which has been associated with chronodisruption of energy metabolism homeostasis [16,17].

Studies analysing dietary intake reveal that night workers tend to change their eating patterns, especially diet composition. Night working is associated with low protein intake and high consumption of carbohydrates, where this combination promotes low sleep efficiency in night shift workers [11]. Corroborating this finding, studies conducted by Chen et al. [9] and Kosmadopoulos et al. [18] found that, although the caloric values of meals consumed by day and night workers were similar, the latter group consumed less protein.

Other studies investigating the relationship between macronutrient distribution and sleep also found an association of shorter sleep duration

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with unhealthier dietary pattern [19] and a preference for high-flavor foods [20]. In fact, night workers tend to have lower adherence to nutritional recommendations for healthy adults [21] and greater intake of carbohydrate-rich and high-fat snacks [22].

This relationship between diet and sleep is believed to be bidirectional, whereby short sleep duration can stimulate craving for high energy dense foods, while healthier foods contain nutrients that aid sleep onset and maintenance [19]. Another putative mechanism to explain the influence of diet composition is that macronutrient distribution can have a continuous effect on sleep quality and thus promote chronic and acute changes in hormonal and neuroendocrine signaling related to energy metabolism [23,24]. Importantly, reliable methods are needed to assess sleep. In this way, some studies have associated objective (actigraphy) and subjective (self-report information) methods for sleep assessment [25–27], as we did in the present study, thus allowing us to verify the agreement data, being one complementary to the other. It has been reported that actigraphic data may estimate sleep about an hour less than questionnaires/diaries [28]. The procedure of using both (actigraphic and self-reported data) increases confidence in the findings [29].

Previous studies have shown that overweight individuals are more likely to have sleep problems [30–33], however, it is not clear whether the dietary pattern can aggravate these problems. Studies investigating this relationship are essential to gain a better understanding of the nutritional impacts of night working, allowing more effective measures to improve the health of these workers.

This is particularly relevant for the health care sector since it works mostly 24/7. Moreover, a recent review showed that the stress, fatigue, increased workload, night shifts, nurse staffing ratio and workflow interruptions are behind medication administration errors by nursing personal. In addition, these factors have a negative impact on nursing personal health. The responsibility of somebody else's health is a heavy load for this occupational category [34].

In this context, the objective of the present study was to assess the relationship of macronutrient intake and meal timing during a work schedule with aspects of sleep among overweight nursing professionals working permanent night shifts. Our hypothesis was that protein intake at irregular timings by overweight workers may be associated with sleep problems.

2. Materials and methods

2.1. Study sample and design

This study is part of a phase II, randomized, clinically-controlled, double-blind, crossover trial at a major hospital in the city of São Paulo, Brazil. Detailed information about the study design is provided elsewhere [35]. The present study drew on baseline data for 39 female nursing professionals (nurses and nursing technicians) who worked permanent nightshifts in a 12 h (from 19:00 to 07:00) on-36 h off regimen. The sample size of the clinical trial was 27 individuals [35]; however, for the baseline, the sample size was calculated a posteriori. The sample size was calculated based on a difference in means test, at 5% level of significance and 90% sampling power for a sample of 34 individuals (G*Power software®).

The study inclusion criteria were: women aged 20–50 years, body mass index ≥25 and <40 kg/m^2 and who had been working in the current night shift for at least 6 months. In addition, participants were asked to refrain from following a diet which was calorie-controlled or restricted to certain food groups and/or from changing their meal times or commencing new physical activities during their participation in the study. Exclusion criteria were as follows: being a pregnant or nursing mother, having infants under one year of age, having any clinically-diagnosed eating disorders, menopause, second night job, regular use of medications or food supplements which affect sleep, alertness or the circadian timing system (barbiturates, benzodiazepines, melatonin, Ritalin, modafinil, soporific agents), prior history of neurological or psychiatric disorders, use of illegal drugs or alcohol abuse, circadian or sleep disturbance, metabolic problems (except controlled type 2 diabetes mellitus, hyperglyceridaemia and hypercholesterolemia), cardiovascular diseases (except controlled systemic arterial hypertension), clinically-diagnosed chronic inflammation and/or infections, had anemia or donated over 400 mL of blood in the three months leading up to the study, or undergone major surgery in the six months leading up to the study.

2.2. Data collection and processing

The clinical trial was carried out between March 2018 and June 2019, and the baseline data collection was carried out from April to November 2018. The dependent variables were objective and subjective sleep parameters. Subjective data consisted in perceived sleep quality, as rated by the Pittsburgh Sleep Quality Index (PSQI) score, which was dichotomized into good sleep (6–21 points) or poor sleep (0–5 points) [36]. The objective data on sleep were collected by actigraphy (Act Trust, Condor Instruments®) monitoring for 10 consecutive days. The parameters assessed were mean sleep duration (hours), sleep onset latency (minutes) and wake-up after sleep onset (WASO) (minutes). Mean values were calculated based on 24-hour periods, starting at 00:00 and ending at 23:59, and taken as representative of sleep characteristics for a typical day (work-day or day-off). The days in which the actigraphy record was less than 40% of the 24 h, that is, 9.6 h, were discarded, as were the days in which it was not used, or the sleep and activity diaries were not correctly filled out. Only records that included at least four days of valid records were considered.

The independent variables (total calorie intake [kcal] and amount of macronutrients [grams and percentages of total kcal intake] The macronutrients assessed were: total saturated fat (SAFA), monosaturated fat (MUFA), polyunsaturated fat (PUFA) and *trans* fat; total, complex and simple carbohydrates; total, soluble and insoluble fibers; total, animal and plant-based protein. Data were collected using food diaries (19:00 to 19:00 the next day), on a work-day and a day-off (totalizing two days of food intake registered). Participants were instructed to fill out the diaries on a work-day and a day-off that they considered as typical as possible, and to provide detailed information on foods and beverages consumed, including names of commercial brands, ingredients used in homemade preparations and meal times. Portion sizes were estimated using household measures, and subsequently converted into unit measures of weight (grams) and volume (millilitres) using the Table for Assessment of Food Intake in Household Measures [37]. The diaries were reviewed by a nutritionist to obtain additional clarifications, where necessary, and analysed using Nutrition Data System for Research Software [38]. Given the existence of cultural differences between dietary intake of Brazilians and North Americans, the composition of typically Brazilian foods and preparations was manually added to the software´s database. For this purpose, the Brazilian Food Composition Table [39] and label information for specific processed foods were used.

The adequacy of dietary intake pattern was estimated using the Recommended Dietary Allowances (RDA) established by the U.S. National Academy of Science [40]. Although intended for the healthy North American population, these reference intakes are traditionally recommended by the Brazilian Society of Food and Nutrition (SBAN) for assessing and planning adequate diets. The updated version of the Brazilian Guideline on Dyslipidaemias and Atherosclerosis Prevention - 2017 was also employed, defined by the Brazilian Society of Cardiology [41]. An intake of macronutrients in the 90–110% range was classified as adequate, as shown in the Results.

2.3. Statistical analysis

Qualitative variables were expressed as absolute and relative frequencies, whereas quantitative variables were expressed as measures of central tendency (mean or median) and of dispersion (standard error - SE or Interquartile range - IQR), according to the distribution of the data. The Shapiro-Wilk test was applied to test for normal data distribution. Correlation analyses (Spearman or Pearson, depending on data distribution) were carried out to assess the relationship between macronutrients and aspects of sleep. Difference in means of macronutrient intake according to sleep duration were tested using Student´s *t*-test for parametric data and using Mann-Whitney for non-parametric data. Sleep duration was dichotomized into <7 h or ≥7hours a day, as per the recommendations of the National Sleep Foundation for the adult population [42].

The level of significance adopted for all tests was a p-value <0.05, while a p-value ≤0.10 indicated tendency [43]. All statistical analyses were carried out using the Stata 12.0 and Statistica software packages (TIBCO Software Inc., Palo Alto, CA, USA, version 7).

3. Results

Mean age of participants was 38.2 years (SE 1 years) and mean time working night shifts was 5.8 years (SE 0.6 years). Detailed sociodemographic description in presented in Table 1.

Most participants had sleep duration <7 h and reported poor sleep quality (74.4% and 79.5%, respectively). Total sleep duration measured by actigraphy averaged 6.27 h (SE 0.2 h); median sleep latency was 11.6 min (IQR 5–23.8 min) and mean WASO was 57.3 min (SE 4.4 min), ranging from 13.7 min to 2.64 h.

Median BMI of participants who had good sleep quality was 30.1 kg/m2 (IQR 28.4–30.7 kg/m2) versus 29.8 kg/m2 (IQR 27–32.3 kg/m2) among individuals who had poor sleep quality, with no statistically significant difference between the groups (Mann-Whitney, $p = 0.83$).

No difference in mean total caloric intake was found between work-days and days off (1765.5 kcal, SE 123.6 kcal and 1686.8 kcal, SE 12.4 kcal, respectively, Mann-Whitney *U test*, $p = 0.54$). Of the other macronutrients assessed, only mean intake of simple refined carbohydrates was higher on work-days than on days off (Table 2). Mean total carbohydrate and total protein intakes exceeded recommended levels, while amounts of MUFA and total fiber consumed on both work-days and days off were below recommended levels (Table 2).

Although a tendency for a negative correlation of total and animal protein intakes on work-days with sleep quality was found, a statistically significant result was not found (Fig. 1). For the other macronutrients assessed, no statistically significant difference was found for work-days or days off.

There was a tendency for correlation of greater consumption of calories from carbohydrates on work-day and from saturated fats on day-off with greater sleep latency, whereas a greater intake of calories from polyunsaturated fats on days off correlated with longer sleep latency, but not statistically significant (Fig. 2). No statistically significant correlation was found for the other macronutrients on days off or work-days.

Although a trend towards a higher total, soluble and insoluble fiber intakes on work-day was found with longer WASO, the result of statistical analysis was not significant (Fig. 3). For the other macronutrients assessed, no statistically significant correlation with WASO was found on work-day or day off.

Individuals who slept <7 h had higher mean intake of animal protein on days off than those who slept ≥7 h per day (Fig. 4). No difference in intake according to sleep duration was found for other macronutrients on work-day or day off.

When evaluating the food intake according to the hours and days (day-off vs. work-day), we verified that the highest energy consumption, as well as total fat, total protein, animal protein, MUFA, PUFA and insoluble dietary fiber occurs between 12:00 and 17:59, followed from 18:00 to 23:59 compared to the period from 00:00 to 05:59 (Table 3). The total carbohydrate consumption was greater on the day-off compared to the work-day (Table 3), in which on day-off the consumption of total carbohydrate was greater between 00:00 to 05:59 and 18:00 to 23:59 in relation to the work-day (Fig. 5). In addition, carbohydrate consumption was higher from 18:00 to 23:59 compared to the period from 12:00 to 17:59 on the day-off, as well as from 12:00 to 17:59 compared to the 06:00 to 11:59 in the work-day (Fig. 5).

Table 1
Description of demographic aspects of overweight nursing professionals ($n = 39$).

Variables	n	%
Occupation		
Nurse	20	51.3
Nursing technique	19	48.7
Status		
Single	10	25.6
Married	25	64.1
Separate	4	10.3
Education		
Complete high school	11	28.2
Incomplete college or studying	6	15.4
Incomplete Graduate or attending	6	15.4
Post-Graduate Level	16	41.0
Family income		
until R$ 1.000,00	1	2.6
R$ 1.001,00 to 3.000,00	10	25.6
R$ 5.001,00 to 10.000,00	22	56.4
Up to R$ 10.000,00	5	12.8
Don't know / Don't want to answer	1	2.6
Worked night shift before		
No	12	30.8
Yes	27	69.2
Hours per week (hours)		
36	33	84.6
40	3	7.7
44	2	5.1
48	1	2.6
Reason to work at night		
Service enforcement	1	2.6
To reconcile with another job	3	7.7
To reconcile with the care of the home and / or children	17	43.6
By personal preference – Because like	7	17.9
To increase income	8	20.5
Other	3	7.7
Other paid activity		
No	34	87.2
Yes. Another activity not related to nursing care	2	5.1
Yes. In nursing care	3	7.7
Use of medication		
Yes	22	56.4
No	17	43.6
Smoker		
No	35	89.7
No. I smoked in the past. but I stopped	4	10.3
Alcohol		
No. I never consumed	11	28.2
No. but I used it in the past	2	5.1
Yes. On special occasions	15	68.1
Alcohol frequency		
Does not consume	7	31.8
Less than once a month	1	4.5
1 time per month	4	18.2
Every 15 days	8	36.4
1 to 2 times a week	2	9.1
Exercise regularly		
Yes	11	28,2
No	28	71,8

4. Discussion

4.1. Sleep duration

Our hypothesis that an inadequate distribution of macronutrients associated with overweight may potentiate sleep problems was partially confirmed. The results revealed that, on work-day, there was a higher

Table 2
Description of diet composition on day-work and day-off among overweight nursing professionals (*n* = 39).

Macronutrients	Day	Mean (SE)	*U test* p-value	Recommendation DRI (%)	Intake adequacy (%)
Total fat (g)	Day-work	64.24 (6.10)	0.39	25–	100.00
	Day-off	58.75 (5.99)		35	100.00
Saturated fat -SAFA (g)	Day-work	22.35 (2.38)	0.57	<10	106.71
	Day-off	21.25 (2.57)			104.10
Monosaturated fat - MUFA (g)	Day-work	21.98 (2.26)	0.34	15	69.73
	Day-off	19.21 (2.04)			64.06
Polyunsaturated fat - PUFA (g)	Day-work	14.31 (1.53)	0.49	05-	100.00
	Day-off	12.93 (1.29)		10	100.00
Trans fat (g)	Day-work	2.48 (0.47)	0.13	#	–
	Day-off	1.92 (0.40)			–
Total carbohydrate (g)	Day-work	218.62 (14.93)	0.84	45–	168.16
	Day-off	218.51 (15.20)		65	168.08
Complex carbohydrate-whole grains (g)	Day-work	17.95 (3.70)	0.71	#	–
	Day-off	21.69 (4.67)			–
Simple Carbohydrate - refined (g)	Day-work	144.27 (12.16)	0.04[1]	#	–
	Day-off	110.64 (10.58)			–
Total fiber (g)	Day-work	16.78 (1.32)	0.74	25	67.12
	Day-off	15.40 (1.01)			61.60
Soluble fiber (g)	Day-work	5.09 (0.37)	0.26	#	–
	Day-off	4.41 (0.31)			–
Insoluble fiber (g)	Day-work	11.64 (1.03)	0.74	#	–
	Day-off	10.93 (0.83)			–
Total protein (g)	Day-work	78.80 (5.64)	0.14	10-	171.30
	Day-off	70.48 (5.22)		35	153.22
Animal protein (g)	Day-work	57.06 (4.96)	0.20	#	–
	Day-off	49.17 (4.48)			–
Plant-based protein (g)	Day-work	21.74 (1.48)	0.87	#	–
	Day-off	21.31 (1.43)			–

Table 3
Food intake according to the meal timing and day (day-off vs. day-work) (*n* = 39).

Macronutrients	Meal time 00:00–05:59 Mean (SE)	06:00–11:59 Mean (SE)	12:00–17:59 Mean (SE)	18:00–23:59 Mean (SE)	p-value	Day Day-off Mean (SE)	Day-work Mean (SE)	p-value	Interaction Meal time and Day p-value
Total Grams	255.5 (35.0)	232.3 (21.3)	255.3 (17.7)	283.1 (16.7)	0.30	273.2 (19.8)	239.9 (13.2)	0.16	0.34
Energy (kcal)	277.9 (47.9)$^{\#}$	233.4 (29.2)*	336.1 (24.3)$^{\#,*}$	330.3 (22.9)$^{\#,*}$	**0.03**	321.8 (27.2)	267.1 (18.1)	0.09	0.34
Total Fat (g)	8.6 (2.3)$^{\#}$	7.5 (1.4)*	12.7 (1.2)$^{\#,*}$	11.8 (1.1)$^{\#,*}$	**0.02**	10.7 (1.3)	9.6 (0.9)	0.49	0.94
Total Carbohydrate (g)	41.9 (5.9)	34.0 (3.6)	37.9 (3.0)	41.8 (2.8)	0.35	44.4 (3.3)	33.4 (2.2)	**<0.01**	**0.04**
Total Protein (g)	9.9 (2.5)$^{\#}$	8.2 (1.5)*	17.2 (1.3)$^{\#,*,\&}$	13.4 (1.2)$^{\#,*,\&}$	**<0.01**	12.6 (1.4)	11.8 (1.0)	0.65	0.78
Animal Protein (g)	6.5 (2.2)$^{\#}$	4.7 (1.3)*	13.1 (1.1)$^{\#,*,\&}$	9.5 (1.0)$^{*,\&}$	**<0.01**	8.5 (1.2)	8.4 (0.8)	0.99	0.94
Vegetable Protein (g)	3.4 (0.7)	3.6 (0.4)	4.1 (0.3)	4.0 (0.3)	0.67	4.1 (0.4)	3.4 (0.3)	0.11	0.20
Total Saturated Fatty Acids (SFA) (g)	2.9 (1.0)	2.9 (0.6)	4.5 (0.5)	4.1 (0.5)	0.11	3.8 (0.5)	3.4 (0.4)	0.49	0.94
Total Monounsaturated Fatty Acids (MUFA) (g)	2.8 (0.8)$^{\#}$	2.5 (0.5)*	4.3 (0.4)$^{\#,*}$	4.0 (0.4)$^{\#,*}$	**0.02**	3.5 (0.5)	3.3 (0.3)	0.72	0.96
Total Polyunsaturated Fatty Acids (PUFA) (g)	2.3 (0.6)	1.5 (0.3)*	2.7 (0.3)*	2.6 (0.3)*	**0.04**	2.4 (0.3)	2.1 (0.2)	0.48	0.95
Total Dietary Fiber (g)	2.8 (0.5)	2.2 (0.3)	3.1 (0.2)	3.0 (0.2)	0.07	3.0 (0.3)	2.5 (0.2)	0.09	0.08
Soluble Dietary Fiber (g)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	0.9 (0.1)	0.63	0.9 (0.1)	0.8 (0.0)	0.33	0.08
Insoluble Dietary Fiber (g)	2.0 (0.4)$^{\#}$	1.4 (0.2)*	2.3 (0.2)$^{\#,*}$	2.2 (0.2)$^{\#,*}$	**0.01**	2.2 (0.2)	1.7 (0.1)	0.09	0.11
Total Trans-Fatty Acids (TRANS) (g)	0.3 (0.2)	0.3 (0.1)	0.5 (0.1)	0.4 (0.1)	0.73	0.3 (0.1)	0.4 (0.1)	0.81	0.99

$^{\#}$ means 00:00–05:59 is different from 06:00–11:59, 12:00–17:59, and 18:00–23:59. * means 06:00–11:59 is different from 12:00–17:59, and 18:00–23:59. "&" means 12:00–17:59 is different from 18:00–23:59.

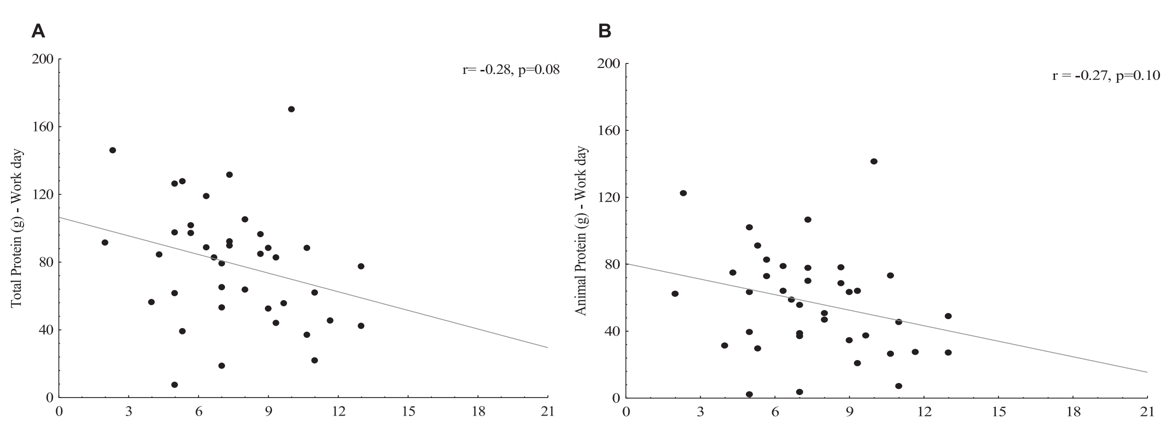

Fig. 1. Correlation of sleep quality with total (A) and animal-based protein (B) intakes on work-day among overweight nursing professionals (*n* = 39).

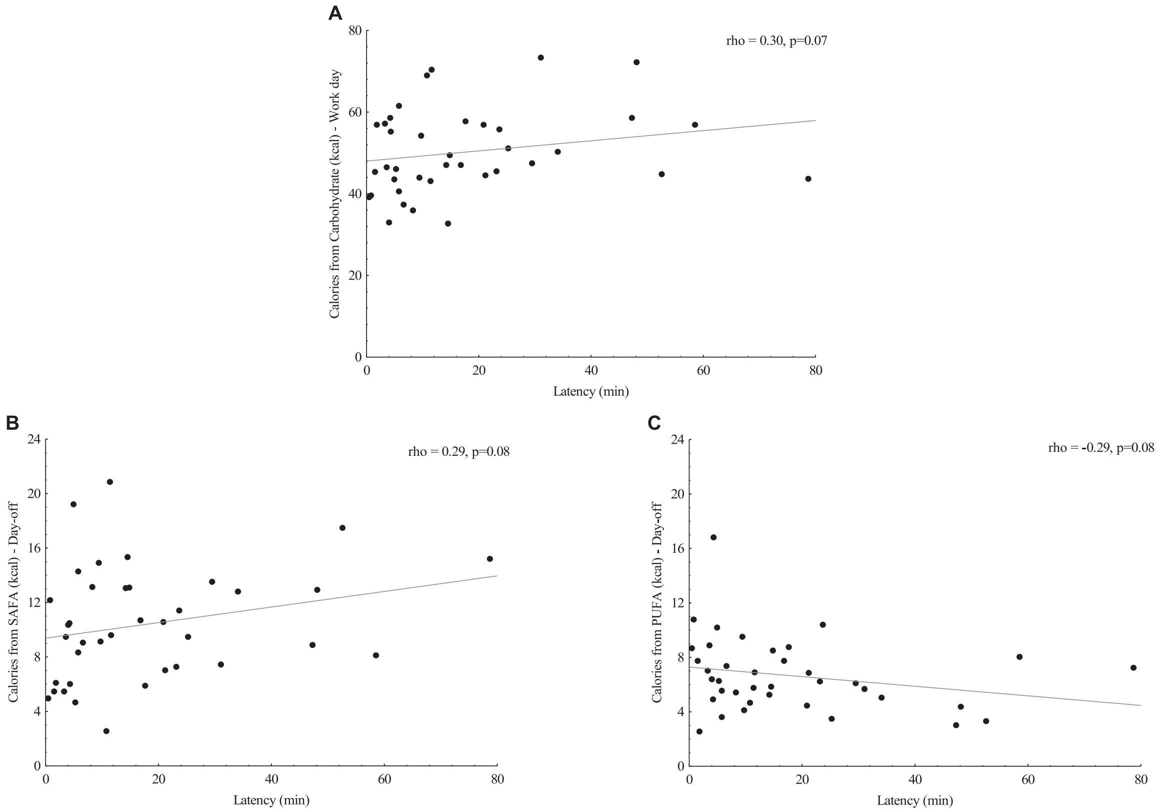

Fig. 2. Correlation of sleep latency with calories from carbohydrates (A) on work-day, calories from saturated fat (SAFA) (B) and polyunsaturated fat (PUFA) (C) on day-off, among overweight nursing professionals (n = 39).

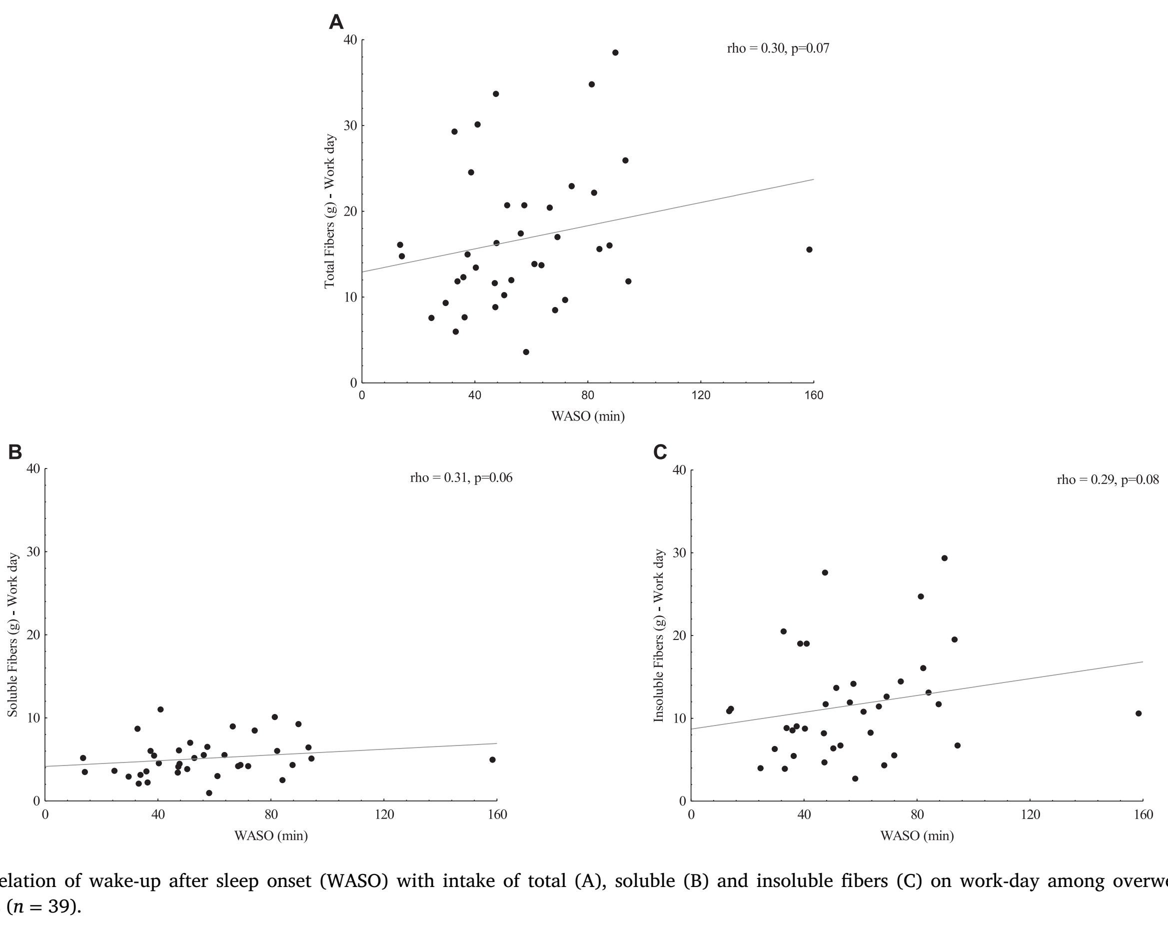

Fig. 3. Correlation of wake-up after sleep onset (WASO) with intake of total (A), soluble (B) and insoluble fibers (C) on work-day among overweight nursing professionals (n = 39).

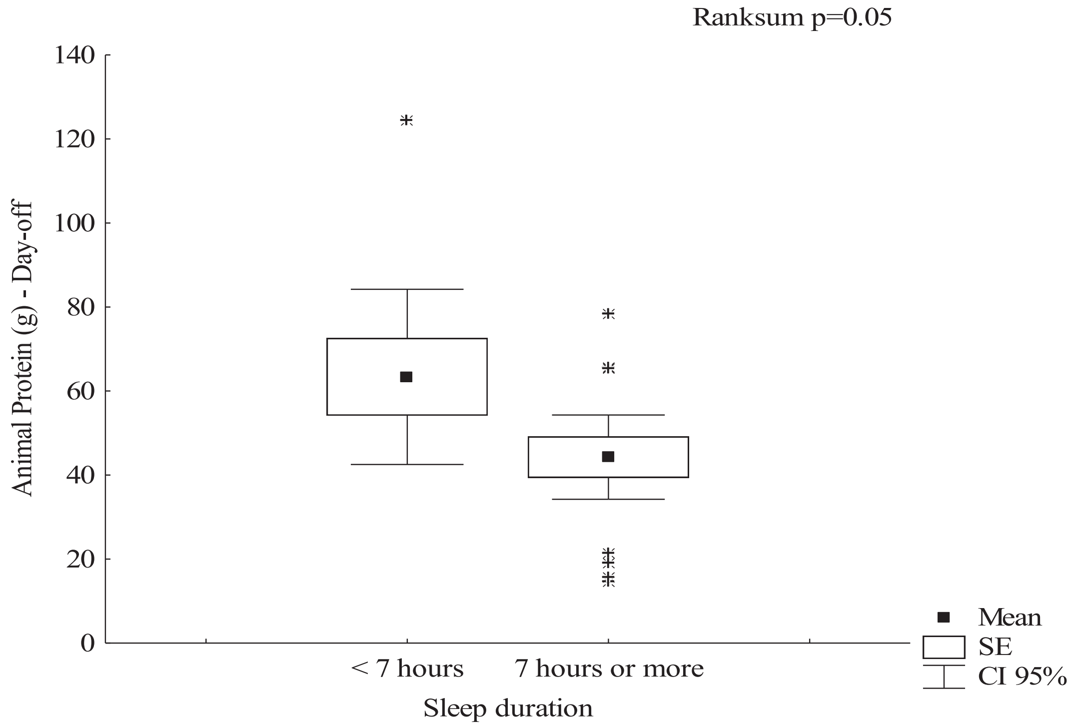

Fig. 4. Comparison of mean animal-based protein intake according to sleep duration on days off among overweight nursing professionals (n = 39). * represent outliers.

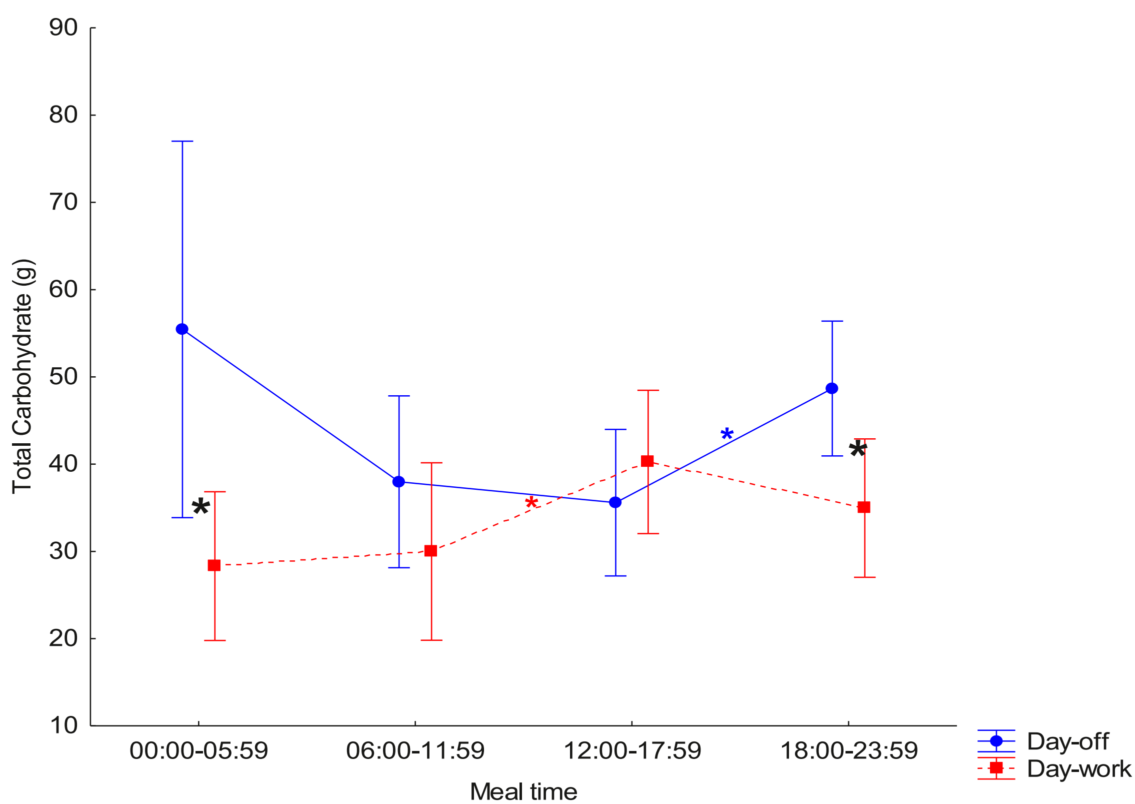

Fig. 5. Consumption of total carbohydrate according to the meal timing and day (day-off vs. day-work).

intake of animal protein among participants that had sleep duration of less than 7 h [42]. This result differs from that observed in the review by Sutanto, Wang and Kim [44], showing that individuals who slept longer than 7 h consumed more protein-derived calories. However, this finding should be interpreted with caution since, although corroborating evidence that a high-protein diet enhances sleep quality, this same relationship might not apply to a diet extremely high in protein [45], such as that observed in the present study. Jansen et al. [46], in a study investigating the association between sleep duration and diet quality in a representative sample of the North American adult population observed an inverted U-shaped curve. This pattern suggests that both higher and lower-than-recommended protein intakes can negatively impact sleep duration.

It is also important to point out that most participants in the present study slept for less than 7 h a day, representing a pivotal factor in regulating food intake on both days on and days off. Dashti et al. [47] conducted inverse-variance weighted, fixed-effect meta-analyses of results of adjusted associations of sleep duration and BMI and macronutrient intake as percentages of total energy as well as interactions with CLOCK variants from 9 cohort studies including up to 14,906 participants of European descent from the Cohorts for Heart and Aging Research in Genomic Epidemiology Consortium, and the authors suggest that longer sleep duration may facilitate compliance to the current recommendations for healthier eating behaviours. As observed by Kosmadopoulos et al. [48], sleep and meal timing are largely dictated by working hours. This evidence shows that shift workers may be negatively affected by their work regime, especially regarding their eating habits.

4.2. Sleep onset latency

The trend for greater sleep latency among participants that consumed more calories from carbohydrates on work-day contrasts with that observed by Lindseth, Lindseth and Thompson [49], who found shorter sleep latency after consumption of a carbohydrate-rich diet in 44 healthy adults over a 4-day period. In the case of night workers, however, carbohydrates are often consumed as a strategy to combat sleepiness, based on perceptions that these foods increase level of alertness during the shift [11]. In fact, lower sleep duration has been associated with a high intake of carbohydrates [11, 50], with particular preference for simple sugars, and a possible explanation is that sleep restriction and changes in sleep pattern can increase the levels of ghrelin, which is an appetite inducing hormone, and reduce the levels of leptin, a hormone related to satiety [24].

Corroborating these findings, the present study also found that the nursing professionals consumed significantly more refined carbohydrates on work-day. It may be the case that a carbohydrate-rich diet, particularly when consumed at night, can delay decline in the core body temperature curve, with this consequent higher temperature promoting greater sleep latency [23]. Thus, it can be assumed that the food-sleep relationship is bidirectional: sleep duration can influence dietary content and vice-a-versa.

There was also a tendency toward greater sleep latency among participants who consumed more calories derived from saturated fats on days off. Similarly, a tendency toward greater sleep latency was found among participants who consumed more calories derived from polyunsaturated fats on days off. In line with these results, the review by Sutanto, Wang and Kim [44] showed that the type of fat consumed can be a determinant of sleep parameters. A study by Crispim et al. [50] in 52 adults found that consumption of foods high in fat and total carbohydrates was associated with high sleep latency among women. Other studies, although not specifically investigating sleep latency, reported results suggesting the same pattern. Calvin et al. [51] showed that healthy adults consumed more fat after 8 nights with lower-than-usual sleep duration. Heath et al. [52] found that workers on permanent night shifts consumed more saturated fats than individuals who worked rotating or permanent day shifts. Souza et al. [53], in a systematic review of 33 observational studies, found a tendency for greater intake of foods high in saturated fats among shift workers. Taken together, these data suggest that low sleep quality and/or duration is a determinant for greater fat intake, which in turn negatively influences these sleep parameters, thus constituting a deleterious vicious circle, further supporting the bidirectional relationship between food and sleep.

4.3. WASO

The trend for greater WASO among participants who consumed more fibers, albeit total, soluble or insoluble may lie in the digestion process of fibers, which acts to promote peristaltic movements and may disrupt sleep onset and maintenance. Insoluble fibers in particular, can produce this effect in a more marked fashion, given this type of fiber passes through the stomach intact and increases fecal volume, further exacerbating peristalsis at a point when these movements are physiologically reduced [54]. By contrast, Nisar et al. [55] showed that fiber intake was associated with deeper, more restorative sleep in young adults. Experimental studies in which fiber intake is controlled should be conducted to assess sleep quality and the extent to which peristalsis movements affect this parameter.

The descriptive analysis of the participants' diet showed that total fiber and monosaturated fat intakes were below recommended levels both on work-day and days off. These two nutrients are associated with lower cardiovascular risk [56] and more commonly found in foods associated with a healthy diet, such as pulses and fruit. Thus, although overall diet quality was not assessed in the present study, these findings suggest a diet with low-nutritional value and unhealthy eating habits, compounded with the deleterious effects of night working, promotes non-restorative sleep.

4.3. Sleep quality

The trend for a correlation between lower total and animal protein intake and better sleep quality on work-day might be explained by the influence of proteins on sleep. The most cited mechanism involves tryptophan, an essential amino acid for serotonin and melatonin synthesis [57]. In a study assessing the results of two randomized controlled trials in obese adults, Zhou et al. [58] found protein intake to be positively correlated with sleep quality. In a recent systematic review on the association between sleep quality and macronutrient distribution, Sutanto, Wang and Kim [44] observed that individuals with good quality sleep (PSQI>5) consumed a higher proportion of calories derived from protein compared to those with poor sleep quality. However, this assertion should also be interpreted with caution, because since obtaining tryptophan from a protein diet may not always be an effective way to induce better sleep [57]. On both days assessed, total protein intake of the participants was 50–70% above recommended levels for healthy women in the same age group [42]. This result contradicts findings of other observational studies, in which night shift work was associated with lower protein intake [11,18]. This disparity might be explained by irregular eating habits with high consumption of snacks, which often incorporate processed meat products. Although a rich source of protein, these products are of low nutritional quality.

Clinically controlled trials assessing the impact of macronutrients, especially proteins and fats, on objective sleep parameters are scarce. However, the trials available indicate that proteins or amino acids promote improvement in both duration and quality of sleep, where these effects were observed after administration of pharmacological doses of the nutrients [59]. Regarding a high-protein diet, Santana et al. [60] reported conflicting results, identifying a negative correlation between sleep duration and protein intake. The authors suggested a high-protein diet promoted high plasma levels of amino acids (valine, tyrosine, isoleucine, leucine and phenylalanine), possibly competing with tryptophan for transport via the blood-brain barrier and reducing its availability for conversion into sleep-inducing neurotransmitters. In addition, as is true for fats, the type of protein consumed should be considered, given that no food provides a single nutrient.

4.4. Meal timing

Conflicting results for diet composition and its impact on sleep parameters may also be associated with an aspect which has been the focus of increasing research, particularly with respect to assessing eating patterns in night workers: the timing of meals. In the present study, no difference in calorie intake was found between work-day and day-off. Nevertheless, a change in distribution of meals during the 24-hour day may take place as a result of night work [55]. Studies show that night workers consume a larger proportion of total calorie intake during shifts [18, 61] and that ingestion during the biological night hampers glucose metabolism and maintaining a healthy body weight [62–64]. Although this aspect was not investigated, we may speculate that, besides composition, the timing of meals may also impact sleep parameters, particularly in a sample of chronically desynchronized permanent night-shift workers. A Brazilian study with nurses from eighteen public hospitals in Rio de Janeiro shows that the years of exposure to night work increases the BMI, this assertion evidence that night shift has a greater risk of being overweight or obese in compare with non-shift workers [65].

The present study has some limitations. Moreover, disparities in the instruments employed to collect diet composition data may also have contributed to this heterogeneity in results. In the present study, food diaries were used, having the advantage of minimizing memory bias, in as far as logs are recorded shortly after consumption of the foods. Also, the ability to provide in-depth information on eating patterns yields a more accurate estimate of usual intake over a given timeframe [11, 66]. However, it is important to note while participants had been instructed to take the diary on typical days, there is no guarantee the distribution of macronutrients recorded represents the individual´s normal eating pattern.

Another aspect which should be emphasized is that the study involved only permanent night workers, where results cannot be extrapolated to represent other working times. Differences such as work place and type may also exist within the group of female night workers studied and likewise among males. In the present study, meals at dinner and breakfast times were subsidized by the hospital. In addition, each facility had a mini-kitchen allowing access to other foods, with workers bringing in their own food items from home or purchasing these from outside delivery services during the work shift. Lack of control of potential factors relevant to sleep, such as the abusive use of the internet and social media is a limitation as well. Recent studies show a strong association between internet use and sleep problems, and this is a factor that should be controlled in future studies [67–69]. Another limitation is a potential sex effect since this study was conducted only with women. Therefore, its results should not be extrapolated to men.

Although the study design precluded determining the temporal relationship among the variables assessed, the investigation contributes by elucidating the study objective. Although still incipient, dietary interventions for the prevention and treatment of diseases caused by circadian desynchronization have shown promising results. In addition, other occupational interventions to improve sleep involving cognitive behavioral therapy and occupational therapy [70–72] could be proposed for shift workers.

5. Conclusions

Short sleep duration was found to be associated with greater animal protein intake on days off. Moreover, greater intake of carbohydrate occurred in later hours both in the work-day and the day-off. Some trends in association between the study variables were also observed, which highlights the need for other studies to investigate them.

Ethics statement

This study was approved by the Research Ethics Committee of the School of Public Health of the University of São Paulo (number 2.450.682) and by the equivalent committee of the hospital studied (number 2.489.636). The protocol of the clinical trial is registered at the World Health Organization's International Clinical Trials Registry Platform (UTN n° U1111–1238–7395) and the Brazilian Registry of Clinical Trials (ReBEC – RBR-6pncm9).

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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