New Research

JCSM
Journal of Clinical Sleep Medicine

http://dx.doi.org/10.5664/jcsm.1476

Relationship between Food Intake and Sleep Pattern in Healthy Individuals

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SCIENTIFIC INVESTIGATIONS

Study Objectives: The purpose of this study was to analyze the relationship between food intake and sleep patterns in healthy individuals.

Methods: Fifty-two healthy volunteers (27 women and 25 men) were recruited to participate in the study. Volunteers underwent sleep evaluation through nocturnal polysomnography and completed a 3-day food diary to evaluate food intake.

Results: No differences in sleep patterns were observed in either gender, except in the percentage of stage 1 sleep, which was greater in men. Different correlations were observed between sleep and dietary variables according to gender. The correlation between dietary and sleep variables in men indicated a negative relationship between nocturnal fat intake and the sleep latency, including REM sleep. The percentage of nocturnal fat intake correlated with sleep efficiency, sleep latency, REM latency, stage 2 sleep, REM sleep, and wake after sleep onset (WASO) in women. The percentage of nocturnal caloric intake correlated with sleep latency and efficiency in women.

Conclusions: We conclude that food intake during the nocturnal period is correlated with negative effects on the sleep quality of healthy individuals. Indeed, food intake near the sleeping period (dinner and late night snack) was negatively associated with sleep quality variables. More studies are necessary to elucidate the real effect of food intake on sleep.

Keywords: Sleep, food intake, sleep quality, nocturnal caloric intake

Citation: Crispim CA; Zimberg IZ; dos Reis BG; Diniz RM; Tufik S; de Mello MT. Relationship between food intake and sleep pattern in healthy individuals. *J Clin Sleep Med* 2011;7(6):659-664.

Obesity is becoming a worldwide epidemic.[1] The etiology of this disease is multifactorial; among the causes are changes in food intake,[2] life style, environment,[2,3] and genetics,[4,5] in addition to physiological[6] and psychological[7] influences and, more recently, alterations in sleep patterns.[8-11]

Sleep curtailment has become common due to the demands and opportunities of modern society.[12] Recent studies show that alterations in sleep time can influence various aspects associated with the nutritional and metabolic balance of the body, such as the control of body mass,[9,11] food intake,[10,13] glycemic levels,[14,15] and the levels of cholesterol and triacylglycerol.[16] Although some studies show that short duration sleep changes the food intake pattern and may cause obesity,[9-11] few studies have analyzed whether the opposite casual sequence also occurs; that is, if food intake promotes alterations in the sleep pattern. Indeed, studies that have examined this matter are controversial and use different methodologies. Some studies indicate an impairment of sleep quality when there is an excessive carbohydrate intake.[17,18] Driver et al.,[19] however, comparing the effect of an evening meal on nocturnal sleep in seven healthy men, did not find any effect. Therefore, this study proposes to analyze the correlation between habitual food intake and sleep patterns in healthy individuals.

BRIEF SUMMARY

Current Knowledge/Study Rationale: Few studies have analyzed if food intake promotes alterations in the sleep pattern. Therefore, the objective of this study was to analyze the correlation between habitual food intake and sleep patterns in healthy individuals.

Study Impact: This study demonstrated that a higher food intake close to the sleeping period is associated with negative aspects of sleep patterns in healthy individuals, especially in women. However, this is an area poorly explored in the literature, and more studies are necessary to elucidate the real influence of food intake upon sleep.

METHODS

Sample

Fifty-two healthy volunteers (27 women and 25 men) between 19 and 45 years old took part in this study. The participants were young adults and were non-obese. They were sedentary and not taking medication. They were all nonsmokers and spent regular times in bed at night (7.5-8.5 h). The subjects did not suffer from sleep disturbances (apnea and hypopnea index [AHI] < 5, and periodic leg movements [PLM] during sleep were < 5, as assessed by polysomnography).[20,21] Volunteers were submitted to a clinical examination including blood, urine, and electrocardiogram tests, which were evaluated by a physician who approved their participation in the study. Enrolment was voluntary, and the subjects were informed of the procedures and objectives of the study.

The study was approved by the Committee of Ethics in Research of the Federal University of São Paulo (0019/08). After participants were informed about all the stages of this study and gave their written informed consent.

Food Intake Evaluation

Food intake was determined through a self-administered food diary for 3 non-consecutive days, filled in immediately before the evaluation by polysomnography (PSG). Volunteers were instructed to provide as much detail as possible about the foods and fluids consumed, including brand names and recipes for home-cooked foods. Portion sizes were estimated using common household measurements such as cups, glasses, bowls, teaspoons, and tablespoons in addition to individual food items/units. The diaries were inspected by a researcher together with the subjects to obtain additional explanations and detail, if required. The Nutwin version 1.5 software (University of São Paulo, Brazil, 2002) was used for the quantitative analyses of caloric and macronutrient intakes. At the end of the study, all volunteers received a report containing the analyzed data from their food diary and individual nutritional guidance.

Sleep Evaluation

Volunteers arrived at the sleep laboratory at 21:30 for electrode attachment and went to bed at 23:00. Sleep parameters were recorded by means of 2 PSGs in the laboratory. The PSG was recorded using an EMBLA S7000 digital system (Embla Systems Inc, Medcare Flaga, Reykjavik, Iceland) in 30-sec epochs.

Electroencephalographic recordings were performed according to the international 10-20 system.[22] Four channels were used for the electroencephalogram (EEG), 2 channels for the electrooculogram, and 2 channels for the electromyogram (submental and legs). The PSG used a thermistor and a nasal cannula to monitor the airflow, belts to monitor thoracic and abdominal effort, transcutaneous oximetry to record oxygen saturation, and a sensor tracking the position of the trunk during sleep.

Interpretations of the PSG were performed according to standard criteria for sleep classification.[23] Analyses included measures of total sleep time (TST), sleep latency, REM sleep latency, sleep efficiency, stages N1, N2, and N3 of NREM sleep and REM sleep, wake after sleep onset (WASO), AHI, oxygen saturation, and PLM. In the results section, data were compared with normative data recommended by Carskadon and Dement.[24]

Except for periods of exercise and PSG monitoring, the volunteers were asked to go about their normal daytime activities. They were instructed to refrain from any extra exercise, evening tea or coffee, all alcohol, and naps. Adherence to these requests was assessed in the pre-PSG questionnaire.

Anthropometric Evaluation

Body mass and height were measured before the polysomnography examination. For the evaluation of height, a Sanny stadiometer with 0.1 cm precision (American Medical do Brasil,Ltd, Brazil) fixed to the wall was used. A Filizola scale (Star, Filizola, Brazil) with 0.1 kg precision was used to measure body mass. Body mass index (BMI) was calculated by dividing the body weight (in kilograms) by the height (in meters) squared (BMI = weight/height^2). All measurements were determined according to the recommended techniques.[25]

Statistical Analysis

All values were expressed as the mean ± standard deviation (SD) or the mean and 95% confidence intervals. Student's *t*-tests for independent samples were used for gender comparison between anthropometric, nutritional, and sleep characteristics. Pearson correlation coefficient was used to assess the association of sleep parameters with food intake. Associations between sleep duration and nutritional intake were further analyzed using multiple regression analysis adjusted for age, gender, BMI, and socioeconomic status. The results from the regression analysis are presented as β-values with P-values. The data were analyzed using Statistica 6.0 (StatSoft, Inc., Tulsa, OK, USA). Statistical tests with $p \leq 0.05$ were accepted as significant.

RESULTS

Fifty-two participants (25 men and 27 women) completed all measurements. The characteristics of the participants are presented in **Table 1**. Men had significantly greater body mass, height, BMI, and caloric intake than women (**Table 1**).

The data for the observed PSG measures by gender appear in **Table 1**. Men had a significantly higher percentage of N1 sleep than did women. Although there were no statistically significant differences between genders, the percentage of waking after sleep onset was higher and REM sleep was lower than normative data. Women had reduced total sleep time (≤ 6 h) in comparison with normative data.

The correlation between dietary and sleep variables (**Table 2**) in men indicated a negative association between nocturnal fat intake, and sleep efficiency, and REM sleep, and a positive association between nocturnal fat intake, and sleep latency, REM sleep latency, N2 sleep, and WASO. In women, there were positive associations between sleep latency and caloric, protein, carbohydrate, and fat nocturnal intake; REM sleep latency and caloric, carbohydrate, and fat nocturnal intake; N2 sleep and caloric, carbohydrate, and fat nocturnal intake; and WASO and caloric, and fat nocturnal intake. In women, negative associations were found between sleep efficiency and caloric, carbohydrate, and fat nocturnal intake, and REM sleep and nocturnal fat intake.

When analyzing the influence of each meal on the sleep variables, we observed that caloric intake in a night (represented as percent of total caloric intake, %) correlated positively with sleep latency in women ($r^2 = 0.45$; $r = 0.67$, $p < 0.001$) ($n = 15$) but not in men (**Figure 1**). Indeed, caloric intake in a night (%) correlated negatively with sleep efficiency in women ($r^2 = 0.26$; $r = -0.51$, $p = 0.007$) ($n = 15$) (**Figure 2**) but not in men.

DISCUSSION

This study demonstrated that food intake, mainly in the evening period, is correlated with several variables related to sleep patterns (sleep efficiency, sleep latency, N2 sleep, REM sleep

Table 1—Nutritional and sleep characteristics of volunteers according to gender*

	Men (n = 25)		Women (n = 27)		
	Mean ± DP	**95% CI**	**Mean ± DP**	**95% CI**	**p value**
Age (yr)	27.2 ± 5.9	24.8 – 29.6	28.8 ± 6.6	26.2 – 31.4	0.37
Anthropometric Variables					
Body mass (kg)	76.6 ± 14.7	70.5 – 82.6	58.0 ± 8.3	54.7 – 61.2	< 0.01
Height (m)	1.75 ± 0.1	1.72 – 1.78	1.61 ± 0.1	1.59 – 1.64	< 0.01
BMI (kg/m²)	24.9 ± 4.2	23.2 – 26.6	22.2 ± 2.6	21.2 – 23.2	0.01
Dietary Variables					
Caloric intake					
kcal/day	2697.6 ± 870.6	2338.3 – 3057.0	1865.5 ± 502.1	1666.9 – 2064.1	< 0.01
Macronutrients (g)					
Protein	108.3 ± 30.1	95.9 – 120.8	73.2 ± 17.3	66.4 – 80.0	0.15
Carbohydrate	359.2 ± 161.8	292.4 – 425.9	247.4 ± 78.1	216.5 – 278.3	0.33
Fat	92.0 ± 27.2	80.7 – 103.2	64.8 ± 23.8	55.4 – 74.2	0.44
Macronutrients (%)					
Protein	16.6 ± 3.9	15.0 – 18.2	16.6 ± 5.4	14.4 – 18.7	0.95
Carbohydrate	51.9 ± 8.2	48.5 – 55.3	52.8 ± 5.3	50.7 – 54.9	0.64
Fat	31.5 ± 5.9	29.0 – 33.9	30.7 ± 5.2	28.6 – 32.7	0.60
Sleep Variables					
Total sleep time (min)	369.2 ± 40.2	352.6 – 385.9	353.7 ± 78.7	322.6 – 384.8	0.37
Sleep efficiency (%)	87.3 ± 6.8	84.5 – 90.2	87.8 ± 7.9	84.7 – 90.9	0.82
Sleep latency (min)	16.5 ± 15.5	10.2 – 23.0	11.3 ± 11.3	6.8 – 15.8	0.16
REM latency (min)	95.9 ± 40.7	79.1 – 112.8	99.8 ± 49.2	80.3 – 119.3	0.75
N1 (%)	3.8 ± 2.2	2.9 – 2.2	2.6 ± 1.8	1.9 – 3.3	0.03
N2 (%)	55.0 ± 6.6	52.4 – 57.8	53.1 ± 7.9	50.0 – 56.3	0.34
N3 (%)	23.1 ± 6.5	20.5 – 25.9	24.6 ± 6.3	22.1 – 6.3	0.41
REM (%)	17.9 ± 4.6	16.0 – 19.8	19.6 ± 5.1	17.7 – 21.7	0.19
WASO (min)	37.3 ± 25.7	26.7 – 47.9	38.0 ± 28.7	26.7 – 49.4	0.92

*All values are mean ± SD and 95% CI. BMI, Body Mass Index; REM, rapid eye movement; WASO, wake after sleep onset.

latency, REM percentage, and WASO). These results indicate that a higher food intake close to the sleeping period is associated with negative aspects of sleep patterns in healthy individuals, especially in women. Studies have shown pronounced gender differences in the occurrence of sleep disorders.[26,27] It has been suggested these differences in sleep, while subtle under baseline conditions, may increase in magnitude under biological or environmental challenges.[26,27] However, the role of food intake pattern in these differences is unknown, and further research should examine this relationship.

There is evidence that an adequate sleep pattern acts to protect against a series of nutritional and metabolic disorders such as obesity,[28,29] dyslipidemia,[16] diabetes, and insulin resistance.[30,31] These disorders probably occur because sleep plays an important role in the metabolic control of the body.[10,11] Therefore, alterations in the quantity and quality of sleep lead to hormonal disturbances; these might be capable of altering the physiological homeostasis and consequently generate diseases.[10,11]

According to our results, high caloric food intake preceding the sleeping period was correlated with greater sleep latency in women (nocturnal caloric intake correlated positively with sleep latency). In general, this meal took place between 30 and 60 minutes before the volunteers went to bed. Contrary to previous studies,[18,19] our results suggest that intake of high fat and carbohydrate foods preceding the sleeping period are associated with higher sleep latency. Other studies[19,20] have demonstrated that individuals who ingested a high-glycemic index, carbohydrate-rich meal 4 hours prior to sleep presented a decrease in sleep latency. In addition to the amount of carbohydrates, the glycemic index may have an important influence on sleep patterns, especially in inducing sleepiness. Different types of fat have also been shown to influence sleep. Grandner et al. found that actigraphic nocturnal sleep duration was negatively associated with total fat, monounsaturated fat, trans fat, saturated fat, and polyunsaturated fat, and that higher intakes of fat were associated with less sleep and subjective napping.[32]

Another factor that could have influenced our findings is that increased gastric volume leads to greater physical discomfort and thus impairs the consolidation of sleep onset. It has been demonstrated that sleep decreases the activity of the digestive tract,[33] which may have an overloaded activity during the night if food intake is excessive.

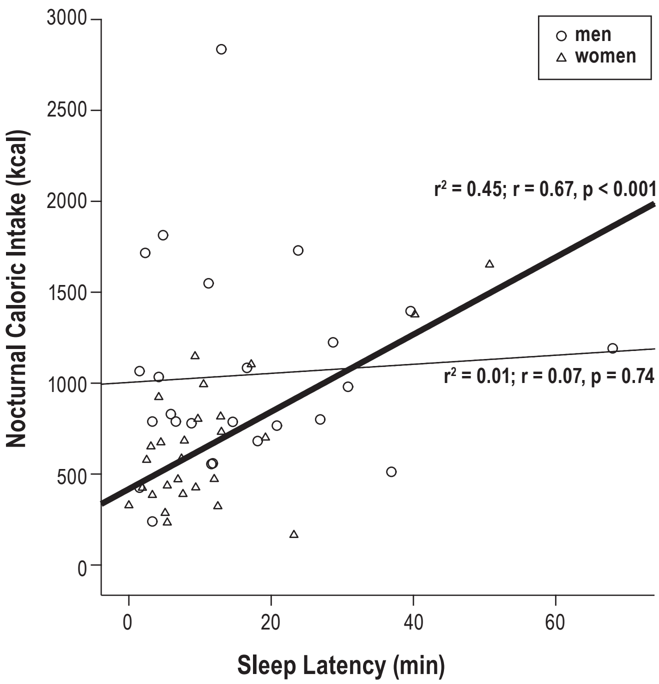
Data from this study suggest that individuals who consume meals with increased fat content in the nocturnal period seem predisposed to have decreased REM sleep. Indeed, previous studies have shown that individuals who ingested a fatty meal

Table 2—Association between nocturnal intake and sleep pattern[a,b]

Variable		Nocturnal Intake (dinner + late-night snack) Calories (kcal)	Protein (g)	Carbohydrate (g)	Fat (g)
Total sleep time (min)	β value	-0.01	-0.03	0.03	-0.72
	p value	0.67	0.95	0.82	0.18
Sleep efficiency (%)	β value	-0.004	-0.06	-0.01	-0.17
	p value	0.09	0.34	0.73	0.004
Sleep latency (min)	β value	0.01	0.18	0.03	0.21
	p value	0.06	0.11	0.33	0.07
REM latency (min)	β value	0.03	0.69	0.06	1.25
	p value	0.03	0.06	0.51	0.001
N1 (%)	β value	-3.00	0.02	-0.00	0.01
	p value	0.96	0.19	0.39	0.44
N2 (%)	β value	0.003	0.04	0.01	0.13
	p value	0.12	0.51	0.36	0.03
N3 (%)	β value	0.00	0.00	0.00	-0.02
	p value	0.91	0.94	0.90	0.69
REM (%)	β value	-0.00	-0.06	-0.01	-0.12
	p value	0.04	0.11	0.25	0.002
WASO (min)	β value	0.01	0.12	-0.00	0.55
	p value	0.21	0.56	0.99	0.01

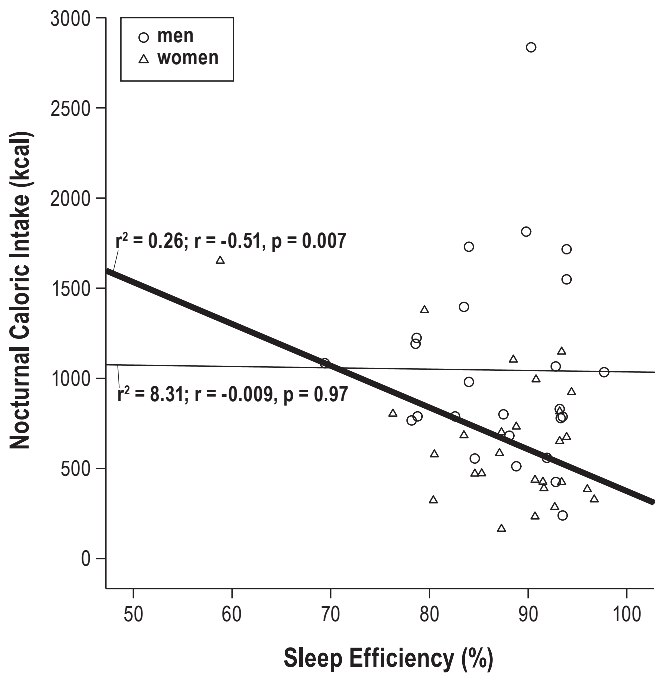
[a]Results are presented as adjusted estimated β values with p values. [b]β values are adjusted for age, gender, economical status and BMI. REM, rapid eye movement; WASO, wake after sleep onset.

Figure 1—Relationship between nocturnal caloric intake and sleep latency



Circles represent men and triangles represent women. Linear regression and Pearson's correlation coefficient are shown in each gender best fitting line: men, thinner line; women, thicker line.

Figure 2—Relationship between nocturnal caloric intake and sleep efficiency



Circles represent men and triangles represent women. Linear regression and Pearson's correlation coefficient are shown in each gender best fitting line: men, thinner line; women, thicker line.

felt sleepier.[34,35] However, there are no studies associating food intake and sleep stages; thus a comparison with our results is not possible.

One issue to consider is the possibility that nocturnal food intake leads to deterioration in sleep patterns and can cause metabolic and nutritional problems. It is widely documented in the literature that changes in sleep patterns can alter the sensations of hunger and appetite and consequently lead to increased body mass.[10,11] On the other hand, we showed recently that fat intake at night is associated with higher values for body fat percentage, body mass index, and waist circumference.[36] This leads us to believe that the mechanism by which nocturnal food intake may trigger an increase in body mass can be modulated by sleep.

Further studies in this area should explore the effect of energy density (the amount of energy in a given weight of food), not just the calorie content, on the sleep patterns of both genders individuals. Studies have indicated that people tend to consume a fairly consistent weight of food over the course of a few days; therefore, the consumption of low-energy-dense foods that contain less energy per gram may decrease overall energy intake.[37] However, the real effect of energy density on sleep patterns is unclear. Consuming water- and fiber-rich foods such as fruit and vegetables is one strategy for decreasing the energy density of the diet.[38] It would be of great interest to understand whether this strategy would promote an effect on sleep patterns.

This study indicates that food intake, primarily preceding sleep, seems to exert a negative influence on sleep quality. However, our research had some limitations, such as the small number of participants. Therefore, more studies are needed, on a larger sample and wider range of individuals; evidence from older people is also required because age may affect sleep and nutrition patterns**.** There is also prominent response-set bias evident in the answers to methods used to investigate food intake. Volunteers may alter their diet records due to social desirability (the tendency to respond in such a way as to avoid criticism) and social approval (the tendency to seek praise).[39] Indeed, this is an area poorly explored in the literature, and more studies are necessary to elucidate the real influence of food intake upon sleep.

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ACKNOWLEDGMENTS

This study was supported by the AFIP, The Sleep Institute, CEDIP/FAPESP (#998/14303-3), CEPE, UNIFESP, FADA, CAPES, CEMSA and CNPQ. The authors thank all volunteers and researchers involved in this study.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication December, 2010
Submitted in final revised form July, 2011
Accepted for publication July, 2011
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DISCLOSURE STATEMENT

This was not an industry supported study. The authors have indicated no financial conflicts of interest.