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Contribution of evening macronutrient intake to total caloric intake and body mass index

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Abstract

The goal of this study was to evaluate the relationship between sleep timing and macronutrient intake as an approach towards better understanding of how sleep and eating affect weight regulation. Fifty-two volunteers (25 women) completed 7 days of wrist actigraphy and food logs. “Average sleepers” (56%) were defined as having a midpoint of sleep <5:30 am and “late sleepers” (44%) were defined as having a midpoint of sleep ≥5:30 am. Data were analyzed using t-tests, correlations and regression. Late sleepers consumed a greater amount of protein fat and carbohydrates in the evening (defined as after 8:00 PM) but less fat in the 4 hours before sleep. Total protein, protein, carbohydrate, and fat consumed after 8:00 PM, protein consumed within 4 hours of sleep as well as the percentage of fat consumed after 8:00 were associated with higher BMI. The amount of protein and carbohydrates consumed within 4 hours of sleep and the amount and percentage of carbohydrate and fat consumed after 8:00 PM were associated with greater total calories. In multivariate analyses controlling for age, gender, sleep timing and duration, protein consumed 4 hours before sleep was associated with BMI; carbohydrates consumed after 8 pm, protein and carbohydrates consumed 4 hours before sleep were associated with higher total calories. Results indicate that evening intake of macronutrients and intake before sleep are not synonymous, particularly among late sleepers. Eating in the evening or before sleep may predispose individuals to weight gain through higher total calories.

Keywords

Sleep; sleep timing; diet composition; macronutrients; body mass index

There has been increasing research investigating the role of sleep in metabolism and weight regulation. The majority of the current literature has focused on sleep duration. Short sleep duration has been associated with increased risk for obesity in cross sectional studies as well as weight gain in longitudinal studies (Gangwisch, 2009; Patel, Malhotra, White, Gottlieb, & Hu, 2006). Curtailing sleep experimentally for 6 days lead to an increase in subjective

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hunger and appetite as well as changes in appetite regulating hormones (Spiegel et al., 2004). Results of another study demonstrated that 5 days of sleep curtailment increased caloric intake, particularly from fat, but did not alter energy expenditure (St-Onge et al., 2011). In a longer study, 14 days of sleep curtailment led to increased intake of calories from snacks (Nedeltcheva, Kilkus, Imperial, Schoeller, & Penev, 2010).

Sleep timing, in addition to sleep duration, may also affect eating patterns and weight regulation (Ruger & Scheer, 2009). Shift work alters the timing of both meals and sleep and has been associated with an increased risk for weight gain and metabolic disease (Antunes, Levandovski, Dantas, Caumo, & Hidalgo, 2010). However, these alterations in sleep timing also lead to shorter sleep durations in shift workers, making it difficult to determine the independent effects of sleep timing. Only a few studies have examined the relationship between sleep timing with energy intake, metabolism and weight regulation. In a study conducted by Buxton and colleagues, individuals were exposed to three weeks of curtailed sleep in the laboratory (5.5 hours) as well as circadian disruption (28 hour day). As a result, participants demonstrated a decrease in resting metabolic rate, and decreased insulin secretion in response to a meal (Buxton et al., 2012). In one study that evaluated circadian misalignment using forced desynchrony, participants demonstrated decreased leptin and higher glucose despite having higher insulin when their sleep/wake was scheduled 12 hours out of phase (Scheer, Hilton, Mantzoros, & Shea, 2009).

In observational studies of sleep timing, individuals with late sleep timing have reported poorer dietary behavior, including higher fat, caffeine and fast food consumption (Fleig & Randler, 2009; Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002; Sato-Mito, Sasaki, et al., 2011; Sato-Mito, Shibata, Sasaki, & Sato, 2011). We previously demonstrated late sleepers (defined as midpoint of sleep > 5:30 am) have later meal timing as well as poorer diet quality (including more fast food meals and fewer fruits and vegetables) compared with average sleep times (Baron, Reid, Kern, & Zee, 2011). Furthermore, our data revealed that the timing of eating (calories consumed after 8:00 PM) was associated with higher BMI, even when controlling for sleep timing and duration, suggesting the effects of timing of eating were greater than sleep timing for BMI. A limitation to our previous study is that it did not include analysis of macronutrients across the day, which may play an important role in weight regulation and provide further information about dietary behavior. For example, a study conducted in mice demonstrated that excess energy intake, via a high fat diet, can lengthen circadian period and disrupt diurnal feeding patterns (Kohsaka et al., 2007). Therefore, there is reason to believe that increased evening caloric intake, in particular fat, may affect circadian timing itself.

The goal of this study was to evaluate the associations between timing of sleep and macronutrient intake with body mass index (BMI) and total caloric intake. We evaluated both evening intake (intake between 8:00 PM and 4:59 AM) as well as the 4 hour period before sleep onset.

Methods

Participants

Data from this study was drawn from a larger study of circadian rhythms. Participants were recruited from the community through advertisements. This study was approved by the Northwestern University Institutional Review Board and all participants provided written informed consent prior to enrollment. This analysis included only individuals who reported an evening or intermediate (neither evening nor morning) diurnal preference. Those with a morning type diurnal preference were excluded from analyses due to low numbers. None of the participants reported shift-work jobs. Additional exclusionary criteria included elevated

depressive symptoms, as indicated by a score > 20 on the Center for Epidemiologic Studies Depression Scale (Radloff, 1977).

Procedure

Participants underwent preliminary telephone or internet screening to determine eligibility and willingness to participate in the study. After informed consent, eligible participants were provided with 7 days of food logs, sleep logs, and a wrist actigraph which was worn for at least 7 days. Participants were asked to list a description of each food (quantity, preparation, name brand etc.), the time and location of the meal or snack. Participants also completed a sleep log and wore an actigraph (AW-L Actiwatch, Mini Mitter Co. Inc., Bend, OR) to determine sleep and wake timing, sleep duration, and sleep quality.

Measures

Diurnal preference was measured by the Horne Ostberg Morningness Eveningness Questionnaire. Scores on this 19 item scale range from 16–86, with higher scores indicating greater preference for morning. Questions assess individual preferences for sleep/wake times including “Considering your own ‘feeling best’ rhythm, at what time would you get up if you were entirely free to plan your day?”. Adequate internal consistency has been reported for this measure ($\alpha=.86$) (Horne & Ostberg, 1976). Horne Ostberg scores have been demonstrated to be correlated with measures of circadian timing, such as body temperature (Kerkhof & Van Dongen, 1996; Ostberg, 1973).

Participants were screened for depressive symptoms using the Center for Epidemiologic Studies-Depression Scale (Radloff, 1977). Adequate internal consistency has been reported for this widely-used 10-item questionnaire (Radloff, 1977).

Body Mass Index (BMI) was calculated as kg/m^2 based upon self-reported height and weight.

Sleep Timing and Duration

Sleep timing and duration were assessed using sleep logs and wrist actigraphy (AW-L Actiwatch, Mini Mitter Co. Inc., Bend, OR). Sleep logs included bed time, sleep time, awakenings during the night, and wake time. Actigraphy data was analyzed using Actiware-Sleep 3.4 software (Mini Mitter Co. Inc., Bend, OR) using a medium activity threshold for sleep. Rest intervals in Actiware were set using sleep logs (bedtime and wake time). The following variables were determined from actigraphy: sleep start (sleep onset), sleep end (final wake time), and objective sleep time (total sleep time). Sleep start was defined as the first 10 minute period in which no more than one epoch was scored as mobile. Sleep end was defined as the last 10 minute period in which no more than one epoch was scored as immobile. Objective sleep time was defined as the amount of time between sleep start and sleep end that was scored as sleep. As a measure of sleep timing, we calculated midpoint of sleep based on the average of the sleep start and sleep end for the 7 day period. In categorical analyses, participants were classified as having average sleep times if midpoint of sleep was between 1:00 am to 5:29 am, and participants were classified as having late sleep times if midpoint of sleep was 5:30 am or later, which is past the 50th percentile of sleep times in the population (4:00 am) (Roenneberg et al., 2007) and comprises nearly half of our sample, allowing for power to conduct categorical analyses.

Sleep logs and actigraphy were conducted during the same 7 days as the food logs in all but four participants. For these four participants, we used actigraphy data from within the same month as the food logs to calculate sleep times but we did not calculate relationships between sleep times and meal times because actigraphy was conducted on different days. In

addition, four participants were missing actigraphy but not food log data: 2 due to equipment failure, one participant was non-compliant with the actigraph and one participant did not have valid actigraphy data for a month before or after the food log. Despite not having actigraphy data, we were able to estimate sleep times based on sleep logs and assign these participants as average or late sleepers for the categorical analyses using the sleep log data in three of these four participants because they clearly fell into a category based on self-reported sleep times. One participant could not be classified as an average or late sleeper due to lack of both sleep logs and actigraphy data, and was therefore excluded in the sleep timing analyses.

Dietary Assessment

Diet was analyzed using food logs because our primary interest was meal timing and pattern, which required multiple assessments, as opposed to a 24-hour recall or food frequency questionnaire (De Castro, 1994). Participants recorded in a food log all food and beverages consumed for a 7 day period. They were asked to record the time the food or beverage was consumed, meal (breakfast, lunch, dinner, or snack), type of food with brand name if possible, the location of the meal or snack (i.e. home or restaurant), portion size, and whether it was a day they consumed less than a typical diet, more than a typical diet, or a typical diet. Participants were provided with paper diet logs as well as instructions on how to complete the logs and a guide to serving size estimation.

Meals were classified as breakfast, lunch, dinner or snacks based upon the diet log. Meals listed as “brunch” were considered neither, and included only in the total nutrition analyses for the day and not a meal type. Logs were considered valid if there were at least 2 weekdays and 1 weekend days completed. Dietary logs were also considered incomplete if total calories per day were <500. Using these criteria, only one participant was removed from the analyses. If participants had fewer than 7 days recorded, all of the available data was used; alternatively, if an excess of seven days were completed, the investigators used the first seven consecutive days that best coincided with actigraphy recordings. In the case of conflicting data, such as a breakfast time listed prior to a wake time, calorie information was utilized but meal time was omitted.

Calories and grams of carbohydrate, fat and protein in each meal was analyzed using publicly available nutrition information as well as restaurant and manufacturer websites. Macronutrients and calories in the evening were defined as consumption after 8:00 PM, since this has previously been reported as the average time of maximum caloric intake for the day (Boston, Moate, Allison, Lundgren, & Stunkard, 2008). The proportion of macronutrients consumed after 8:00 PM was also calculated, in order to adjust to energy intake. Finally, we calculated the grams of carbohydrates, fat and protein within 4 hours of sleep (as determined by actigraphy). We chose 4 hours because this was the average duration between last meal or snack and sleep onset.

Statistical Analysis

Data were analyzed using SPSS (v17.0). We first conducted bivariate correlations and t-tests for independent means to determine the univariate relationships between sleep timing and diet composition for the entire day as well as intake after 8:00 PM (both total grams and proportion of total intake). Then, we conducted multivariate regression analyses controlling for age, gender, sleep duration, and sleep timing to determine the independent associations of timing of macronutrients with BMI and total caloric intake. Significance was determined as .05 on two tailed tests.

Results

Participants

Characteristics of the participants are listed in Table 1. The sample included 52 individuals, approximately half were male and the majority of participants (71%) identified their race/ethnicity as non-Hispanic white. Demographic and sleep characteristics of the sample based on sleep timing groups are listed in Table 2. There was no difference between sleep timing groups in age or in gender distribution. The late sleepers group had later sleep onset ($p < .001$), offset ($p < .001$) and midpoint of sleep ($p < .001$). In addition, the late sleeper group had shorter sleep duration ($p < .001$).

Total Macronutrient Intake and Intake by Meal

There were no significant differences between average and late sleepers in total carbohydrate, fat or protein (Table 3). There were few differences in the macronutrient intake per meal between average and late sleepers (data not listed). Late sleepers had more protein ($p < .01$) at dinner and more protein, fat and carbohydrates consumed after 8:00 PM. Despite higher fat intake after 8:00 PM, late sleepers consumed less fat in the 4 hours before sleep ($p < .01$).

Associations among BMI, Total Caloric Intake and Macronutrient Intake

Correlations between BMI, total calories, sleep duration and timing macronutrient totals, macronutrients consumed after 8:00 PM and within 4 hours of sleep, are listed in Table 4. Total protein ($p < .05$) intake of carbohydrates ($p < .05$), fats ($p < .05$) and protein ($p < .01$) after 8:00 PM and protein consumed within 4 hours of sleep ($p < .05$) were associated with higher BMI. In addition, later sleep timing (later midpoint of sleep) and shorter sleep duration were associated with higher total protein intake as well as higher intake of all three types of macronutrients after 8:00 PM (p values $< .01$). Sleep timing and duration were not associated with macronutrient intake within 4 hours of sleep. Higher intake of macronutrients after 8:00 PM was associated with higher total calorie intake ($p < .001$).

The associations between the proportion of carbohydrate, fat, and protein consumed after 8:00 PM and within 4 hours of sleep were also evaluated (not listed). Consuming a greater proportion of fat after 8:00 PM was associated with higher BMI ($r = .30$, $p < .05$), and higher total calories ($r = .32$, $p < .05$). A higher proportion of carbohydrates after 8:00 PM was also associated with higher total calories ($r = .30$, $p < .05$). The proportion of macronutrients consumed within 4 hours of sleep was not associated with BMI or total calories.

In multiple regression analyses controlling for age, gender, sleep duration and sleep timing, protein consumed 4 hours before sleep was positively associated with BMI ($\beta = .31$, $p = .03$, $r^2 \Delta = .09$). The relationship between total protein, fat and protein after 8:00 PM with BMI was no longer significant. Carbohydrates after 8 PM ($\beta = .61$, $p < .001$, $r^2 \Delta = .23$), protein 4 hours before sleep ($\beta = .33$, $p = .02$, $r^2 \Delta = .10$) and carbohydrates 4 hours before sleep ($\beta = .29$, $p = .046$, $r^2 \Delta = .07$) remained predictors of total calories. Protein after 8:00 PM, amount and proportion of fat after 8:00 PM were no longer significant predictors of total calories in multivariate models.

Discussion

We previously reported evening caloric intake was associated with higher BMI independent of sleep timing or duration and that evening caloric intake explained the relationship between late sleep timing and BMI (Baron et al., 2011). The goal of this study was to further explore this result by evaluating the associations between sleep timing and the timing of

macronutrients with BMI and total caloric intake among average and late sleepers. As would be expected, we found that late sleepers consumed a greater proportion of protein, fat and carbohydrates in the evening despite similar total consumption. However, when we examined intake in the 4 hours prior to bed, we found that late sleepers consumed less fat at that time, despite higher evening intake (i.e. after 8:00 PM). Our analyses demonstrated that both timing of macronutrient by clock time and hours before sleep had associations with BMI and caloric intake. Protein intake within 4 hours of sleep was the only variable independently associated with BMI after controlling for confounding factors (age, gender, sleep timing, and sleep duration). We also found higher intake of protein and carbohydrates in the 4 hours before sleep as well as carbohydrates after 8:00 PM were associated with total caloric intake, after controlling for confounding variables. These results suggest the timing of macronutrient intake, particularly protein and carbohydrates may predispose individuals to greater caloric intake.

In contrast, a recent study from Japan which included self-reported sleep behavior, BMI, and a survey of dietary behavior data in female students demonstrated women with later sleep timing reported a higher percentage of their energy intake from fats, alcohol, and specific energy adjusted food categories including noodles, confections, fat, oil, and meat as well as a lower percent of energy intake from protein and carbohydrates (Sato-Mito, Sasaki, et al., 2011; Sato-Mito, Shibata, et al., 2011). Differences in the setting of the study (Japan versus USA), the age and sociodemographics (female students only versus young men and women, some students some non-students) and methodological aspects (e.g. food questionnaire versus food logs) are likely to contribute to some of the differences seen between our study and the studies by Sato-Mito.

The finding in our data that higher protein is correlated with BMI may be surprising, especially considering the popularity of low carbohydrate diets for weight loss (e.g. The Atkins, Zone diets). However, this association is consistent with several previous studies that link protein, especially meat consumption to higher BMI and weight gain (Fogelholm, Anderssen, Gunnarsdottir, & Lahti-Koski, 2012). A recent cross-sectional study that collected diet and body measurements in multiple countries including US, Europe, and Asia demonstrated this relationship between higher meat intake and BMI (Shay et al., 2012). Although our analysis did not determine the source of protein, given the typical American diet, it is likely that most protein is animal-based.

The concept of circadian disruption may explain in part why evening caloric intake may affect weight and dietary patterns. Research in animal models suggests animals with disrupted circadian rhythms demonstrate disrupted feeding patterns, and vice versa. In fact, consuming a high calorie diet may contribute to delayed sleep timing; mice fed a high fat diet demonstrated phase delays in locomotor activity, greater irregularity in their feeding patterns as well as changes in circadian gene expression in both central and peripheral rhythms (Kohsaka et al., 2007). High fat feeding has also been associated with increased sleep fragmentation (Jenkins et al., 2006) and altered phase synchronization to light (Mendoza, Pevet, & Challet, 2008). In addition, animals with mutations in CLOCK genes demonstrate hyperphasia, disrupted eating and sleep patterns, as well as obesity, elevated glucose and lipids (Turek et al., 2005). Human CLOCK gene polymorphisms have been also been associated with risk for obesity and excess caloric intake, suggesting circadian disruption, either genetic or environmental, may affect weight regulation (Garaulet et al., 2009, 2010; Sookoian et al., 2008). Taken together, late eating may contribute to or maintain a phase delay, thus perpetuating circadian disruption. Furthermore, phase delays in humans often lead to shorter sleep duration due to the need to rise in the morning at a fixed time for work or school, which confers another risk factor for weight gain in late sleepers (Roenneberg et al., 2007; Roepke & Duffy, 2010; Soehner, Kennedy, & Monk, 2011). This

was demonstrated in our sample in that late sleepers had approximately one hour less of sleep per day.

Short sleep duration itself has also been associated with diet composition. Weiss (2010) reported that shorter sleep duration was related to greater proportion of fat and lower proportion of carbohydrates in adolescents (Weiss et al., 2010). Also, in the Women's Health Initiative, sleep duration and napping were associated with greater fat and caloric intake (Grandner, Kripke, Naidoo, & Langer, 2010). Finally, snacking, preference for fatty foods, and eating out were associated with short sleep duration in a sample of Japanese workers (Nishiura, Noguchi, & Hashimoto, 2010).

In addition to biological factors, there are likely to be environmental factors at play that link later eating times to increased caloric intake and weight gain. For example, late eating may influence the availability of foods and the environment in which meals are consumed. Studies of shift workers have shown that shift work affects access to healthful foods (Stewart & Wahlqvist, 1985). In addition, the social aspects of meal times may also be altered in later sleepers. Timing of meals, if later than family and friends, may lead to greater consumption of convenience foods or fast foods. Our findings are consistent with prior research demonstrating the energy intake and diet composition is more strongly related to social/environmental factors than endogenous factors (Minors & Waterhouse, 1979; Waterhouse et al., 2005; Waterhouse et al., 2004). Using a forced desynchrony protocol, which requires individuals to live under constant conditions on a 28 hour day that progressively moves sleep and wake around the clock, Waterhouse and colleagues demonstrated that appetite and meal composition was related to the amount of time awake, rather than biological time (Waterhouse et al., 2004). For example, individuals would prefer a breakfast type meal as their first meal, even when that meal was occurring at different points in the biological day. Furthermore, social and practical consideration for meal composition has been cited as the most important factors in meal patterns in interviews of eating patterns, above and beyond endogenous factors (Waterhouse et al., 2005). This may explain why late sleepers consume more calories in the evening, and why the majority of those are consumed during times when others are awake, rather than in the 4 hours before sleep. In this study there were low to moderate correlations between macronutrients consumed after 8:00 PM and macronutrients consumed within 4 hours of sleep. Further, consumption after 8:00 PM was associated with sleep timing and duration whereas consumption within 4 hours of sleep was not significantly correlated.

There are limitations to our study that should be taken into account when interpreting then findings. Many of the limitations stem from our sample size, which limits our statistical power to observe associations. The analyses did not control for race or socioeconomic factors, and for gender but were underpowered to fully evaluate gender differences, which have relationships with both sleep and eating patterns (Brandhagen et al., 2012; Cornier, Salzberg, Endly, Bessesen, & Tregellas, 2010; Lauderdale et al., 2006). Participants were recruited for their sleep timing preferences, and were not randomly selected. In addition, our dietary analysis was limited to major categories and did not discriminate fine details, such as types of fat in participants' diets (saturated vs. unsaturated) or sources of protein (e.g. meats versus non-meat protein). Furthermore, approximately 30% of participants who complete any type of dietary assess tend to underreport, through forgetting, inaccurate measurement, and underreporting (Poslusna, Ruprich, de Vries, Jakubikova, & van't Veer, 2009). Finally, we utilized a self-reported measure of BMI. Although respondents tend to overestimate BMI at the lower range and underestimate BMI at the higher range, young and normal weigh adults, such as those included in this study, show relatively less bias (Stommel & Schoenborn, 2009).

Although controlled trials need to be conducted, our results suggest that altering the timing of eating (e.g. reducing night eating or eating before sleep) may be a plausible weight management intervention. Future research using self-reported and observational measures of appetite and eating behavior both in the laboratory and under naturalistic condition will help elucidate some of the cognitive and behavioral mechanisms that link evening caloric intake to increased calories and weight. Furthermore, controlled experiments testing the timing of eating as well timing of food types and macronutrient percentages may help determine specifically such interventions can be optimized. At this time, there is insufficient evidence to recommend reducing one particularly macronutrient over another at a certain time of day or time of the circadian phase (e.g. altering protein before sleep). Despite our findings, other studies have found protein to be associated with greater satiety (Leidy, Armstrong, Tang, Mattes, & Campbell, 2010). Therefore, further research is warranted in this area prior to making recommendations for interventions.

In conclusion, this study demonstrates a difference in the distribution but not overall intake of protein, carbohydrates, and fats associated with sleep timing. Our results suggest timing of eating was more important than timing of sleep in predicting caloric intake and BMI. Consuming calories in the evening, particularly consuming more protein in the 4 hours before sleep, was independently associated with a higher BMI and greater caloric intake, independent of demographic and sleep variables. Therefore, those with late eating, regardless of sleep timing may have weight gain through increased caloric intake.

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Highlights

- We examined macronutrient intake in individuals with average and late sleep times.
- Late sleepers ate more in the evening but did not eat more 4 hours before sleep.
- More protein 4 hours before bed predicted higher BMI independent of sleep.
- Protein and carbs 4 hours before sleep independently predicted higher calories.

Table 1

Participant characteristics (N=52)

	Mean (SD) or N (%)	
Age	31 (12), range 18–71	
Sex	27 Males (52%), 25 (48%) Females	
Race	White (non-Hispanic)	37 (71%)
	Black	4 (8%)
	Asian	6 (12%)
	Hispanic	3 (6%)
	Other	2 (4%)

Table 2

Participant characteristics according to sleep timing

	Average Sleep Timing N= 28	Late Sleep Timing N=23
	M (SD)	M (SD)
Age	33.11 (14.80)	30.04 (9.49)
Sex	13 males, 15 females	13 males, 10 females
BMI	23.7 (3.2)	26.0 (6.9)
Total Activity Counts	277794 (101620)	307752 (81372)
Sleep Onset Time ***	12:32 am (0:54)	3:42 am (1:11)
Sleep Offset Time ***	8:02 am (1:18)	10:47 am (1:29)
Midpoint of Sleep ***	4:08 am (1:00)	7:05 am (1:17)
Objective Sleep Duration ***	6:39 (0:47)	5:43 (1:11)

 $p < .001$ "Average sleepers" were defined as having a midpoint of sleep $< 5:30$ am and "late sleepers" were defined as having a midpoint of sleep $> 5:30$ am. Missing actigraphy data: n=2 equipment malfunction, n=1 participant non-compliance, n=1 actigraphy was not conducted in the same time period as food diary, therefore it was not included. Data from one participant could not be classified as average or late sleeper, therefore only 51 participants are included in categorical analyses.

Table 3**Caloric and Macronutrient Intake by Sleep Timing Group**

	Average Sleep Timing M±SD (%)	Kcal	Late Sleep Timing M±SD (%)	Kcal
Total Energy kcal	1905± 526	--	2153± 524	--
Daily Carbs g (%), kcal	237 ± 81 (49)	948	260 ± 72 (49)	1040
Daily Fat g (%), kcal	78 ± 23 (38),	702	82 ± 24 (35)	738
Daily Protein g (%), kcal	69 ± 21 (14)	276	84 ± 26 (15)	336
Carbs after 8 pm g (%), kcal **	47 ± 31 (19)	188	87 ± 39 (33)	348
Fat after 8 pm g (%), kcal *	16 ± 12 (19)	144	30 ± 17 (35)	270
Protein after 8 pm g (%), kcal **	15 ± 12 (21)	60	32 ± 16 (37)	128
Carbs 4 hours before bed g (%), kcal	33±30 (13)	132	25±28 (10)	100
Fat 4 hours before bed g (%), kcal **	26±30 (33)	234	8±13 (9)	72
Protein 4 hours before bed g (%), kcal	11±9 (16)	44	10± 12 (12)	40

*
 $p < .05$

**
 $p < .01$,

 $p < .001$

Table 4

Correlations among sleep, calories, macronutrients, and body mass index

	BMI	Total Calories	Total Carbs	Total Fat	Total Protein	Sleep Duration	Midpoint	Carbs after 8	Fat after 8	Protein After 8	Carbs 4 hours before bed	Fat 4 hours before bed	Protein 4 hours before bed
BMI	--	.26 [†]	.14	.15	.33 [*]	-.21	.35 [*]	.29 [*]	.32 [*]	.39 ^{**}	.19	.00	.37 [*]
Total Calories		--	.82 ^{***}	.75 ^{***}	.85 ^{***}	-.23	-.11	.56 ^{***}	.60 ^{***}	.68 ^{***}	.36 [*]	.23	.43 [*]
Total Carbs			--	.49 ^{***}	.54 ^{***}	-.07	-.03	.53 ^{***}	.38 ^{**}	.41 ^{**}	.42 ^{**}	.27	.31 [*]
Total Fat				--	.65 ^{**}	-.06	.10	.94 [*]	.61 ^{***}	.43 ^{**}	.41 ^{**}	.24	.37 [*]
Total Protein					--	-.20	.26	.42 ^{**}	.54 ^{***}	.71 ^{***}	.18	.07	.34 [*]
Sleep Duration						--	-.24	-.47 ^{**}	-.50 ^{***}	-.49 ^{***}	-.00	.27	-.21
Midpoint							--	.52 ^{***}	.48 ^{**}	.53 ^{***}	-.07	-.12	.07
Carbs after 8								--	.82 ^{***}	.81 ^{***}	.14	.13	.44 ^{**}
Fat after 8									--	.85 ^{***}	.38 ^{**}	.22	.47 ^{**}
Protein After 8										--	.32 [*]	.20	.49 ^{**}
Carbs 4 hours before bed											--	.42 ^{**}	.77 [*]
Fat 4 hours before bed												--	.36 [*]
Protein 4 hours before bed													--

BMI= Body mass index, Midpoint= midpoint of sleep, a measure of sleep timing.

^{*} $p < .05$ ^{**} $p < .01$,^{***} $p < .001$,[†] $p < .10$