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Original Article

Association between Eating-Fasting and Sleep-Wake Cycles with Eating Times and Food Consumption throughout the Day: Longitudinal Study with Pregnant Women

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Sleep Sci

Abstract

Objective To investigate the associations of the sleep–eating interval with eating times and food consumption throughout the day in pregnant women.

Materials and Methods A longitudinal study with 100 pregnant women treated at the public health network in the city of Uberlândia, state of Minas Gerais (MG), Brazil, during the entire gestational period. The time intervals between waking up and the first eating episode and between the last eating episode and going to sleep (independent variables) were investigated. Outcome measures were meal and sleep times, as well as food consumption throughout the day.

Results Food consumption closer to sleep at night is associated with higher total daily caloric intake in the first ($\beta = -0.337$, $p = 0.016$) and second trimesters (Ts) of pregnancy ($\beta = -0.240$, $p = 0.023$), and with longer sleep duration on weekdays ($p < 0.05$ for all three trimesters). We did not find associations between the wake-up to first eating episode interval and total calories ($p > 0.05$ for all three trimesters), but the longer this interval, the greater the percentage of calories at dinner (1T: $\beta = 0.266$, $p = 0.003$; 2T: $\beta = 0.269$, $p = 0.045$) and at the last meal (1T: $\beta = 0.324$, $p = 0.001$; 2T: $\beta = 0.231$, $p = 0.033$).

Discussion Taking longer to eat the first meal after waking up is associated with higher caloric intake later in the day, while taking longer to sleep after eating the last meal is associated with higher total daily caloric intake and shorter sleep duration, especially in the beginning and middle of pregnancy.

Keywords
- food consumption
- chrononutrition
- gestation
- mealtimes
- sleep

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Introduction

Chrononutrition is an emerging research field based on the relationship between temporal eating patterns, circadian rhythms, and metabolic health.[1,2] Research in this area encompasses energy distribution,[3–7] meal frequency and regularity,[8,9] duration of the eating period,[10] nighttime eating,[11,12] and the importance of these factors for metabolic and nutritional health,[13] and the risk of chronic diseases.[14] An increasing body of evidence from animal and human studies indicates that the timing of food intake throughout the day is associated with metabolic health.[15–18]

Although the eating–fasting and sleep–wake cycles occur in parallel and mutually influence each other, eating and sleep behaviors are distinct and should not occur at the same times of the day. Therefore, the interval between awakening and the first meal has been identified as a relevant variable.[19] Clinical research has indicated that breakfast is an important meal for maintaining daily calorie intake and satiation throughout the day.[9,20,21] Furthermore, skipping this meal has been associated with an increased risk of obesity,[21] type 2 diabetes mellitus,[22] and cardiovascular diseases.[23]

Concurrently, current evidence has pointed towards a modification in temporal eating patterns over the decades, as evidenced by late eating,[24] which has been associated with nonbeneficial health implications.[25] Eating at night refers to eating late in the waking period, as denoted by the clock hour. This construct is relevant to chrononutrition because the timing of this eating event marks the end of the daily eating/fasting cycle. Thus, the duration of time, in minutes, between the last meal and the beginning of sleep is also important to consider.[26]

The timing of eating has been associated with various health outcomes, and previous research has also correlated it with gestational parameters such as gestational weight gain,[27–29] gestational diabetes,[30,31] and fetal growth.[32,33] It is inferred that the timing of maternal food intake has the potential to influence maternal and fetal circadian rhythms, fetal development during pregnancy, and the subsequent metabolic health of the offspring,[34–36] though this is still not fully understood. Previous studies conducted with pregnant women in our group have shown that pregnant women who tend to be evening chronotype consume breakfast later in the day, have poorer dietary patterns concerning total fruit intake,[37] have a higher energy and carbohydrate consumption at night, and exhibit a worse pattern of gestational weight gain in the third trimester (T),[38] as well as a higher likelihood of gaining weight early in the gestational period.[39] Additionally, pregnant women with higher nighttime energy intake showed a lower percentage of energy, protein, and lipid consumption in morning meals, and a worse pattern of gestational weight gain in the third trimester.[37] Furthermore, it was found that poorer subjective sleep quality also leads to inadequate weight gain distribution during pregnancy, with greater weight gain observed during the first to the second trimesters of pregnancy.[40] Moreover, social jetlag (SJL), which is a discrepancy between sleep schedules on workdays and free days, is quite prevalent during the gestational period.[38]

Given the above, we can infer that the sleep–eating relationships, such as the interval between awakening and the first eating episode and between the last eating episode and bedtime, may be related to eating times and food consumption throughout the day, including among pregnant women. Therefore, the present study's objective was to investigate the effects of sleep–eating intervals on eating and sleeping times and food consumption throughout the day. Our hypothesis is that a shorter interval between waking up and the first eating episode is associated with a better dietary pattern, lower daily calorie intake, and a higher meal frequency, and that a shorter interval between the last eating episode and bedtime is associated with a higher daily calorie intake and shorter sleep duration.

Materials and Methods

Participants and Ethics

This is a longitudinal study in which data were collected from 100 pregnant women attending the Integrated Care Units of Uberlândia and the Prenatal Service of the Teaching Hospital of Universidade Federal de Uberlândia, who agreed to participate in the study and provided informed consent by signing the Informed Consent Form. The present study was approved by the Ethics Committee of Universidade Federal de Uberlândia (CAAE: 43473015.4.0000.5152/2015).

Data collection occurred once per trimester: first trimester being $\leq$ 12 weeks of gestation; second 20 to 26 weeks of gestation; and third being 30 to 37 weeks of gestation. the present study included pregnant women aged 18 years or older, with no previous chronic noncommunicable diseases, and those who did not provide the necessary information were excluded, as well as those who reported using illicit substances or were previously diagnosed with acquired immunodeficiency syndrome, toxoplasmosis, and syphilis.

Sample Size

The sample size calculation was based on the independent samples t-test, with an effect size of 0.25, an alpha level of 0.05, 95% power, 2 groups, 3 measurements, a correlation between repeated measures of 0.5, and a nonsphericity correction ε of 1. Given these specifications, a total sample of 94 women was required. During the time of the study, 130 women in the first trimester of pregnancy were invited to participate. However, 30 participants were excluded because they did not provide all necessary information ($n = 25$), presented previous diseases ($n = 3$), or had twin pregnancy ($n = 2$), obtaining a final sample of 100 pregnant women participants. The sample size required for this study was determined using the G*Power (Heinrich Heine University, Düsseldorf, NRW, Germany) software, version 3.1.

Evaluations

Preliminary Questionnaire

Pregnant women in the first trimester of gestation were invited to participate in the research during prenatal appointments. After obtaining their consent, a questionnaire was administered to collect sociodemographic data (gestational age, marital status, education level), previous and current medical history, level of physical activity, and gestational data (date of last menstruation, gestational age, estimated due date, frequency of nausea and vomiting in the last 30 days). The level of physical activity was assessed by asking participants if they had engaged in any physical activity in the last month (yes/no), as well as the type, frequency, and duration. The evaluation of the level of physical activity was conducted in each trimester.

Food Intake Evaluation

Food intake and meal timing were assessed using three 24-hour dietary recalls for each trimester, administered by trained researchers. Participants were instructed to provide as many details as possible about the foods and beverages consumed on the day prior to the interview, including brand names and homemade food recipes. Portion sizes were estimated using common household measures, such as cups, glasses, teaspoons, tablespoons, and individual food items/units. Nutritional supplementation was not taken into account in the assessment of food intake composition.

For the definition of each meal (breakfast, lunch, snacks, or dinner) and the timing of meals, participants reported according to their individual perception.[41] Additionally, the type of food frequently consumed by the Brazilian population in all meals was also considered.[42] We also evaluated meals in periods: morning meals encompassing breakfast and morning snacks, and evening meals encompassing dinner and evening snacks. The number of eating episodes was determined by the number of caloric events $\geq$ 50 kcal/day, with intervals of time between food and/or beverage consumption of $\geq$ 15 minutes.[43]

The eating duration was determined by the interval between the first and last caloric episodes in the 24-hour dietary recall.[44] The overnight fasting period was determined by calculating the hours between the first and last eating episodes for each day and subtracting this time from 24 hours.[45] The caloric midpoint was defined as the time at which 50% of the calories intake during the day were reached.[46]

The analysis of energy and macronutrients was performed using the DietPro software (AS Sistemas, Viçosa, MG, Brazil).

Anthropometric Variables

The anthropometric parameters included the pre-pregnancy weight, current weight, and height of the pregnant women. Height was measured in the first trimester using a stadiometer with an accuracy of 0.1 cm (Welmy, Santa Barbara D'Oeste, SP, Brazil). Prepregnancy weight was self-reported, and the weight in each trimester was measured using a scale with an accuracy of 0.1 kg (Welmy). To determine the pre-pregnancy body mass index (BMI), the classifications from the World Health Organization[47] were used. The current BMI was classified according to the gestational week, following the recommendations of Atalah et al..[48]

Sleep Pattern

To assess the sleep pattern, the participants were asked to report their habitual bedtime and wake-up time on weekdays and weekends, through an adapted form of the Munich ChronoType Questionnaire,[49] as well as the sleep onset latency and habitual sleep duration. The sleep duration was determined by calculating the average self-reported sleep duration, considering both weekdays and weekends, using the following formula: [(sleep duration reported on weekdays x 5) + (sleep duration reported on weekends x 2)] / 7.[50]

Chronotype and Social Jetlag

The chronotype was derived using the mean sleep time on free days (MSF), with an additional correction for sleep debt —calculated as the difference between the average sleep duration on work and free days.[51] The SJL was calculated as the absolute difference between the average sleep time on weekdays and weekends.[52]

Sleep–eating Variables

The variables related to sleep–eating interactions were calculated by measuring the interval between the waking time and the first eating episode and between the last eating episode and the bedtime during the three trimesters of pregnancy.[53]

Statistical Analysis

The statistical analyses were conducted using the IBM SPSS Statistics for Windows (IBM Corp., Armonk, NY, USA) software, version 20.0. First, the Kolmogorov-Smirnov test was performed to assess the normality of the data. Then, the gestational period's means for the intervals of waking time to first eating episode and between the last eating episode and bedtime were calculated. Subsequently, the medians of both intervals were determined. These steps are common in data analysis to understand the central tendencies and distributions of the variables under investigation.

The values of the intervals across the 3 trimesters showed no significant differences (waking time to first eating episode: $p = 0.816$; and last eating episode to bedtime: $p = 0.068$). So, the medians were used to categorize the sample into two groups for the sleep–eating relationships in each interval: shorter/longer morning interval for waking time to first eating episode (median: 3.12 h; shorter interval $\leq$ 3.12 h; and longer interval $>$ 3.12 h), and shorter/longer evening interval for last eating episode to bedtime (median: 5.83 h; shorter interval $\leq$ 5.83 h; and longer interval $>$ 5.83 h). The independent samples *t* test was used to compare the categories of the sleep–eating variables. The chi-square test was used to compare the proportion of categorical variables.

Linear regression analyses were conducted to associate sleep pattern, chronotype, SJL, food intake, meal timing, and chrono-nutritional variables with sleep–eating intervals. An independent model was performed to assess the association of each independent variable with the dependent ones (sleep–eating interval) in each trimester of pregnancy. The independent variables included were bedtime and wake-up time, sleep duration, chronotype, SJL, total calories and macronutrients, percentage of meals and calories, meal and snack times, and chrono-nutritional variables (overnight fasting, eating duration, number of eating episodes, and caloric midpoint). All models were adjusted for age, education level, frequency of nausea in the last 30 days, and prepregnancy BMI. Statistical tests with $p < 0.05$ were considered significant, indicating a relevant association between the variables.

Results

The sample data was characterized according to the categories for the sleep–eating intervals, as presented in ►**Table 1**. Pregnant women classified with a longer waking time to first eating episode interval wake up earlier on workdays and free days and go to sleep later on free days. Additionally, they have a lower chronotype value compared to pregnant women with a shorter waking time to first eating episode interval. Regarding the last eating episode to bedtime interval, pregnant women classified with a longer interval go to sleep later on free days (►**Table 1**). The frequency of breakfast skipping among participants during different gestational trimesters was: 6% in the first trimester, 6% in the second, and 7% in the third (data not presented in table).

►**Table 2** presents the associations between sleep-eating intervals and sleep pattern and chronobiological variables. Negative associations were found between the waking time to first eating episode interval and the following variables: waking time on workdays (1T: $\beta = -0.509$, $p < 0.001$; 2T: $\beta = -0.503$, $p < 0.001$; 3T: $\beta = -0.423$, $p < 0.001$) and sleep duration on workdays in all trimesters of pregnancy (1T: $\beta = -0.427$, $p < 0.001$; 2T: $\beta = -0.483$, $p < 0.001$; 3T: $\beta = -0.445$, $p < 0.001$); sleep duration on free days in the first trimester (1T: $\beta = -0.344$, $p < 0.001$); and chronotype in the third trimester (3T: $\beta = -0.235$, $p = 0.022$). Furthermore, the last eating episode to bedtime interval was associated with sleep duration on workdays in all trimesters of pregnancy (1T: $\beta = -0.391$, $p < 0.001$; 2T: $\beta = -0.293$, $p = 0.004$; 3T: $\beta = -0.288$, $p = 0.003$) and with sleep duration on free days in the second trimester of pregnancy (2T: $\beta = -0.225$, $p = 0.031$).

Positive associations were also found between the waking time to first eating episode interval and SJL in the second and third trimesters (2T: $\beta = 0.317$, $p = 0.003$; 3T: $\beta = 0.220$, $p = 0.032$). The last eating episode to bedtime interval was positively associated with bedtime on workdays (1T: $\beta = 0.394$, $p < 0.001$; 2T: $\beta = 0.542$, $p < 0.001$; 3T: $\beta = 0.551$, $p < 0.001$) and free days in all trimesters of pregnancy(1T: $\beta = 0.223$, $p = 0.027$; 2T: $\beta = 0.308$, $p = 0.002$; 3T: $\beta = 0.393$, $p < 0.001$), as well as with waking time on free days, and with chronotype in the third trimester of pregnancy ($\beta = 0.211$, $p = 0.036$; and $\beta = 0.244$, $p = 0.015$; respectively) (►**Table 2**).

►**Table 3** presents the associations between sleep-eating intervals and food consumption variables. A positive association was found between the waking time to first eating episode" interval and the percentage of calories at dinner and the percentage of calories in the last meal in the first (1T: $\beta = 0.266$, $p = 0.003$; 2T: $\beta = 0.269$, $p = 0.045$) and second trimesters (1T: $\beta = 0.324$, $p = 0.001$; 2T: $\beta = 0.231$, $p = 0.033$); the percentage of calories in the first meal in the first and third trimesters (1T: $\beta = 0.404$, $p = 0.003$; 3T: $\beta = 0.432$, $p < 0.001$); and the percentage of calories in evening meals in the first trimester ($\beta = 0.251$, $p = 0.009$). Positive associations were also found between the last eating episode to bedtime interval and the percentage of calories at lunch in the second trimester ($\beta = 0.263$, $p = 0.50$); the percentage of calories in the last meal in the first and third trimesters (1T: $\beta = 0.334$, $p = 0.001$; 3T: $\beta = 0.392$, $p = 0.000$); and the calories in the last meal in the third trimester ($\beta = 0.304$, $p = 0.001$).

Furthermore, negative associations were found between the last eating episode to bedtime interval and total calories in the first and second trimesters (1T: $\beta = -0.337$, $p = 0.016$; 2T: $\beta = -0.240$, $p = 0.023$), carbohydrate (kcal; $\beta = -0.367$, $p = 0.006$), calories in afternoon snacks ($\beta = -0.308$, $p = 0.006$), calories in evening meals ($\beta = -0.213$, $p = 0.023$), and percentage of calories in afternoon snacks in the first trimester ($\beta = -0.267$; $p = 0.001$), as well as protein (kcal; $\beta = -0.250$, $p = 0.038$) and lipid (kcal; $\beta = -0.209$, $p = 0.021$) in the second trimester (►**Table 3**).

In ►**Table 4**, the associations between sleep–eating intervals and chrononutritional variables are presented. We found a positive association of the waking time to first eating episode interval with: breakfast time in the first and second trimesters of pregnancy (1T: $\beta = 0.298$, $p < 0.001$; 2T: $\beta = 0.381$, $p < 0.001$); morning snack time in the third trimester of pregnancy ($\beta = 0.336$, $p = 0.030$); time of first meal in all trimesters of pregnancy (1T: $\beta = 0.608$, $p < 0.001$; 2T: $\beta = 0.431$, $p < 0.001$; 3T: $\beta = 0.645$, $p < 0.001$); and night fasting in the first trimester ($\beta = 0.256$, $p = 0.005$). Negative associations of the waking time to first eating episode interval were dinner time ($\beta = -0.262$, $p = 0.029$) and last meal time ($\beta = -0.242$, $p = 0.010$) in the first trimester; midpoint caloric time in the first trimester ($\beta = -0.265$, $p = 0.003$); eating duration (1T: $\beta = -0.471$, $p < 0.001$; 2T: $\beta = -0.452$, $p < 0.001$; 3T: $\beta = -0.342$, $p = 0.003$) and number of eating episodes (1T: $\beta = 0.552$, $p < 0.001$; 2T: $\beta = 0.343$, $p = 0.010$; 3T: $\beta = 0.468$, $p < 0.001$) in all trimesters were also observed.

Regarding the last eating episode to bedtime interval, we found a positive association of this variable with the timing of the first meal in the first trimester ($\beta = 0.210$, $p = 0.006$); and with night fasting in all trimesters of pregnancy (1T: $\beta = 0.535$, $p < 0.001$; 2T: $\beta = 0.508$, $p < 0.001$; 3T: $\beta = 0.485$, $p < 0.001$). Additionally, a negative association of the last eating episode to bedtime interval variable was found with dinner time in the first and second trimesters (1T: $\beta = -0.455$, $p = 0.001$; 2T: $\beta = -0.379$, $p = 0.013$); last meal time (1T: $\beta = -0.550$, $p < 0.001$; 2T: $\beta = -0.525$, $p < 0.001$; 3T: $\beta = -0.525$, $p < 0.001$) and eating duration (1T: $\beta = -0.527$, $p < 0.001$; 2T: $\beta = -0.426$, $p < 0.001$; 3T: $\beta = -0.465$, $p < 0.001$) in all trimesters; the midpoint caloric time in the first trimester ($\beta = -0.294$, $p = 0.013$); the number of eating episodes in the first and third trimesters (1T: $\beta = -0.502$, $p < 0.001$; 3T: $\beta = -0.372$, $p = 0.001$); and midpoint caloric time in the first and second trimesters (1T: $\beta = -0.338$, $p = 0.016$; 2T: $\beta = -0.247$, $p = 0.018$) (►**Table 4**).

Table 1 Sociodemographic, anthropometric, sleep pattern, and chronotype data during pregnancy (n = 100).

Variables	Overall (n = 100)	Shorter interval Waking time to first eating episode (n = 50)	Longer interval Waking time to first eating episode (n = 50)		Shorter interval Last eating episode to bedtime (n = 52)	Longer interval Last eating episode to bedtime (n = 48)	
	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)	*p*-value	Mean ± SD or n (%)	Mean ± SD or n (%)	*p*-value
Age (years)	27.72 ± 0.56	27.56 ± 5.67	27.80 ± 5.35	0.393	29.00 ± 5.53	26.50 ± 5.38	0.589
Schooling							
Basic education	5 (5)	1 (2)	5 (10)	0.920	3 (6)	2 (4)	0.788
Highschool education	68 (68)	43 (86)	30 (60)	0.870	37 (71)	31 (65)	0.869
Higher education	27 (27)	6 (12)	15 (30)	0.524	12 (23)	15 (31)	0.750
Physical activity							
1st trimester	83 (83)	41 (82)	41 (82)	0.901	46 (88)	37 (77)	0.879
2nd trimester	79 (79)	38 (76)	40 (80)	0.905	37 (71)	41 (86)	0.744
3rd trimester	80 (80)	39 (78)	40 (80)	0.897	42 (81)	39 (81)	0.993
Pregestational BMI (kg/m^2)	24.25 ± 0.43	23.83 ± 4.45	24.61 ± 4.14	0.227	24.21 ± 4.30	24.20 ± 4.29	0.900
Sleep pattern and chronotype (hour:minute)							
Sleep time (weekday)	22:49 ± 01:07	22:57 ± 01:15	22:41 ± 00:59	0.084	22:31 ± 01:03	23:09 ± 01:07	0.877
Wake-up time (weekday)	07:24 ± 01:31	08:00 ± 01:30	06:44 ± 01:12	**0.015**	07:23 ± 01:33	07:24 ± 01:28	0.992
Sleep duration (weekday)	08:34 ± 01:35	09:04 ± 01:24	08:02 ± 01:34	0.350	08:51 ± 01:39	08:15 ± 01:25	0.525
Sleep time (weekend)	23:51 ± 01:06	23:48 ± 01:15	23:55 ± 00:59	**0.037**	23:40 ± 01:12	00:01 ± 00:59	**0.039**
Wake-up time (weekend)	08:46 ± 01:25	08:59 ± 01:31	08:32 ± 01:15	**0.038**	08:47 ± 01:28	08:45 ± 01:22	0.904
Sleep duration (weekend)	08:55 ± 01:24	09:10 ± 01:18	08:38 ± 01:25	0.653	09:06 ± 01:30	08:42 ± 01:14	0.639
Chronotype	04:26 ± 01:26	04:38 ± 01:45	04:05 ± 01:10	**0.005**	04:16 ± 01:41	04:30 ± 01:16	0.066

Abbreviations: BMI, body mass index; SD, standard deviation.
Notes: The chronotype was derived from the midpoint of sleep on free days (weekends), with an additional correction for calculated sleep debt—the difference between the average sleep duration on weekends and weekdays. Median for waking time to first eating episode: 3.12 h; shorter interval ($\leq$ 3.12) and longer interval ($>$ 3.12). Median for last eating episode – bedtime: 5.83 h; shorter interval ($\leq$ 5.83) and longer interval ($>$ 5.83). The independent samples t-test was used for numerical variables. The chi-square test was used to compare the proportion of categorical variables according to the categories. The values in bold are statistically significant at $p < 0.05$.

Table 2 Linear regression analysis to associate the sleep-eating intervals (dependent variable) with sleep pattern and chronobiological variables (independent variable) during pregnancy (n = 100).

Variables	Sleep–eating interval											
	1st trimester				2nd trimester				3rd trimester			
	Waking time to first eating episode		Last eating episode to bedtime		Waking time to first eating episode		Last eating episode to bedtime		Waking time to first eating episode		Last eating episode to bedtime	
	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value
Sleep Patterns												
Sleep time (weekday)	−0.006	0.955	0.394	< **0.001**	0.022	0.839	0.542	< **0.001**	0.069	0.503	0.551	< **0.001**
Wake-up time (weekday)	−0.509	< **0.001**	−0.103	0.313	−0.503	< **0.001**	0.020	0.849	−0.423	< **0.001**	0.105	0.302
Sleep duration (weekday)	−0.427	< **0.001**	−0.391	< **0.001**	−0.483	< **0.001**	−0.293	**0.004**	−0.445	< **0.001**	−0.288	**0.003**
Sleep time (weekend)	0.166	0.119	0.223	**0.027**	−0.010	0.927	0.308	**0.002**	0.023	0.819	0.393	< **0.001**
Wake-up time (weekend)	−0.185	0.081	0.138	0.177	−0.027	0.807	−0.021	0.837	−0.067	0.516	0.211	**0.036**
Sleep duration (weekend)	−0.344	< **0.001**	−0.032	0.748	−0.019	0.863	−0.225	**0.031**	−0.087	0.403	−0.141	0.166
Chronobiological variables												
Chronotype	−0.140	0.190	0.038	0.706	−0.205	0.059	0.162	0.117	−0.235	**0.022**	0.244	**0.015**
Social Jetlag	0.179	0.092	0.013	0.897	0.317	**0.003**	0.084	0.419	0.220	**0.032**	−0.059	0.560

Note: The chronotype was derived from the midpoint of sleep on free days (weekends), with an additional correction for calculated sleep debt—the difference between the average sleep duration on weekends and weekdays. Linear regression analysis, with the model adjusted for age, education level, frequency of nausea in the last 30 days, and prepregnancy body mass index (BMI). The value in bold indicates statistical significance at $p < 0.05$.

Table 3 Linear regression analysis to investigate the association between sleep-eating intervals (dependent variable) and daily total of calories and macronutrients, as well as meals and calories (independent variable) during pregnancy (n = 100).

Variables	Sleep–eating interval											
	1st trimester				2nd trimester				3rd trimester			
	Waking time to first eating episode		Last eating episode to bedtime		Waking time to first eating episode		Last eating episode to bedtime		Waking time to first eating episode		Last eating episode to bedtime	
	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value
Daily total of calories and macronutrients												
Energy (kcal)	−0.215	0.263	−0.337	**0.016**	−0.164	0.071	−0.240	**0.023**	−0.157	0.284	−0.063	0.421
Protein (kcal)	−0.142	0.144	−0.225	0.158	−0.047	0.502	−0.250	**0.038**	−0.120	0.261	−0.067	0.224
Fat (kcal)	−0.183	0.356	−0.271	0.084	−0.145	0.053	−0.209	**0.021**	−0.210	0.144	−0.032	0.519
Carbohydrates (kcal)	−0.218	0.289	−0.367	**0.006**	−0.186	0.074	−0.197	0.100	−0.069	0.700	−0.069	0.655
Protein (%)	0.167	0.113	0.149	0.080	0.137	0.490	−0.057	0.873	−0.091	0.776	−0.067	0.689
Fat (%)	−0.014	0.958	0.007	0.951	−0.024	0.362	−0.002	0.287	−0.254	0.121	0.030	0.893
Carbohydrates (%)	−0.079	0.662	−0.084	0.944	−0.075	0.325	0.040	0.290	0.235	0.224	0.012	0.880
Meals (kcal)												
Breakfast	−0.084	0.096	−0.085	0.171	−0.028	0.108	−0.176	0.102	0.077	0.589	0.034	0.725
Morning snack	−0.183	0.251	0.140	0.149	−0.049	0.255	0.137	0.310	−0.222	0.134	−0.056	0.572
Lunch	−0.022	0.571	−0.114	0.414	−0.087	0.421	−0.063	0.088	0.205	0.052	< **0.001**	0.129
Afternoon snacks	−0.164	0.093	−0.308	**0.006**	−0.037	0.568	0.020	0.451	−0.116	0.329	−0.030	0.355
Dinner	0.008	0.077	−0.152	0.061	0.048	0.704	−0.244	0.158	−0.062	0.182	0.075	0.170
Night snack	0.062	0.349	0.025	0.883	0.097	0.756	−0.113	0.629	0.141	0.734	−0.245	0.386
First meal	0.198	0.060	−0.018	0.098	0.143	0.481	−0.190	0.264	0.183	0.342	−0.058	0.718
Last meal	0.155	0.145	0.122	0.231	0.097	0.198	0.053	0.178	−0.148	0.140	0.304	**0.001**
Morning	−0.200	0.066	−0.064	0.528	−0.178	0.058	−0.183	0.089	−0.065	0.323	−0.095	0.450
Night	−0.018	0.124	−0.213	**0.023**	0.030	0.926	−0.294	0.143	−0.035	0.493	−0.045	0.491
Percentage of calories in meals (%)												
Breakfast	−0.100	0.427	0.185	0.156	0.037	0.804	−0.038	0.883	0.007	0.855	0.076	0.671
Morning snack	−0.207	0.280	0.336	0.101	−0.052	0.444	0.236	0.087	−0.249	0.497	−0.042	0.994
Lunch	0.308	0.056	0.233	0.157	0.089	0.390	0.263	**0.050**	0.215	0.111	0.010	0.480

(*Continued*)

Table 3 (*Continued*)

Variables	Sleep–eating interval											
	1st trimester				2nd trimester				3rd trimester			
	Waking time to first eating episode		Last eating episode to bedtime		Waking time to first eating episode		Last eating episode to bedtime		Waking time to first eating episode		Last eating episode to bedtime	
	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value
Afternoon snacks	−0.150	0.163	−0.267	**0.001**	0.109	0.469	0.097	0.566	0.114	0.462	0.063	0.445
Dinner	0.266	**0.003**	0.108	0.291	0.269	**0.045**	−0.077	0.306	0.166	0.154	0.148	0.183
Night snack	0.209	0.452	0.082	0.652	0.005	0.821	−0.182	0.493	0.244	0.451	−0.249	0.233
First meal	0.404	**0.003**	0.265	0.071	0.272	0.251	0.046	0.979	0.432	**< 0.001**	0.006	0.474
Last meal	0.324	**0.001**	0.334	**0.001**	0.231	**0.033**	0.167	0.064	0.012	0.144	0.392	**< 0.001**
Morning	−0.214	0.123	0.207	0.085	−0.105	0.447	−0.056	0.551	−0.147	0.298	−0.070	0.430
Night	0.251	**0.009**	0.015	0.883	0.236	0.228	−0.188	0.325	0.198	0.288	−0.026	0.790

Notes: Regression analysis model adjusted for age, education, frequency of nausea in the last 30 days, and pregestational body mass index (BMI). The value in bold is statistically significant at $p < 0.05$. It was categorized into morning—breakfast and morning snacks—and evening—dinner and night snack.

Discussion

The timing between morning food intake after waking up and the interval between the last eating episode and bedtime seems to play a relevant role in the health outcomes of the general population.[6,54,55] In this sense, the present study aimed to investigate the associations of sleep-eating intervals with meal timing and dietary intake throughout the day in pregnant women, considering that there are still few studies on the subject to date. Our results partially confirm our hypothesis, since we found negative associations between the last eating episode to bedtime interval and total caloric intake, and sleep duration on workdays. We also found a positive association between the waking time to first eating episode and the percentage of calories later in the day.

Studies investigating the association between sleep and meal timings are still scarce in the literature. Reid et al.[53] examined the relationship between meal timings, caloric intake, and BMI in 59 individuals and found that a shorter duration between the last eating episode and the sleep onset predicted higher total caloric intake. The study's results suggested that eating meals closer to bedtime, particularly eating near sleep onset, may lead to weight gain due to a higher number of eating occasions and increased total daily caloric intake. Consistent with these findings, our study also found negative associations between the last eating episode to bedtime interval and total caloric intake in the first and second trimesters of pregnancy. In other words, the shorter the interval between the last eating episode and the start of sleep, the higher the total caloric intake throughout the day, confirming our initial hypothesis.

We also investigated associations between sleep-eating intervals and sleep patterns and chronobiological variables. We found a negative association between the last eating episode to bedtime interval and sleep duration on workdays in all trimesters of pregnancy. Our findings contradict those of Bandín et al.,[56] since the authors found that consuming food close to bedtime led to shorter sleep duration and altered sleep stage timing. However, there are studies indicating that a longer interval between the last meal and sleep onset was associated with poorer sleep quality[57] and that restricting eating time during pregnancy might negatively affect nighttime sleep duration,[58] which could explain our group's results. Nevertheless, the authors observed that this finding was based on a small sample, and larger studies are needed to confirm these results. Additionally, the time interval during which food interferes with sleep and the nature of this interference have not been clearly elucidated.[59] According with Kogevinas et al.,[60] eating 2 hours or less before initiating sleep has been associated with negative health outcomes. The authors also commented that adherence to daytime eating patterns, specifically, a longer interval between the last meal and sleep, is associated with a lower risk of cancer.[60] Other studies have also addressed this topic of the eating-sleep interval and have demonstrated that a prolonged interval between the last meal and nighttime sleep can improve sleep quality and promote circadian rhythm regulation[61–63] and reduce the risk of metabolic diseases.[64]

Table 4 Linear regression analysis to assess the association between sleep-eating intervals (dependent variable) and chrononutritional variables (independent variable) during pregnancy (n = 100).

Variables	Sleep – eating interval											
	1st trimester				2nd trimester				3rd trimester			
	Waking time to first eating episode		Last eating episode to bedtime		Waking time to first eating episode		Last eating episode to bedtime		Waking time to first eating episode		Last eating episode to bedtime	
	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value
Meal and snack times (hour:minute)												
Breakfast	0.298	< **0.001**	0.170	0.094	0.381	< **0.001**	0.092	0.147	0.362	< **0.001**	0.193	0.060
Morning snack	0.154	0.554	0.011	0.589	0.031	0.847	−0.155	0.094	0.336	**0.030**	0.070	0.402
Lunch	−0.034	0.915	0.029	0.815	−0.176	0.166	−0.074	0.332	−0.011	0.979	−0.004	0.985
Afternoon snacks	−0.227	0.117	0.019	0.694	−0.034	0.539	−0.030	0.740	−0.105	0.919	−0.106	0.906
Dinner	−0.262	**0.029**	−0.455	**0.001**	0.092	0.795	−0.379	**0.013**	−0.005	0.845	−0.237	0.179
Night snack	−0.169	0.418	−0.223	0.741	0.312	0.644	−0.216	0.606	−0.091	0.694	−0.261	0.752
First meal	0.608	< **0.001**	0.210	**0.006**	0.431	< **0.001**	0.127	0.246	0.645	< **0.001**	0.132	0.098
Last meal	−0.242	**0.010**	−0.550	< **0.001**	−0.058	0.671	−0.525	< **0.001**	0.052	0.750	−0.525	< **0.001**
Chrononutritional variables												
Night fasting	0.256	**0.005**	0.545	< **0.001**	0.094	0.492	0.508	< **0.001**	−0.030	0.891	0.485	< **0.001**
Eating durations	−0.552	< **0.001**	−0.527	< **0.001**	−0.343	**0.010**	−0.426	**0.001**	−0.468	< **0.001**	−0.465	< **0.001**
Number of eating episodes	−0.471	< **0.001**	−0.502	< **0.001**	−0.452	< **0.001**	−0.218	0.189	−0.342	**0.003**	−0.372	**0.001**
Caloric midpoint (kcal)	−0.211	0.271	−0.338	**0.016**	−0.165	0.071	−0.247	**0.018**	−0.157	0.284	−0.063	0.421
Caloric midpoint (time)	−0.294	**0.013**	−0.265	**0.003**	0.021	0.879	−0.222	0.356	0.005	0.999	−0.062	0.471

Note: Linear regression analysis model adjusted for age, education, frequency of nausea in the last 30 days, and pregestational body mass index (BMI). The value in bold is statistically significant at $p < 0.05$.

Nogueira et al.[65] aimed to determine the interval between the last meal and bedtime and its relationship with daytime and nighttime sleep parameters, as well as to evaluate the association of the adequacy of this meal with sleep parameters in 30 female nursing professionals who worked permanent 12 by 36-hour night shifts. Our results are opposite to what was found by them,[65] who discovered that a shorter interval between the last meal and the beginning of sleep was associated with a longer duration of daytime sleep. However, it is important to note that the two studies have methodological differences that may explain these discrepancies. Additionally, the sample in the Nogueira et al.[65] study consisted of shift workers, that have daytime sleep due to their work schedules, while our study evaluated pregnant women in all trimesters of pregnancy, who primarily experience nighttime sleep.

In this sense, it is well established that sleep quality is associated with various hormonal and metabolic changes, including the modulation of macronutrients.[66] Therefore, it is hypothesized that eating at night has a greater impact on sleep than consuming the same foods during the day. One possible mechanism to explain this dietary influence is that the distribution of macronutrients can continuously affect sleep, promoting changes in neuroendocrine signals related to energy metabolism.[67–69]

The present study not only assessed the interval between the last eating episode and bedtime but also the interval between waking up and the first eating episode. Our initial hypothesis was that a shorter interval between waking up and the first eating episode would be associated with a better dietary pattern. However, we did not find associations between the waking time to first eating episode interval and total calories. Instead, we found a positive association with the percentage of calories in dinner and the percentage of calories in the last meal in the first and second trimesters. It is known that the first meal of the day is considered health-protective, and clinical studies have demonstrated the importance of food intake in the early hours of the day for successful changes in body mass.[6,54,55] Possible mechanisms for the association between breakfast and health protection may be that morning food intake is particularly satiating and can reduce the total amount of energy consumed during the day.[70] Additionally, breakfast is considered a central component of daily nutritional needs and significantly contributes to energy intake and nutritional quality.[71,72]

An interesting finding in the present study was the positive association between SJL and waking time - first eating episode interval in the second and third trimesters, indicating that pregnant women who took longer to have their first meal in both trimesters seemed to be more misaligned. SJL is the result of a mismatch between social activities and the body's natural circadian rhythm.[73] It is important to note that during pregnancy, many women experience hormonal, physiological, and emotional changes, which can affect sleep and overall well-being.[74,75] Therefore, during pregnancy, disruptions in circadian rhythm and sleep may occur due to changes in social schedules and daily routines during this period, which seems to be more pronounced as pregnancy progresses. Previous studies from our group have related SJL to impaired clinical and metabolic control in individuals with non-communicable chronic diseases.[76] We found a worse profile after one year of follow-up.[76] It is important to emphasize that SJL is quite prevalent during pregnancy, and excessive pre-pregnancy and during pregnancy BMI is associated with an increased risk of having SJL of more than 1 hour in the third and second trimesters, respectively.[38]

We also studied the associations between sleep–eating intervals and chrononutritional variables. There was a positive association between the waking time to first eating episode interval and the breakfast time in the first and second trimesters of pregnancy, meaning that a longer interval between sleep and the first meal was related to a later breakfast time. These findings are in line with the results of the Vriendenboom et al.[19] study conducted with adolescents, where those with a longer interval between waking up and the first meal tended to have a later breakfast time and a higher BMI. Furthermore, it is known that the timing of food intake has been considered a strong zeitgeber—synchronizer—for peripheral circadian clocks, as well as the composition of the diet.[77]

The present study has some limitations. Although the pregnant women were instructed to report their food intake, the 24-hour dietary recall relies on the participants' memory and motivation. To guarantee accurate data, however, the respondents were instructed before participating in the research, and our team was also highly trained.[78] Additionally, the data related to sleep patterns, although previously validated in other studies, are subjective and dependent on memory and motivation. Finally, the present study assessed 100 pregnant women who attended regular appointments in the public health system, and the generalization of the results to all pregnant women cannot be made, especially regarding high-risk pregnancies.

Conclusion

We concluded that delaying the first meal after waking up is associated with higher late-day caloric intake, while delaying sleep after the last meal is associated with lower total daily caloric intake, and shorter sleep duration, especially in early and mid-pregnancy. Additional studies are needed for a more comprehensive understanding of this subject.

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Conflict of Interests
The authors have no conflict of interests to declare.

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