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Eating time variation from weekdays to weekends and its association with dietary intake and BMI in different chronotypes: findings from National Health and Nutrition Examination Survey (NHANES) 2017–2018

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Abstract

Evidence suggests that differences in meal timing between weekends and weekdays can disrupt the body's circadian rhythm, leading to a higher BMI. We aimed to investigate the associations between mealtime variation from weekdays to weekends (eating midpoint jetlag), dietary intake and anthropometric parameters, based on individuals' chronotype. The study utilised data from National Health and Nutrition Examination Survey 2017–2018. Food consumption was estimated by weighted average of participants' food intake on weekdays and weekends. Eating midpoint jetlag, defined as the difference between the midpoint of the first and last mealtimes on weekends and weekdays, was calculated. Chronotype was assessed by participants' mid-sleep time on weekends, adjusted for sleep debt. Linear regression analysis was conducted to investigate the associations between variables. The sample was categorised into chronotype tertiles. Among individuals in the third chronotype tertile, there was a positive association between eating midpoint jetlag and BMI ($\beta = 1{\cdot}2$; 95 % CI (1·13, 1·27)). Individuals in the first tertile showed a positive association between eating midpoint jetlag and energy ($\beta = 96{\cdot}9$; 95 % CI (92·9, 101·7)), carbohydrate ($\beta = 11{\cdot}96$; 95 % CI (11·2, 12·6)), fat ($\beta = 3{\cdot}69$; 95 % CI (3·4, 3·8)), cholesterol ($\beta = 32{\cdot}75$; 95 % CI (30·9, 34·6)) and sugar ($\beta = 8{\cdot}84$; 95 % CI (8·3, 9·3)) intake on weekends. Among individuals with an evening tendency, delaying meals on weekends appears to be linked to a higher BMI. Conversely, among individuals with a morning tendency, eating meals later on weekends is associated with higher energetic intake on weekends.

Keywords: Eating midpoint: Mealtime: BMI: Food intake: Chronotype

Obesity is considered a chronic, relapsing and multifactorial disease[1,2]. It has already been addressed in the literature that obesity implies several health risks such as type 2 diabetes[3], heart disease[3] and cancer[4]. The excessive weight becomes even more alarming when it is identified that the prevalence of obesity has grown exponentially worldwide, including in the North American population. Data from the National Health and Nutrition Examination Survey (NHANES) found that the prevalence of obesity in the adult American population increased from 22·3 % in 1988 to 43 % in 2018[5].

Studies have shown that not only excessive energy intake and sedentary lifestyle can contribute to the development of obesity, but also various genetic and environmental factors, such as family history[6], mental health[7] and socio-cultural factors[8]. From a nutritional perspective, it has been recognised that the global obesity epidemic cannot be solely explained by focusing on food products and the amount of food intake. Several factors related to eating habits can predict food consumption and weight status[6–8]. In this regard, chrononutrition, an emerging field that links the circadian timing system to metabolic physiology and nutrition[9], has suggested that not only the quantity and quality of food determine a healthy diet but also the timing of meals may be an important factor to consider[10].

Studies have proposed that eating at later times may be a risk factor for obesity and weight gain[10–12]. Our previous research indicated that adults consumed a significant portion of their daily energy intake later in the day had higher BMI[11]. Additionally, Baron *et al.*[10] found that eating in the evening or before sleep may influence individuals to weight gain through higher total energy content intake. An epidemiological study conducted in a Swedish population (*n* 3610) demonstrated that eating late at night was associated with a higher risk of obesity (OR 1·62; 95 %

Abbreviations: NHANES, National Health and Nutrition Examination Survey.

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CI (1·10, 2·39)) compared with those who did not consume energy during late-night hours[12]. Moreover, recent evidence suggests that variations in mealtime between weekends and weekdays may be linked to a higher BMI in the Spanish population[13].

The term *chronotype* is used to describe a person's natural tendency for the timing of sleep and activity patterns, including working, studying, engaging in physical activities and eating throughout the day[14]. Studies have indicated a close correlation between mealtime and chronotype, as individuals with an evening chronotype tend to have their meals at later times compared with morning and intermediate types[15]. Also, eveningness preference has been associated with higher energy intake in the evening[16,17] Lucassen *et al.*[17] previously investigated the difference of food intake according to chronotype in weekdays and weekend, separately, and did not find any difference in total food intake between weekdays and weekend but found a higher food intake after 8 pm among evening chronotype in both weekend and weekdays. Also, higher BMI values also appear to be more prevalent among evening chronotypes[17–19]. However, the relationship between mealtime variability and body mass, as well as food intake has been poorly explored in the literature. To the best of our knowledge, no studies have addressed this topic specifically in relation to chronotype. Therefore, the aim of this study was to investigate the associations of mealtime variation on weekdays and weekend with energy and nutrients intake, as well as anthropometric parameters. An additional objective was to examine these associations based on individuals' chronotype. We hypothesised that greater variation in mealtime would be associated with higher energy and nutrient intake, as well as higher BMI values. Furthermore, we hypothesised that these associations would be stronger among individuals with an evening chronotype tendency.

Methods

Study population

We used data from the NHANES 2017–2018. NHANES is a population-based cross-sectional survey conducted in the USA by National Center for Health Statistics based on a multistage, probability and stratified sampling design to assess the nutritional status and health of a nationally representative sample of the noninstitutionalised US population. For our study, we included individuals aged 18 years or older, of both sexes, who had completed two non-consecutive 24-h dietary recall interviews, with one recall occurring on a weekend. Pregnant or breast-feeding women were excluded from the analysis, as well as individuals with only one 24-h recall, both 24-h recall during weekdays/weekend or those with inconsistent food consumption reports (defined as energy intake <500 and >3500 for women, and <800 and >4000 for men[20] or only a single meal throughout the day). Individuals with missing data on variables of interest, such as eating window, sleep and wake time data, waist circumference and BMI, were also excluded. Our final sample consisted of 1184 participants, and a flow chart outlining the study selection process is presented in Fig. 1.

NHANES is a public dataset and all participants provided a written informed consent, consistent with approval from the National Center for Health Statistics Research Ethics Review Board.

Study variables

Demographic variables such as age (years), sex (male or female), education level (primary school, high school or college) income (< $25 000; between $25 000 and $74 999; > $74 999) and marital status (married or living with a partner; single; divorced or widowed) were self-reported and assessed using the Demographic Variables data file.

Anthropometric data

Anthropometric data were collected using the Body Measures data file. These measurements were conducted by trained health technicians at the mobile examination centre. Participants' weight was measured in kg using a digital weight scale, while height was evaluated following the protocol established by Lohman[21]. BMI values were calculated by dividing weight (in kg) by the square of height (in m). Waist circumference was measured by extending a measuring tape around the waist, passing it over the right ilium of the pelvis. Hip circumference was assessed by extending the measuring tape around the maximum protuberance of the buttocks.

Food intake evaluation

The intake of energy (kcal) and nutrients, including carbohydrates (g), protein (g), fat (g), dietary fibre (g), cholesterol (mg) and sugar (g), was assessed using 2 d of 24-h dietary recall (Total Nutrient Intakes data file first day and second day). The first dietary recall interviews were conducted in person by trained dietary interviewers. The second dietary recall was collected by telephone and was scheduled 3–10 d later. To estimate usual food intake of energy and nutrients, a weighted average of food consumption on weekdays and weekends was calculated using the following formula: ((reported current weekday food consumption × 5) + (reported current weekend food consumption × 2))/7.

The eating duration – defined as the length between the first and the last energetic event (in hours)[22] – was calculated by the difference between the time of the last and first meal. The first meal was determined by the first energetic event ≥ 50 kcal/d and the last meal was determined by the last energetic event ≥ 50 kcal/d. To calculate average eating duration, we first estimated the eating duration for weekdays and weekends using the formula: Eating duration (h) = Timing of the last meal – Timing of the first meal. Then, the average eating duration was determined as a weighted mean using the formula: Average eating duration (h) = ((eating duration on weekdays × 5) + (eating duration on weekends × 2))/7.

The eating midpoint – which represents the middle time point between the first and the last meal – was calculated separately for weekdays and weekends based on a methodology proposed to estimate the midpoint of sleep[23]. Then, the eating midpoint was

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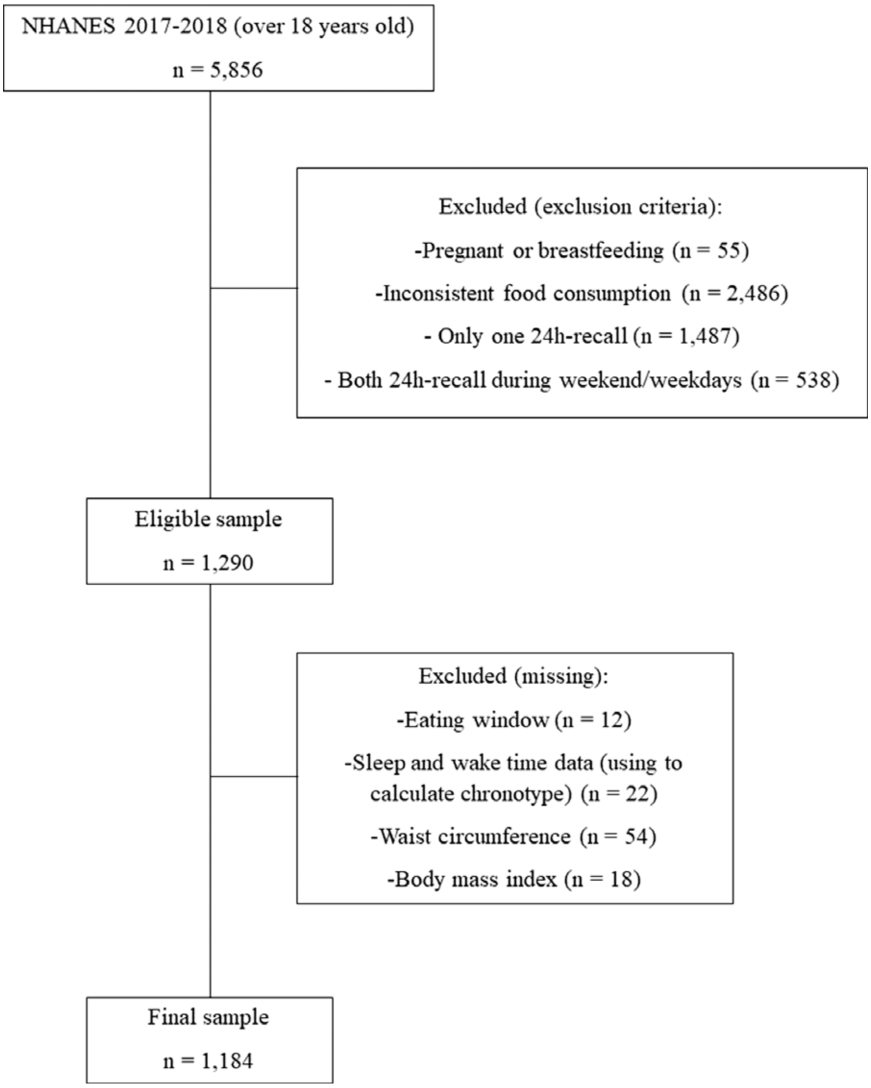

Fig. 1 Flow chart of the sample selection from NHANES 2017-2018. NHANES, National Health and Nutrition Examination Survey.

calculated using the formula: Eating midpoint = ((Timing of the last meal – Timing of the first meal)/2) + Timing of the first meal.

The eating midpoint jetlag was calculated by the absolute difference between eating midpoint on weekends and weekdays[13].

Chronotype

Data of sleep and wake time on weekdays and weekend were assessed by sleep disorders questionnaire. The NHANES participants were asked, by trained interviewers, about the usual sleep and wake time on weekdays and weekend. Usual sleep duration was calculated for both weekdays and weekends according to the following formula: ((reported current weekday sleep duration × 5) + (reported current weekend sleep duration × 2))/7[24], and then, chronotype (MSFsc) was assessed via mid-sleep time on weekend with correction for sleep debt – assessed by the difference between average sleep duration on the weekend and the average sleep on weekdays[25].

Statistical analysis

Linear regression tests were performed to determine the associations between eating midpoint jetlag (independent variable), dietary (energy content, carbohydrate, protein, total fat, fibre, cholesterol and sugar; dependent variables) and anthropometric (BMI, waist circumference, hip circumference and weight; dependent variables) variables. We categorised the sample according to the chronotype tertiles. The first tertile indicates morningness tendency and the third tertile indicates evening tendency. Linear regression analysis was also performed for each chronotype tertile to analyse the association between eating midpoint jetlag (independent variable) and dietary and anthropometric variables (dependent variables).

Data were analysed using Stata 14.0 software (StataCorp.), and $P < 0.05$ was considered as statistically significant. All statistical analyses were adjusted for potential confounders such as age, sex, race, education level, income, marital status, sleep duration, energy content (only to anthropometric variables) and

BMI (only to food intake variables), considering the examination sample weight provided by Nhanes (wtdr2d).

Results

The socio-demographic data for the total sample and according to chronotype are presented in Table 1. The results show that there were no significant differences in sex, marital status, income, education level and race among the different chronotype tertiles. However, it was observed that individuals with a morning chronotype tended to be younger and had a shorter eating duration compared with other chronotypes.

The mean of eating midpoint jetlag is illustrated in Fig. 2. The overall mean eating midpoint jetlag for all participants was 1:08 (SD 0:02) h. Specifically, the mean eating midpoint jetlag for the morning chronotype tertile was 1:15 (SD 0:04) h, for the intermediate chronotype tertile was 1:09 (SD 0:05) h and for the evening chronotype tertile was 0:53 (SD 0:04) h.

Associations of eating midpoint jetlag and food intake are presented in Table 2. No significant associations were found between eating midpoint jetlag and energetic intake or nutrients intake for all participants. However, among individuals with a morning chronotype tendency, positive associations were observed between eating midpoint jetlag and ($\beta = 96·9$; 95 % CI (92·9, 101·7)), carbohydrate ($\beta = 11·96$; 95 % CI (11·2, 12·6)), fat ($\beta = 3·69$; 95 % CI (3·4, 3·8)), cholesterol ($\beta = 32·75$; 95 % CI (30·9, 34·6)) and sugar ($\beta = 8·84$; 95 % CI (8·3, 9·3)) intake on the weekend. A negative association was found between eating midpoint jetlag and dietary fibre intake in the weekly average ($\beta = -0·76$; 95 % CI (−0·8, −0·7)) and on weekdays ($\beta = -0·93$; 95 % CI (−0·9, −0·8)) (Table 2).

Associations of eating midpoint jetlag with anthropometric parameters are presented in Table 3. No significant association was found among all participants and other chronotype tertiles, neither to other variables such as waist circumference, hip circumference and weight. A positive association between eating midpoint jetlag and BMI was found in the eveningness tendency tertile ($\beta = 1·2$; 95 % CI (1·13, 1·27)) (Table 3). Furthermore, we found a negative association between eating midpoint jetlag and MSF chronotype ($\beta = -0·159$; 95 % CI (−0·16, −0·15)) for all participants (result not shown).

Discussion

The aim of this study was to investigate the associations of mealtime variation from weekdays to weekend with anthropometric parameters and energy and nutrients intake. The study also examined these associations based on individuals' chronotypes, which refer to their preference for morningness or eveningness. The results of the study did not find any significant associations between eating midpoint jetlag and anthropometric parameters, energy intake or nutrient intake for all participants. However, when analysing the data based on chronotype, some interesting associations were observed. Among individuals with a tendency towards eveningness, there was a positive association between eating midpoint jetlag and BMI. On the other hand, among individuals with a tendency towards morningness, higher eating midpoint jetlag was associated with higher energy intake, carbohydrate intake, total fat intake, cholesterol intake and sugar intake on the weekends. Additionally, there was a negative association between eating midpoint jetlag and dietary fibre intake. In summary, the study partially confirmed the hypothesis that higher eating midpoint jetlag is associated with poorer anthropometric parameters among individuals with an eveningness tendency. However, it revealed a surprising finding that higher eating midpoint jetlag was associated with higher energy and nutrient intake among individuals with a morningness tendency.

The characteristics of morning types include waking up and going to bed at earlier times compared with evening types[26]. As a result, morning types tend to organise their day around their sleep and wake-up schedule, and, consequently, eat earlier in the day[26]. While morningness is often considered beneficial for health, morning types are not immune to disturbances, particularly due to social norms and routines established by society. Social events, late dinners, work demands and business opening times may not align with the schedules of morning types, posing inconveniences for individuals with diurnal characteristics, especially definitely morning types. These discrepancies can impact their food consumption patterns. Research suggests that morning types exhibit greater stability and regularity in their routines[27,28], making it more challenging for them to deal with unexpected situations and changes in their routine, which can lead to negative feelings and potentially disrupt their food consumption patterns. A recent study conducted by our research group found that morning and non-evening types (including morning and intermediate types) experienced changes in contextual, psychological and physiological states that triggered food cravings in response to specific situations[29]. These factors help explain the result observed in our study, where a greater variation in the consumption schedule from weekdays to weekends among morning types was associated with higher energy, carbohydrate, protein, fat, cholesterol and sugar intake on weekends. This finding reinforces the idea that deviating from the usual routine, as often occurs on weekends, leads to an increased food consumption among morning types during these atypical days.

In the present study, we also observed a positive association between mealtime variation from weekdays to weekends and BMI among individuals with eveningness tendencies. This finding aligns with a recent study that identified a strong association between greater variation in food consumption from weekdays to weekend meals – referred by the authors as 'eating jetlag' – and higher BMI[13]. Furthermore, several studies have demonstrated that habitual late eating as a habitual behaviour, *per se*, can contribute to increased weight gain, higher BMI and a greater prevalence of obesity[11,12,30].

The habit of eating later appears to be intrinsically related to the evening chronotype. A recent study conducted by our group demonstrated a negative correlation between the

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Table 1. Socio-demographic data for all participants and according to chronotype tertile, NHANES 2017–2018
(Mean values and standard deviations; numbers and percentages)

	All (*n* 1184)		Morningness tendency tertile* (*n* 440)		Indifferent tendency tertile* (*n* 397)		Eveningness tendency tertile* (*n* 347)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P*
Age (years)	48·4	17·9	46·2	16·8	49·1	17·5	49·3	20·1	**0·01**
	n	%	*n*	%	*n*	%	*n*	%	
Sex									
Male	559	47·25	212	48·3	182	45·8	136	39·3	0·3
Female	625	52·75	228	51·6	215	54·1	211	60·6	
Race/ethnicity									
Non-Hispanic	736	62·2	323	73·5	290	73·0	255	73·4	0·8
Hispanic	448	37·8	117	26·5	107	27·0	92	26·6	
Education level†									
Primary school	111	9·4	42	9·6	28	7·2	39	11·4	0·7
High school	325	27·5	137	31·1	90	22·7	101	29·0	
College	744	62·8	259	58·8	278	69·9	206	59·3	
Marital status†									
Married or living with partner	745	62·9	279	63·4	252	63·4	214	61·6	0·8
Single	226	19·1	78	17·8	77	19·4	71	20·6	
Divorced or widowed	209	17·7	81	18·4	67	16·9	61	17·5	
Annual income†									
Less than $25 000	208	17·5	58	13·3	64	16·1	86	24·7	0·5
Between $25 000 and $74 999	431	36·4	162	36·8	146	36·7	123	35·6	
More than $74 999	521	44·0	206	46·9	183	46·0	132	37·9	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Mealtime									
First meal (weekly average)	8:35	2:00	8:20	1:58	7:57	1:32	8:42	1:42	0·06
First meal on weekdays	8:20	2:25	7:54	2:09	7:35	1:32	8:24	1:42	**0·03**
First meal on weekend	8:50	2:30	9:24	2:22	8:51	2:06	9:24	2:16	0·5
Last meal (weekly average)	20:08	1:59	20:00	2:08	19:37	1:25	19:34	1:58	0·2
Last meal on weekdays	20:15	2:20	19:43	2:18	19:19	1:39	19:34	1:57	0·1
Last meal on weekend	20:00	2:20	20:43	2:32	20:24	1:42	20:28	2:00	0·8
Eating duration (weekly average)	**11·58**	**2·5**	**11·66**	**2·41**	**11·66**	**1·8**	**11·01**	**2·16**	**0·006**
Eating duration on weekdays	**11·83**	**2·91**	**11·83**	**2·83**	**11·71**	**2·1**	**11·01**	**2·38**	**0·02**
Eating duration on weekend	11·25	2·83	11·31	3·0	11·55	2·43	11·0	2·75	0·4
Sleep duration and chronotype									
Sleep time (h; weekly average)	23:06	1:18	23:29	1:24	22:48	1:03	22:36	1:19	<**0·001**
Sleep time on weekdays (h)	22:42	1:18	22:06	1:25	22:33	1:04	22:23	1:19	<**0·001**
Sleep time on weekend (h)	23:24	1:30	23:52	1:34	23:04	1:10	22:49	1:30	<**0·001**
Wake time (h; weekly average)	7:06	1:30	6:03	1:28	7:00	1:09	8:09	1:27	<**0·001**
Wake time on weekdays (h)	6:24	1:30	5:49	1:29	6:28	1:12	7:43	1:31	<**0·001**
Wake time on weekend (h)	7:42	1:48	7:22	1:54	7:33	1:24	8:34	1:38	<**0·001**
Sleep duration (h; weekly average)	**7·8**	**1·3**	**6·91**	**1·0**	**8·0**	**0·5**	**9·45**	**0·86**	<**0·001**
Sleep duration on weekdays (h)	**7·6**	**1·4**	**6·7**	**1·3**	**7·91**	**0·56**	**9·33**	**0·91**	<**0·001**
Sleep duration on weekend (h)	**8·3**	**1·5**	**7·5**	**1·46**	**8·46**	**0·89**	**9·75**	**1·0**	<**0·001**
MSF chronotype (h)	3:30	1:12	2:54	1:22	3:39	0:39	4:28	0:40	<**0·001**

NHANES, National Health and Nutrition Examination Survey; MSF, mid-sleep time on free days.
*MSF chronotype varies between 0 and 3·25 for morningness tendency tertile; 3·5 and 4 for indifferent tendency tertile and 4·25 and 7·5 for eveningness tendency tertile.
†Missing data: Education level = 4; marital status = 4; annual income = 24.

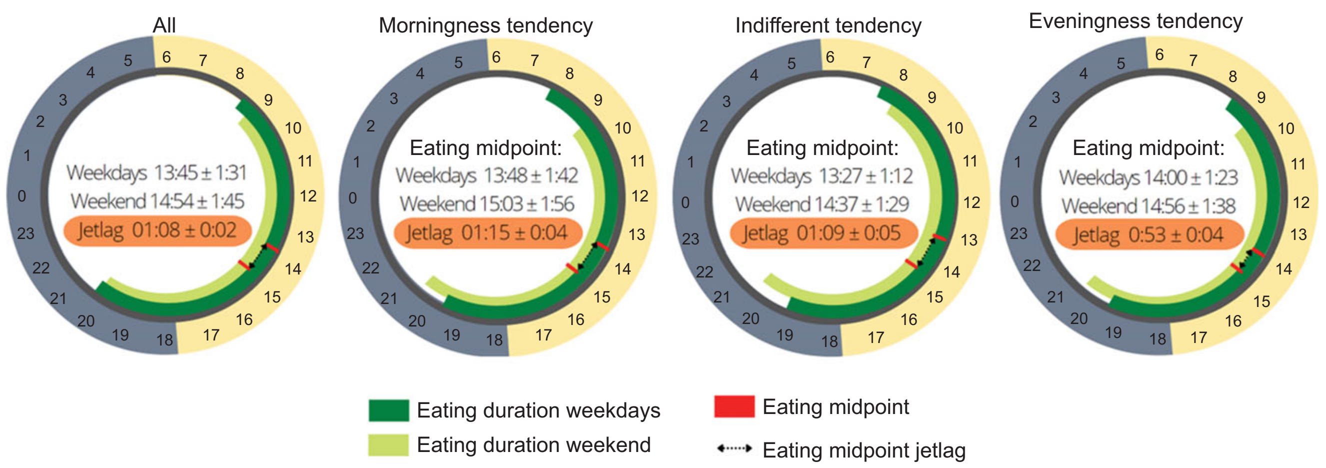

Fig. 2 Eating midpoint variability of all participants and according to chronotype.

Table 2. Associations of eating midpoint jetlag and food intake according to chronotype tertile, NHANES 2017–2018
(Beta-coefficients and 95 % confidence intervals)

	Eating midpoint jetlag*															
	All (*n* 1184)				Morningness tendency tertile (*n* 440)				Indifferent tendency tertile (*n* 397)				Eveningness tendency tertile (*n* 347)			
	Mean	SD	*β*	95 % CI	Mean	SD	*β*	95 % CI	Mean	SD	*β*	95 % CI	Mean	SD	*β*	95 % CI
Energy content (weekly average; kcal)	1970·9	631·9	17·64	-48·6, 23·8	1954·2	640·1	24·35	-47·7, 46·6	2064·3	630·8	13·94	-76·8, 51·2	1846·3	529·8	-45·19	-117·6, 37·9
Energy content on weekdays (kcal)	1963·8	710·7	11·72	-59·4, 22·9	1939·7	699·0	-4·68	-61·3, 49·0	2052·4	721·0	22·8	-79·9, 62·3	1791·3	677·3	-53·96	-145·0, 25·4
Energy content on weekend (kcal)	1988·6	739·5	32·45	-35·5, 39·7	**1990·4**	**796·2**	**96·9**	**92·9, 101·7†**	2094·3	713·3	-8·33	-92·5, 46·7	1983·6	729·5	-23·27	-68·7, 88·6
Carbohydrate (weekly average; g)	225·2	85·3	-0·28	-8·6, 1·5	222·2	82·8	-0·05	-7·8, 5·3	240·4	96·1	-0·47	-16·2, 3·7	215·6	78·3	-6·85	-17·4, 2·6
Carbohydrate on weekdays (g)	225·9	97·4	-2·14	-10·6, 1·0	222·8	93·2	-4·85	-10·6, 5·1	241·7	112·0	-0·41	-17·9, 4·6	212·7	87·7	-8·05	-20·7, 1·2
Carbohydrate on weekend (g)	223·5	95·4	4·36	-5·6, 4·8	**220·7**	**98·7**	**11·96**	**11·2, 12·6†**	237·1	95·7	-0·63	-14·7, 4·3	222·9	91·8	-3·85	-11·5, 8·5
Protein (weekly average; g)	77·6	29·6	0·04	-2·2, 1·0	76·5	28·9	0·72	-2·5, 2·5	81·5	29·4	-1·20	-4·2, 1·4	73·9	28·8	-1·08	-4·4, 2·1
Protein on weekdays (g)	77·7	34·5	-0·03	-2·8, 0·8	76·1	32·0	-0·09	-3·4, 2·2	81·3	34·8	-1·04	-4·8, 1·7	71·9	35·1	-0·72	-5·0, 2·2
Protein on weekend (g)	77·2	33·9	0·26	-1·4, 2·2	77·6	35·2	2·76	-1·0, 4·1	81·9	35·1	-1·61	-4·2, 2·0	79·0	34·5	-2·00	-4·6, 3·5
Total fat (weekly average; g)	81·3	32·9	1·61	-1·6, 1·9	81·0	31·9	1·95	-2·0, 2·5	82·3	31·9	2·27	-1·8, 4·6	74·7	30·6	-1·40	-4·5, 3·2
Total fat on weekdays (g)	80·9	37·9	1·77	-1·8, 2·3	80·2	35·5	1·30	-2·3, 3·1	81·0	38·0	2·95	-2·1, 5·7	71·7	36·0	-1·37	-5·7, 3·1
Total fat on weekend (g)	82·3	38·4	1·22	-1·8, 1·8	**83·2**	**40·9**	**3·69**	**3·4, 3·8†**	85·7	35·6	0·06	-2·9, 3·6	82·2	40·1	-1·48	-3·1, 4·8
Fibre (weekly average; g)	16·1	9·0	-0·37	-0·9, 0·06	**15·7**	**8·3**	**-0·76**	**-0·8, –0·7†**	17·8	11·6	0·07	-1·0, 0·7	15·2	8·35	-0·59	-1·9, 0·2
Fibre on weekdays (g)	16·5	10·4	-0·42	-1·0, 0·009	**16·2**	**9·6**	**-0·93**	**-0·9, –0·8†**	18·3	13·1	0·06	-1·1, 1·0	15·1	9·9	-0·49	-2·3, 0·1
Fibre on weekend (g)	15·2	9·2	-0·25	-0·8, 0·03	14·5	8·8	-0·33	-0·9, 0·1	16·6	10·9	0·10	-1·2, 0·5	15·6	9·68	-0·86	-1·6, 0·06
Cholesterol (weekly average; mg)	288·9	187·3	11·12	-7·9, 11·4	**289·5**	**172·3**	**18·86**	**17·8, 19·9†**	284·8	173·6	13·30	-14·7, 22·6	256·3	154·0	3·88	-14·9, 19·7
Cholesterol on weekdays (mg)	278·7	217·6	10·57	-10·6, 11·6	274·1	194·6	13·30	-16·3, 19·5	267·1	212·1	12·19	-19·2, 22·0	239·7	180·1	5·05	-18·3, 22·4
Cholesterol on weekend (mg)	314·7	229·7	12·49	-7·5, 17·2	**327·9**	**244·4**	**32·75**	**30·9, 34·6†**	329·2	203·8	16·09	-13·0, 33·5	297·9	230·8	0·93	-19·3, 24·8
Sugar (weekly average; g)	93·6	51·1	1·14	-4·1, 1·8	91·6	47·7	2·97	-3·8, 4·0	100·3	63·1	1·18	-9·7, 3·9	91·8	52·3	-6·03	-8·0, 2·1
Sugar on weekdays (g)	93·4	57·7	0·45	-5·3, 1·5	90·7	53·4	0·62	-4·8, 4·2	100·6	73·7	1·83	-10·6, 4·7	89·8	58·4	-7·79	-10·5, 0·1
Sugar on weekend (g)	94·1	57·6	2·87	-2·7, 4·2	**93·9**	**57·4**	**8·84**	**8·3, 9·3†**	99·4	58·1	-0·43	-8·5, 3·0	96·8	59·7	-1·63	-3·4, 9·8

NHANES, National Health and Nutrition Examination Survey.
*Linear regression analysis adjusted for age, sex, race, marital status, education level, income, BMI and sleep duration. Independent variable: eating midpoint jetlag.
Dependent variable: energy content, carbohydrate, protein, total fat, fibre, cholesterol and sugar.
†$P < 0·05$ was statistically significant.

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Table 3. Association of eating midpoint jetlag with anthropometric variables according to chronotype tertile, NHANES 2017–2018 (Beta-coefficients and 95 % confidence intervals)

	Eating midpoint jetlag*															
	All (*n* 1184)				Morningness tendency tertile (*n* 440)				Indifferent tendency tertile (*n* 397)				Eveningness tendency tertile (*n* 347)			
	Mean	SD	*β*	95 % CI	Mean	SD	*β*	95 % CI	Mean	SD	*β*	95 % CI	Mean	SD	*β*	95 % CI
BMI (kg/m^2)	29·8	7·4	0·449	-0·10, 0·96	29·6	7·4	0·33	-0·39, 1·31	29·3	6·6	-0·26	-0·76, 0·57	**29·7**	**8·1**	**1·20**	**1·13, 1·26**†
WC (cm)	100·5	17·7	1·025	-0·27, 2·19	100·7	18·1	0·84	-0·83, 3·34	100·3	15·9	-0·54	-1·88, 1·17	100·2	18·9	1·61	-0·83, 2·66
HC (cm)	107·6	14·3	0·863	-0·20, 1·84	107·5	14·6	0·71	-0·79, 2·54	107·3	12·2	-0·67	-1·47, 0·94	107·5	15·1	1·92	-0·45, 2·76
Weight (kg)	83·8	23·4	1·123	-0·39, 2·57	84·4	24·1	1·35	-1·06, 3·79	83·2	22·0	-1·24	-2·55, 1·60	83·2	25·6	2·19	-0·91, 3·55

NHANES, National Health and Nutrition Examination Survey; WC, waist circumference; HC, hip circumference.
*Linear regression analysis adjusted for age, sex, race, marital status, education level, income, energy content and sleep duration. Independent variable: eating midpoint jetlag. Dependent variable: BMI, WC, HC, weight.
†$P < 0·05$ was statistically significant.

Morningness-Eveningness Questionnaire score, which measures an individual's chronotype, and the energetic midpoint ($P < 0·001$)[11]. This indicates that individuals with an eveningness tendency tend to concentrate their energetic consumption later in the day. Another study involving ninety-six women found that the lunch ($P = 0·004$) and mid-afternoon snack time ($P = 0·04$) in the evening type group were significantly later compared with the morning type group. In addition, the percentage energy intake after 3 pm was higher ($P = 0·008$) in those women with late chronotype[31]. Furthermore, evening types also exhibit life behaviours that can contribute to excessive weight gain, such as frequently skipping breakfast[32], sedentary lifestyle[33] and regularly worse food choices[17]. Late-night eating has also been associated with adverse health effects, such as insulin resistance[34], lower lipid oxidation and, consequently, more lipid accumulation[35], which may reflect a higher BMI.

There are some limitations in the present research. First, this exploratory study was cross-sectional and, although we performed analyses that potentially addressed the effects of possible confounding factors, this experimental design limits its ability to establish causal relationships. Also, our study was conducted with the adults in the US population only and its results cannot be extrapolated to all populations. In addition, because our variable of interest is related to food consumption – and necessarily needs to report consumption on weekdays and weekends – we had many losses in the sample available in the database and, what was previously guaranteed to be representative of population, now the results found in this study may not reflect the behaviour of all adults in the USA. Finally, the estimation of food consumption was done using the mean, and although we calculated the average taking into account the representativeness of each day through weighting, it may not fully reflect the usual consumption of the population.

In conclusion, our study found that mealtime variation on weekdays and weekends is associated with higher food consumption among morning types on weekends. Additionally, mealtime variation from weekdays to weekends was associated with higher BMI values in evening types. However, further studies are needed to confirm the influence of mealtime variability on BMI and the risk of obesity.

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