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Temporal patterns of energy intake identified by the latent class analysis in relation to prevalence of overweight and obesity in Iranian adults

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Abstract

We aimed to identify temporal patterns of energy intake and investigate their association with adiposity. We performed a cross-sectional study of 775 adults in Iran. Information about eating occasions across the day was collected by three 24-h dietary recalls. Latent class analysis (LCA) was used to identify temporal eating patterns based on whether or not an eating occasion occurred within each hour of the day. We applied binary logistic regression to estimate the OR and 95 % CI of overweight and obesity (defined as BMI of 25–29·9 and ≥ 30 kg/m^2, respectively) across temporal eating patterns while controlling for potential confounders. LCA grouped participants into three exclusive sub-groups named 'Conventional', 'Earlier breakfast' and 'Later lunch'. The 'Conventional' class was characterised by high probability of eating occasions at conventional meal times. 'Earlier breakfast' class was characterised by high probability of a breakfast eating occasion 1 h before the conventional pattern and a dinner eating occasion 1 h after the conventional pattern, and the 'Later lunch' class was characterised by a high probability of a lunch eating occasion 1 h after the conventional pattern. Participants in the 'Earlier breakfast' pattern had a lower likelihood of obesity (adjusted OR: 0·56, 95 % CI: 0·35, 0·95) as compared with the 'Conventional' pattern. There was no difference in the prevalence of obesity or overweight between participants in the 'Later lunch' and the 'Conventional' patterns. We found an inverse association between earlier eating pattern and the likelihood of obesity, but reverse causation may be a plausible explanation.

Key words: Chrononutrition: Chronotype: Dietary patterns: Temporal eating patterns

According to the latest global data, a higher BMI is one of the top risk factors for developing non-communicable chronic disease[1]. Adiposity, defined as elevated BMI[2], waist measures[3] or body fat content[4], is associated with a greater risk of premature death. Adiposity is also associated with a higher risk of developing type 2 diabetes[5], cite-specific cancers[6] and CVD[7]. The worldwide prevalence of obesity has increased during the past three decades[8] and, thus, finding its modifiable risk factors has become a global health priority[9].

Recent evidence suggests that some eating styles, such as meal timing[10] and frequency[11] and irregular energy intake[12], may have a role in the aetiology of obesity. For instance, higher energy intake in the morning was associated with a lower likelihood of adiposity[13] and, in contrast, consumption of energy later in the day may be associated with a higher risk[14,15]. The 2017 American Heart Association scientific statement suggested that some meal-specific eating styles, such as meal timing and frequency, are associated with cardiometabolic health and suggested focusing on such meal-specific properties to achieve a healthier lifestyle and improved risk factor management[16].

Traditional statistical approaches such as factor analysis, principal component analysis, and cluster analysis have been frequently used to explore data-driven patterns of dietary intake in various populations[17]. In this regard, novel statistical approaches that consider other aspects of the data, such as time, can present helpful information about the potential interaction between time and dietary intake and, thus, can extend our understanding of the complex relationship between diet and health.

However, studies that addressed the potential interaction between time and dietary intake have mainly focused on the proportion of total energy intake in a single meal[18], the proportion

Abbreviations: AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; LCA, latent class analysis.

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of energy in a specific time period in the day (e.g. after 17.00)[19], meal skipping[20], meal frequency and timing[21] or the ratio of the morning to the evening energy intake[22].

The addition of time to the dietary pattern analysis resulted in a new concept named '*temporal eating patterns*'[23]. Temporal eating pattern analysis simultaneously integrates time, amount of energy and sequence of all eating occasions during the 24 h to explore the temporal distribution of energy intake. For this purpose, some studies applied k-means cluster analysis to explore posteriori-defined, data-driven temporal eating patterns[24–26], and some others applied a latent class analysis (LCA) approach[27,28]. These exploratory approaches do not require a predefined definition of meal and snack timing and, thus, can identify unknown patterns in exclusive subgroups based on a set of observed categorical variables. Of note, LCA has several advantages, such as modeling observed outcomes with different distributions simultaneously, accounting for correlated errors, assessing goodness-of-fit, and multi-group analysis[29]. Thus has been recognised as a practical statistical approach to investigating complex relationships between diet and human health at the 2000 International Workshop of Dietary Patterns[30].

Almost all of the evidence regarding the association between meal timing and obesity are from Western countries, and limited data are available about this association from countries in the Middle East. Due to geographical disparities, people living in the Middle East have different meal timing as compared with those living in Western countries. Therefore, we aimed to investigate the association between meal timing, as assessed by data-driven temporal eating patterns obtained from the LCA approach, and the likelihood of adiposity in a cross-sectional study of adults in Iran.

Subjects and methods

We performed a cross-sectional study in Tehran, the capital city of Iran, from 2018 to 2019. The study sample size was estimated by using the following formula: n = (pqz2)/E2[31,32], where the prevalence of overweight and obesity in Tehranian adults was (65 %)[33], and error coefficient and α level were considered as d = 0·04 and $\alpha = 0{\cdot}05$, respectively. The sample size of 546 participants was therefore obtained. Considering the design effect of 1·5 and to compensate for the potential exclusion of participants due to under- and overreporting of total energy intake or attrition due to other reasons, the final sample size of 850 participants was selected for inclusion.

Study participants

Eligible participants were apparently healthy men and women who were not diagnosed as having any disease according to their statement, aged 20–59 years, attended the local health care centres across Tehran during the study period and volunteered to participate in the study. Apparently, healthy participants were defined as those without a known history of CVD, cancers, diabetes, kidney diseases and autoimmune disorders. We applied a two-stage cluster sampling for selecting participants from healthcare centres. We first provided a list of active healthcare centres available in five city districts (North, South, East, West and centre). Next, eight health centres were randomly selected from each district (forty health centres). Finally, the total sample size (850) was divided by the health centres (40) to determine the number of participants in each health centre. For the present study, participants with missing data about meal timing (breakfast = 22, lunch = 9, dinner = 13 and snack = 35) were excluded, leaving 775 participants for the analyses (online Supplementary Fig. 1).

Ethical approval

The protocol of the study and informed consent form were approved by the ethics committee of the Tehran University of Medical Sciences (Ethic Number: IR.TUMS.VCR.REC.1397·157). At the recruitment stage, written information regarding the background and procedures of the study was presented to all participants, and then, written informed consent was signed by the study participants.

Data collection

During a private interview and by using pre-specified data extraction forms, participants' demographic characteristics were recorded. A trained interviewer completed a researcher-developed questionnaire designed to assess the participants' demographics, including age (year), sex (male, female), educational level (illiterate, high school, high school diploma and undergraduate/graduate), marital status (married or other (not married or divorced)), occupation (employed, retired, house-keeper or unemployed) and smoking status (never smoker, former smoker or current smoker).

Dietary assessment

We used three 24-h dietary recalls to assess the dietary intake of the participants. The first recall was performed during the first visit to each health centre (weekday). The other two 24-h dietary recalls were conducted on random days, including one weekend, by telephone. A trained dietitian recorded all food and beverages that the participant had consumed during the denominated meal. Daily intakes of all food items obtained from 24-h dietary recall were computed and then converted into grams per day by using household measures[34]. The three-day dietary intakes were summed and averaged over the 3 days to estimate the mean dietary intake. Participants with at least two completed 24-h dietary recalls were eligible for inclusion in the present study. To calculate the overall diet quality of the study participants, we calculated Health Eating Index-2015 for each participant[35].

Energy misreporting

Previous research suggested that participants who underreport their total energy intake may also underreport their eating occasions[36,37]. Energy misreporting may bias the association between temporal eating patterns and the likelihood of adiposity[18]. Therefore, we calculated the frequency of energy misreporting in the study participants[27,38]. We first calculated the ratio of total energy intake to energy expenditure (EI:EE). Then,

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participants whose EI:EE was within the range of mean ± 1 sd were considered plausible reporters. Those with a ratio of less than mean – 1SD and greater than mean + 1SD were considered underreporters and overreporters, respectively[39,40].

Eating occasions

For the present study, an eating occasion was defined as any occasion at which food or drink was consumed and provided a minimum energy content of 210 kJ (50 kcal) and was separated in time from the surrounding eating occasions by 15 min, which was reported in the 24-h dietary recalls[27]. We defined eating occasions based on energy intake since this method may be better than other approaches, such as time-based approaches[16,41] or methods with no energy criterion[41,42] to predict total energy intake and adiposity measures. Main meals, including breakfast, lunch and dinner, were defined as the greatest eating occasion that occurred between 05.00 and 11.00, 12.00 and 16.00 and 17.00 and 23.00, respectively.[43]. Other eating occasions were classified as snacks.

Anthropometric measurements and physical activity assessment

Weight was measured using an adult's digital scale (Seca model 808, measurement accuracy +/–100 g)[44]. Height was measured, unshod, using a wall stadiometer with a sensitivity of 1 mm (Seca, Germany)[44]. BMI was calculated by dividing weight in kilograms by the square of height in meters. Physical activity was evaluated using the International Physical Activity Questionnaire[45] and expressed as metabolic equivalent minutes (MET) per week[46].

Definition of general obesity

Overweight and obesity were defined as a BMI of 25–29·9 and ≥ 30 kg/m^2, respectively[47].

Chronotype assessment

We used the Morningness-Eveningness Questionnaire, developed by Horne and Ostberg[48], which is a validated and reliable tool for chronotype assessment in the Iranian population[49]. The Morningness-Eveningness Questionnaire contains nineteen questions that are related to daily performance and sleep-related behaviours, such as sleep time preferences and sleep duration. The range of scores varies from 16 to 86, with higher scores indicating a propensity towards morningness and lower scores showing a tendency towards eveningness. Based on the Morningness-Eveningness Questionnaire score, we divided subjects into three groups, including morning-, intermediate- and evening-type chronotypes[50]. Due to the very low number of participants who had morning type chronotype (≤ 2 %), we combined morning type and intermediate categories for the robustness of the analysis.

Statistical analysis

We used M-*Plus* version 5.1[51] to identify LCA-derived temporal eating patterns across the day in the study participants[27,52]. LCA is a person-oriented statistical procedure that identifies categorical latent class variables based on observed categorical variables[53]. LCA was first used in psychological research to classify individuals into exclusive sub-groups with similar data patterns to determine the degree of the association between these patterns and a specific outcome[54,55]. Similar to cluster analysis, LCA is a statistical approach in which participants, based on the similarity of their data pattern, are classified into exclusive sub-groups with similar data patterns. For the analyses, we classified each day into 24 h (24 eating occasions) as observed categorical variables. Energy intake within each hour of the day was estimated and averaged over the dietary recalls (at least two dietary recalls). Then, we generated binary variables based on whether or not an eating occasion providing a minimum energy content of ≥ 50 kcal had occurred within each hour. Finally, 24 binary variables, indicating the pattern of energy intake across 24 h of the day, were included in the LCA.

We first performed LCA with 1–8 classes to determine the optimum number of classes using the Lo–Mendell–Rubin likelihood ratio test, the Bayesian Information Criterion (BIC) and the Akaike Information Criterion (AIC)[56]. The optimum number of classes was selected based on the lower values of the BIC and AIC. Then we performed LCA using the optimum number of classes to classify study participants into exclusive temporal eating patterns.

All statistical analyses to compare characteristics of the study participants across LCA-derived temporal eating patterns and to investigate their association with overweight and obesity were performed by SPSS version 22[57]. We used ANOVA and χ^2 tests to compare the characteristics of the study participants across LCA-derived temporal eating patterns. We performed binary logistic regression to investigate the association between LCA-derived temporal eating patterns and odds of having overweight and/or obesity. Participants classified as obesity were not included in the analysis in which overweight was a dependent variable. Similarly, participants classified as overweight were not included (in the comparison group) in the analysis in which obesity was a dependent variable. The OR and 95 % CI of overweight and/or obesity were calculated while controlling for age, marital status, occupation, physical activity, cigarette smoking, educational level, sleep duration, frequency of eating occasions, chronotype and daily energy intake. To control for energy misreporting, we additionally adjusted for EI:EE and performed a sensitivity analysis after the exclusion of underreporters and overreporters. Since there was evidence of a potential effect modification by sex in the association between temporal eating patterns and obesity[27], we did an additional sub-group analysis by sex. $P < 0{\cdot}05$ was considered statistically significant.

Results

Temporal eating patterns

In total, 775 men and women participated in the present study. LCA identified three data-driven temporal eating patterns. We named each pattern based on the conditional probabilities of eating occasions that occurred at certain times

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Table 1. Conditional probability of eating occasions across the day by temporal eating patterns*

Time of day (hours)		Temporal eating patterns		
		Conventional (*n* 280)	Earlier breakfast (*n* 131)	Later lunch (*n* 364)
01.00–02.00	Yes	0·01	0	0
	No	0·99	1	1
02.00–03.00	Yes	0·01	0	0
	No	0·99	1	1
03.00–04.00	Yes	0·01	0	0
	No	0·99	1	1
04.00–05.00	Yes	0·01	0·01	0·01
	No	0·99	0·99	0·99
05.00–06.00	Yes	0·01	0·01	0·01
	No	0·99	0·99	0·99
06.00–07.00	Yes	0·04	0·06	0·06
	No	0·96	0·94	0·94
07.00–08.00	Yes	0·35	**0·52**	0·24
	No	0·65	0·48	0·76
08.00–09.00	Yes	**0·51**	0·35	**0·55**
	No	0·49	0·65	0·45
09.00–10.00	Yes	0·07	0·07	0·14
	No	0·93	0·93	0·86
10.00–11.00	Yes	0·01	0·01	0·01
	No	0·99	0·99	0·99
11.00–12.00	Yes	0·01	0·01	0
	No	0·99	0·99	1
12.00–13.00	Yes	0·04	0·04	0
	No	0·96	0·96	1
13.00–14.00	Yes	**0·88**	**0·81**	0
	No	0·12	0·19	1
14.00–15.00	Yes	0·01	0	**1**
	No	0·99	1	0
15.00–16.00	Yes	0·08	0·13	0·01
	No	0·92	0·87	0·99
16.00–17.00	Yes	0·14	0·14	0·10
	No	0·86	0·86	0·90
17.00–18.00	Yes	0·42	0·39	0·42
	No	0·58	0·61	0·58
18.00–19.00	Yes	0·30	0·37	0·36
	No	0·70	0·63	0·64
19.00–20.00	Yes	0·10	0·03	0·10
	No	0·90	0·7	0·90
20.00–21.00	Yes	**0·87**	0	**0·60**
	No	0·13	1	0·40
21.00–22.00	Yes	0·02	**1**	0·33
	No	0·98	0	0·67
22.00–23.00	Yes	0·03	0	0·03
	No	0·97	1	0·97
23.00–24.00	Yes	0·01	0	0·01
	No	0·99	1	0·99
24.00–01.00	Yes	0·01	0	0·01
	No	0·99	1	0·99

* High conditional probability was defined as > 0·50 that is indicated in bold numbers.

across the day relative to the other classes (Table 1 and Fig. 1). The first pattern, named 'Conventional' (*n* 280, 36 % of participants), was characterised by high conditional probabilities of eating occasions that occurred at traditional meal times in Iran(e.g., breakfast at 08.00, lunch at 13.00 and dinner at 20.00). The second pattern, named 'Earlier breakfast' (*n* 131, 17 % of participants), was mainly characterised by breakfast eating occasion that occurred 1 h before the conventional pattern (at 07.00) and dinner eating occasion 1 h after the conventional pattern (21.00). We named the third pattern as 'Later lunch' (*n* 364, 47 % of participants), since participants in this class had a high probability of a lunch eating occasion 1 h after the conventional pattern (at 14.00).

Characteristics of the study participants

Characteristics of the study participants across LCA-derived temporal eating patterns are described in Table 2. In brief, the average age of the participants was 44·5 ± 10·7 years, of whom 68 % were women. Eighty-one percent of the participants were married, 34 % were university graduates and 62 % had low levels of physical activity. The average BMI of the participants was 27·7 ± 4·5 kg/m^2, of whom 44 % were overweight and 26 % were obese. Participants in the 'Earlier breakfast' class had a lower frequency of total eating occasions and snacks across the day as compared with those in the 'Conventional' and 'Later lunch' patterns. There were no other differences in terms of general characteristics across temporal eating patterns.

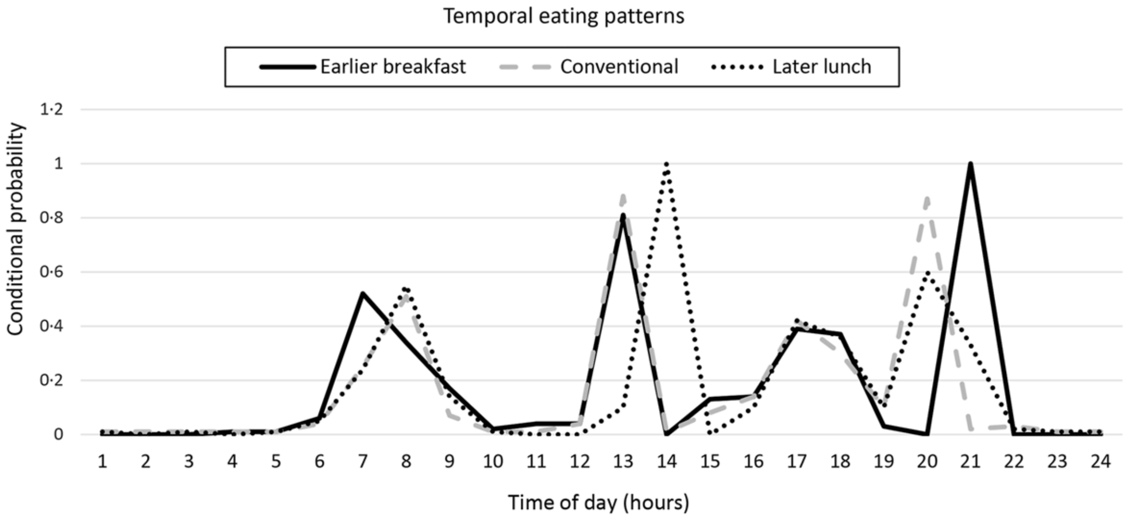

Fig. 1. Temporal eating patterns across the day in the study participants identified by the latent class analysis.

Sex-specific analyses suggested some potential differences in men and women (Table 2), in ways that the proportion of those with no job was significantly higher in women and, in contrast, the proportion of current smokers and those who were married were significantly higher in men. Although the average BMI was relatively equal across either sex, the proportion of overweight (BMI 25–29·9 kg/m^2) was higher in men, but the proportion of obesity (BMI ≥ 30 kg/m^2) was higher in women. The average waist circumference was larger in men, but the average hip circumference was larger in women. Women also had a higher frequency of eating occasions and a shorter sleep duration than men. Regarding energy misreporting, the proportion of overreporting was lower, and the proportion of underreporting was higher in men than in women. The proportion of under- and overreporting did not differ across temporal eating patterns.

Table 3 presents the dietary intake of the study participants across LCA-derived temporal eating patterns. Intake of energy, overall diet quality as assessed by the Healthy Eating Index-2015 and intake of macronutrients and major food groups did not differ across temporal eating patterns. The Healthy Eating Index-2015 score was similar in men (50·5 ± 6·5) and women (50·4 ± 7·5) (P = 0·89).

The association between temporal eating patterns and the likelihood of overweight and obesity is indicated in Table 4. When compared with the ‘Conventional’ pattern, there was no association between ‘Earlier breakfast’ and ‘Later lunch’ eating patterns and odds of having overweight. However, participants in the ‘Earlier breakfast’ pattern had a lower likelihood of obesity as compared with those in the ‘Conventional’ pattern (adjusted OR: 0·56, 95 % CI: 0·35, 0·95). There was no association between the ‘Later lunch’ pattern and the odds of having obesity. We also did an additional sub-group analysis by sex, where women in the ‘Earlier breakfast’ pattern had a lower likelihood of having obesity (adjusted OR: 0·40, 95 % CI: 0·22, 0·75) as compared with those in the ‘Conventional’ pattern. There was no association between temporal eating patterns and the odds of having overweight or obesity in men (Table 4).

The inverse associations with obesity persisted after additional adjustment for EI:EE, where being in the ‘Earlier breakfast’ class was associated with a 62 % lower likelihood of obesity in all participants (adjusted OR: 0·38, 95 % CI: 0·22, 0·70) and a 71 % lower likelihood of obesity in women (adjusted OR: 0·29, 95 % CI: 0·18, 0·62) (online Supplementary Table 1). A sensitivity analysis after the exclusion of participants with under- and overreporting of energy intake (n 531) indicated similar results with the main analysis, where being in the ‘Earlier breakfast’ class, as compared with ‘conventional’ class, was associated with a lower odds of obesity in all participants (adjusted OR: 0·59, 95 % CI: 0·31, 0·97) and in women (adjusted OR: 0·34, 95 % CI: 0·18, 0·78) (online Supplementary Table 2).

Discussion

The present cross-sectional study used LCA to identify data-driven temporal eating patterns in a sample of Iranian adults. We found three temporal eating patterns, named ‘Conventional’, ‘Earlier breakfast’ and ‘Later lunch’. Those in the ‘Conventional’ pattern had high probabilities of eating occasions at traditional meal times in Iran. Participants in the ‘Earlier breakfast’ pattern had a high probability of a breakfast eating occasion that occurred 1 h before the ‘Conventional’ pattern and a high probability of a dinner eating occasion that occurred 1 h after the ‘Conventional’ pattern. Those in the ‘Later lunch’ pattern had a high probability of a lunch eating occasion that occurred 1 h after the ‘Conventional’ pattern. The analyses suggested an inverse association between the ‘Earlier breakfast’ pattern and the odds of having obesity as compared with the ‘Conventional’ pattern. There was no association between the ‘Later lunch’ pattern and the odds of having overweight and obesity. The sub-group analyses suggested a potential effect modification by sex, where the inverse association between ‘Earlier breakfast’ pattern and obesity was significant in women, but not in men.

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Table 2. Characteristics of the study participants by latent class of temporal eating patterns

	All participants (*n* 775)			Men (*n* 244)			Women (*n* 531)				Conventional (*n* 280)			Earlier breakfast (*n* 131)			Later lunch (*n* 364)			
	%	Mean	SD	%	Mean	SD	%	Mean	SD	*P**	%	Mean	SD	%	Mean	SD	%	Mean	SD	*P*†
Age (years)		44·5	10·7		45·2	10·2		44·2	11·0	0·22		44·9	10·1		45·4	10·7		44·0	11·0	0·40
Sex (% women)	68			0			100				70			68			67			0·76
University graduate (%)	34			38			33			0·08	33			30			36			0·84
Employment status (%)										< 0·001										0·43
With job	27			41			20				27			20			29			
No job/retired	18			30			13				17			22			17			
Homemaker	55			29			67				56			58			54			
Smoking status (% current)	5			12			2			< 0·001	4			3			7			0·19
Marital status (% married)	81			89			77			< 0·001	80			77			83			0·29
Physical activity level (% low)	62			63			60			0·23	62			63			62			0·98
BMI (kg/m^2)		27·7	4·5		27·5	3·9		27·7	4·8	0·55		27·9	4·2		27·3	4·0		27·7	4·3	0·34
Weight status																				
Overweight (%)	44			53			39			< 0·001	44			47			42			0·62
Obesity (%)	26			24			30			0·046	31			22			28			0·18
Sleep duration (h/d)		6·4	1·0		6·5	1·0		6·4	1·1	0·02		6·4	1·1		6·5	1·1		6·5	1·1	0·86
Chronotype										0·06										0·89
Morning type/Intermediate (%)	47			50			46				48			47			46			
Evening type (%)	53			50			54				52			53			54			
Feeding frequency																				
Eating occasion frequency (*n*)		6·3	0·9		6·1	0·9		6·3	0·9	< 0·001		6·3	0·9		6·0	0·9		6·3	0·9	0·009
Meal frequency (*n*)		2·9	0·3		2·9	0·3		2·9	0·3	0·20		2·9	0·2		2·9	0·3		2·9	0·2	0·66
Snack frequency (*n*)		3·4	0·8		3·2	0·8		3·5	0·8	< 0·001		3·4	0·8		3·2	0·8		3·4	0·8	0·008
Energy misreporting status (%)‡										< 0·001										0·79
Plausible reporters	17			18			16				18			17			15			
Underreporters	68			75			66				67			66			70			
Overreporters	15			7			18				15			17			15			

† Obtained from ANOVA for continuous variables or χ^2 test for categorical variables. **P* value is considered significant at < 0·05.
‡ Defined by using the ± SD cut-off for EI:EE of < 1·0496 for underreporters and > 2·0362 for overreporters.

Table 3. Dietary intake of the study participants across temporal eating patterns

	Conventional (*n* 280)		Earlier breakfast (*n* 131)		Later lunch (*n* 364)		
	Mean	SD	Mean	SD	Mean	SD	*P**
Daily energy intake (kcal/d)	2271	688	2337	784	2321	686	0·58
Diet quality							
Healthy Eating Index-2015	49·8	7·0	51·3	6·7	50·6	7·4	0·20
Macronutrients							
Carbohydrates (g/d)	335	116	343	127	348	117	0·46
Fat (g/d)	75	30	72	29	74	32	0·68
Protein (g/d)	78	27	81	29	81	29	0·44
Food groups							
Grains (g/d)	383	181	425	202	385	181	0·08
Fruits (g/d)	272	195	285	190	279	190	0·81
Vegetables (g/d)	346	203	388	200	347	188	0·10
Legumes (g/d)	27	25	29	29	26	24	0·52
Nuts (g/d)	12	17	15	17	11	13	0·05
Red meat (g/d)	38	33	40	36	36	32	0·56
Processed meat (g/d)	3	6	3	6	3	9	0·86
Fish (g/d)	11	20	12	23	12	22	0·88
Egg (g/d)	22	30	22	25	20	21	0·53
Low-fat dairy (g/d)	292	209	317	204	309	209	0·48
High-fat dairy (g/d)	76	70	77	69	75	73	0·95
Soft drinks (g/d)	32	77	39	145	28	92	0·58

* Obtained from ANOVA.

Table 4. The association between temporal eating patterns and likelihood of overweight and obesity in the study participants (odds ratio and 95 % CI)

		Earlier breakfast		Later lunch	
	Conventional	Odds ratio	95 % CI	Odds ratio	95 % CI
Overweight (BMI 25–29·9 kg/m^2)					
All participants (cases/noncases)	124/156	61/70		153/211	
Crude	1·00	1·09	0·71, 1·68	0·90	0·66, 1·24
P value		0·68		0·53	
Adjusted*	1·00	1·06	0·68, 1·63	0·90	0·66, 1·24
P value		0·71		0·47	
Women (cases/noncases)	78/117	41/48		93/150	
Crude	1·00	1·21	0·71, 2·04	0·92	0·62, 1·36
P-value		0·48		0·66	
Adjusted	1·00	1·13	0·74, 2·03	0·92	0·65, 1·31
P value		0·41		0·67	
Men (cases/noncases)	46/39	20/22		60/61	
Crude		0·87	0·40, 1·88	0·82	0·47, 1·45
P-value		0·72		0·80	
Adjusted	1·00	0·89	0·46, 1·81	0·86	0·50, 1·38
P value		0·80		0·65	
Obesity (BMI ≥ 30 kg/m^2)					
All participants (cases/noncases)	86/194	28/103		101/263	
Crude	1·00	0·62	0·38, 1·03	0·87	0·61, 1·23
P value		0·07		0·42	
Adjusted	1·00	0·56	0·35, 0·95	0·91	0·67, 1·34
P value		0·03		0·52	
Women (cases/noncases)	68/127	18/71		73/170	
Crude		0·46	0·25, 0·87	0·80	0·53, 1·20
P value		0·014		0·28	
Adjusted	1·00	0·40	0·22, 0·75	0·84	0·52, 1·23
P value		0·004		0·46	
Men (cases/noncases)	18/67	10/32		28/93	
Crude	1·00	1·27	0·52, 3·10	1·12	0·57, 2·19
P value		0·60		0·74	
Adjusted	1·00	1·41	0·50, 3·49	1·18	0·60, 2·30
P value		0·50		0·52	

* Adjusted for age, sex (in the main analysis), smoking status, physical activity, educational level, occupation, marital status, sleep duration, chronotype, frequency of eating occasions and total energy intake.

Temporal eating patterns focus on the timing, frequency and regularity of eating occasions across the day[23]. Considering the interaction between the timing of food intake, circadian rhythms, physiology and metabolism, it is proposed that timing of food intake may play a role in human health[58]. Chrononutrition is an emerging field in nutrition research that focuses on the timing of food intake[58]. During recent years, several investigations have been performed to understand the timing or patterning of eating occasions across the day, as well as the potential association between these eating patterns and multiple health outcomes[59,60].

However, most studies on the timing of food intake have mainly focused on the timing of a specific meal. For example, studies have addressed the proportion of total energy intake in a single meal[18], the proportion of energy in a specific time period in the day (e.g. after 17·00)[19] or the ratio of the morning to the evening energy intake[22]. Temporal eating patterns consider all eating occasions across the day[61] and explore how well posteriori-defined temporal distribution of energy intake across the day is associated with diet quality[23] and health outcomes[27].

'Conventional' and 'Later lunch' patterns found in the present study were similar with those identified in a cross-sectional study of Australian adults[27]. A cross-sectional study of 4544 Australian adults used a similar LCA approach to identify temporal eating patterns across the day and found three eating patterns named 'Conventional', 'Later lunch' and 'Grazing' patterns. The 'Grazing' pattern found in the Australian study was characterised by more frequent eating occasions across the day and lower conditional probabilities of an eating occasion at standard meal times. Instead, we found an 'Earlier breakfast' pattern, in which participants had a high probability of a breakfast eating occasion 1 h before the 'Conventional' pattern and a high probability of a dinner eating occasion 1 h after the 'Conventional' pattern. Another cross-sectional analysis in a nationally representative sample of 1627 USA adults used cluster analysis to find temporal eating patterns considering timing and frequency of energy intake across the day[62]. They found four temporal dietary patterns, of which, a temporal dietary pattern characterised by evenly spaced, energy-balanced eating occasions was associated with a lower BMI, waist circumference and likelihood of obesity as compared with other patterns with higher eating occasions at different times throughout the day[62].

The associations between meal timing and the risk of obesity and other cardiometabolic abnormalities have been a topic of interest recently. A small cross-sectional study of Malaysian adults found a temporal eating pattern characterised by smaller energy intake earlier in the day and greater energy intake later in the day and indicated a positive association between this eating pattern and odds of metabolically unhealthy obesity[63]. Another cross-sectional study in the USA indicated that each 1 h later start of eating was associated with a 1·25 unit increase in percent body fat[64]. In addition, two randomised trials implementing a weight loss intervention indicated that participants with a high energy intake at breakfast and lunch meals and a low energy intake at dinner meals experienced a greater weight loss and reduction in insulin resistance than other participants[65,66]. A recent review of observational studies also suggested a positive association between energy intake in the evening and adiposity[58]. In total, accumulative evidence from cross-sectional studies suggests that meal timing and frequency may be related to adiposity and levels of other cardiometabolic risk factors, in ways that higher intake of energy earlier in the day, defined as early eating, may be associated with better cardiovascular consequences and in contrast greater energy intake later in the day, defined as late eaters, may be associated with unfavourable health outcomes[67].

There exist some potential mechanisms that may explain the observed inverse association between the 'Earlier breakfast' pattern and lower odds of obesity in the present study. Previous studies suggested that intake of energy and macronutrients and overall diet quality may be different across temporal eating patterns[23,27]. Thus, the observed difference in the prevalence of obesity across temporal eating patterns may be due to difference in dietary intake. However, our results indicated that energy intake and overall diet quality were relatively similar across temporal eating patterns. In addition, evidence suggests that greater energy intake later in the day and, thus, a later temporal eating pattern may be correlated with insulin resistance and weight gain[65,68]. Evidence also suggests a potential link between temporal eating patterns and chronotype in a way that energy intake earlier in the day may be correlated with more morning type and, thus, may be inversely associated with adiposity[69]. In addition, studies suggested a link between genetic predisposition to morning type and lower body weight[70]. It is also suggested that the temporal distribution of energy intake during the day may have been affected by employment status[25]. Although our results did not indicate any significant difference in chronotype and employment status across temporal eating patterns, there might be some other unmeasured lifestyle-related factors that can be associated with both timing of energy intake during the day and obesity.

Similar to the study conducted by Leech *et al.*[27], we found a potential effect modification by sex, where being in the 'Earlier breakfast' pattern was associated with a lower odds of obesity in women, but not in men. In the study by Leech *et al.*[27], they found a positive association between the 'Grazing' pattern and the likelihood of obesity in women, but not in men. Other studies also suggested a potential sex difference in the association between dietary patterns and obesity[71,72]. Some potential explanations, such as shorter sleep duration, higher prevalence of obesity and lower proportion of those who had a job, were married and were current smokers in women compared with men, may partly explain the observed sex difference in the present study. These differences suggest a potential difference in the socio-economic status across sex in the present study and, thus, the observed sex difference in the association between the 'Earlier breakfast' pattern and the likelihood of obesity may partly be due to the difference in socio-economic status. In addition, the frequency of eating occasions was significantly higher in women than in men. There is evidence that increased meal frequency may have effects in favour of weight loss[73]. However, due to limited evidence in the literature, more research is needed to investigate the potential sex difference in the association between temporal eating patterns and the likelihood of obesity.

Strengths and limitations of the study

In the present study, we used a novel statistical approach to identify posteriori-defined data-driven eating patterns based on the timing and frequency of eating occasions. Previous investigations have mainly focused on specific meal timing and, thus, it is not well determined how well distribution patterns of all eating occasions across the day may be associated with adiposity. We found a strong inverse association between the 'Early breakfast' pattern and odds of obesity, especially in women, supporting the use of a novel posteriori-defined approach to explore temporal eating patterns considering all eating occasions. This statistical approach considers the potential interactions between the timing and frequency of all eating occasions and, thus, may have important public health implications. There exists evidence of a change in temporal eating patterns, in ways that the consumption of energy later in the day[74] and frequency of eating occasions across the day[75] have increased during recent years. But limited evidence is available to determine how well temporal eating patterns may be associated with health outcomes. In addition, we obtained dietary data through private interviewing with trained dietitians.

There exist some limitations that deserve consideration when interpreting the results. We used a data-driven statistical approach to identify temporal eating patterns and, thus, our results may not be generalisable to populations living in other countries. As stated above, there were some differences in temporal eating patterns identified in our study compared with other studies conducted in the USA[61] and Australia[27]. We used 24-h dietary recalls to obtain information about dietary intake, which are subject to recall bias and underreporting[76]. In addition, our results are based on a cross-sectional study and, thus, are subject to reverse causality bias. Therefore, more research, especially those of cohort design, is still needed to identify data-driven temporal eating patterns and investigate their association with obesity.

Conclusion

In the present cross-sectional study, we used a novel statistical approach to identify temporal eating patterns across the day in the study participants. We found three LCA-derived posteriori-defined temporal eating patterns named 'Conventional', 'Earlier breakfast' and Later lunch'. As compared with the 'Conventional' pattern, those in the 'Earlier breakfast' pattern had a lower odds of having obesity, but reverse causation may be a plausible explanation. The sub-group analyses suggested a potential effect modification by sex, in a way that there was a significant inverse association between the 'Earlier breakfast' class and odds of obesity in women, but not in men. More research is needed to identify data-driven temporal eating patterns using LCA or other statistical approaches, such as cluster analysis. In addition, prospective observational studies in different geographical regions are needed to present more robust evidence about the association between temporal eating patterns and the risk of obesity.

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There are no conflicts of interest to declare.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S000711452300096X

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