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Associations between Temporal Eating Patterns, Chronotypes and Overweight/Obesity: A Cross-Sectional Study among College Students

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Abstract: Aim: This study aimed to investigate the associations between temporal eating patterns, chronotypes and overweight/obesity among college students. Methods: In this cross-sectional study, 1101 undergraduates completed a validated meal pattern questionnaire (MPQ) and body composition assessment. Based on the meal timing data, the latent class analysis (LCA) method was used to identify four different dietary patterns. Overweight and obesity are defined by body mass index (BMI). Associations between these patterns, chronotypes and overweight/obesity were analyzed using logistic regression, calculating odds ratios (ORs) and 95% confidence intervals (CIs). Results: The temporal eating patterns were significantly associated with chronotypes and overweight/obesity. Compared to the "Conventional" pattern, the "Later snack" pattern was significantly associated with higher odds of overweight/obesity, particularly pronounced in female students. Compared to the "Intermediate Type" chronotypes, the "Definite Morning Type" was negative associated with the "Early Dinner", "Late Dinner", and "Later Snack" patterns. Similar negative associations were also observed for the "Moderate Morning Type" chronotypes. Both "Moderate Evening Type" and "Definite Evening Type" chronotypes showed strong positive associations with the "Later Dinner" pattern. No significance observed between chronotypes and overweight/obesity. Conclusions: A temporal eating pattern characterized by irregular meal and later snack timing was associated with an increased risk of overweight/obesity in college students, especially among females. Promoting earlier snack and regular meal schedules may help mitigate overweight/obesity risk in this population.

Keywords: Meal timing, Temporal eating patterns, Overweight, Obesity, College students

INTRODUCTION

Obesity, characterized by abnormal or excessive fat accumulation, poses a significant threat to health and represents a major global public health challenge burdening healthcare systems worldwide [1]. Globally, obesity affects 13% of the population, while 39% of adults aged over 18 are overweight [2]. This condition elevates risks of cardiometabolic diseases, including hypertension [3], diabetes [4], and cardiovascular disease (CVD) [5], while increasing all-cause mortality [6]. Prevention is particularly crucial among young adults. Individuals reporting overweight or obesity at approximately 21 years of age exhibit mortality rates 19% (95% CI: 12, 27) and 64% (95% CI: 52, 78) higher, respectively, than their normal-weight counterparts [7]. Alarmingly, multinational data indicate that over one-fifth of university students experience overweight or obesity [8].

The university period represents a critical window for establishing lifelong health behaviors. During the transition from high school to college, dietary patterns are highly susceptible to environmental influences, such as the autonomy of campus catering and the increased social pressure, which often promotes detrimental eating practices [9]. Students gain full control over food choices while facing social pressures regarding consumption of specific foods or beverages [10], accompanied by diminished parental influence [11], reduced self-control [12, 13] , and greater accessibility of low-quality, inexpensive foods [14]. While dietary quality, physical activity [15], and psychological factors [16] remain established determinants of obesity, emerging evidence highlights meal timing as a significant contributor to weight dysregulation [17].

The concept of meal timing stems from circadian biology research. The endogenous circadian clock coordinates physiology across hierarchical systems, from central to peripheral tissues, synchronizing with 24-hour light-dark cycles [18, 19]. Meal timing acts as a potent regulator for peripheral clocks, and its misalignment is associated with an elevated risk of obesity and related metabolic disturbances, such as type 2 diabetes and cardiovascular diseases [20]. Conversely, chrono-nutrition misalignment – manifested through delayed meals or nocturnal eating – elevates risks of obesity [21, 22] and metabolic disorder [23]. Meta-analyses consistently confirm associations between specific temporal eating patterns (e.g., breakfast omission, late lunch, and evening hyperphagia) and adverse metabolic outcomes [24], including disruptions in fat accumulation and mobilization [16], increased body fat percentage (PBF) and fat mass index (FMI) [25], and altered lipid profiles and body weight [26]. Similarly, a study among college students indicated that later first and last meal times are associated with lower lean body mass, while a longer eating window is linked to a lower PBF [27].

Nevertheless, as noted in the studies, most current studies focus on analyzing single meal events rather than characterizing holistic temporal eating architectures [16, 24-26] [28], particularly within the college student population. Although one study explored the association between temporal eating patterns and body composition in college students, it relied solely on the first and last meal times and eating window[27], overlooking the role of other daily eating occasion such as snacks. Crucially, no integrated assessment has simultaneously examined temporal eating patterns, chronotypes, and overweight/obesity status in this demographic, leaving their collective relationship undefined.

To address these limitations, this cross-sectional study employed latent class analysis (LCA) on meal pattern questionnaire (MPQ) [29] data to objectively generate overall temporal eating patterns based on the probabilities of typical daily meal and snack timings. This approach avoids predefined categories to capture behavioral phenotype, thereby investigating associations between temporal eating patterns, chronotypes, and overweight/obesity among young adults.

MATERIALS AND METHODS

Study Design and Participants

This cross-sectional survey recruited undergraduate students from a medical university in Chongqing, China, from February 2025 to April 2025. Participants were recruited at the dormitories by providing 5-yuan RMB cash as an incentive. The study has been approved by the Ethics Committee of Chongqing Medical University (approval number: No. 2024–138). All undergraduate students were eligible for participation. Those with eating disorders, anxiety disorders, depression, digestive disorders, and those whose religious beliefs or medications affected their normal eating behaviors, were excluded. Written informed consent was obtained prior to survey administration.

Meal Pattern Investigation

We administered the validated MPQ [29] to assess meal frequency, type, and timing during a typical day. Participants specified their dietary behaviors between 06:00–23:59 on their most representative day based on predefined questionnaire descriptions. Four meal categories were predefined: main meal, light meal, snack meal, and drink meal (Supplementary Table 1). Based on previous studies' definitions of meal times, the periods of morning, lunch, dinner and snacks were divided [30-33], and factors related to Chinese dining culture and university cafeteria systems were also taken into account (Supplementary Table 2).

Physical Examination

Height was self-reported. Body weight and body fat distribution were measured using a body composition analyzer (MIJIA eight-electrode weighing scale, Zhuhai Yunmai Technology Co., Ltd.). body mass index (BMI) was calculated by dividing the body weight (kg) by the square of the height (m2). According to the China Obesity Working Group criteria, a BMI below 18.5 kg/m2 is underweight, a BMI between 18.5 and 23.9 kg/m2 is normal, a value between 24.0 and 27.9 kg/m2 is overweight, and a value over 28.0 kg/m2 is defined as obesity. According to the Chinese guidelines for the diagnosis and treatment of obesity (2024 edition) [34], excessive body fat was defined as the percentage of body fat (PBF) >25% for males or >30% for females; values below these thresholds were considered normal.

Other Variables

Data were collected via paper-based questionnaires during face-to-face interviews. Assessed characteristics included: 1) Sociodemographic: including age, gender (male, female), ethnicity (Han, the others), grade (freshman, sophomore, junior, senior or above), residence (town, country), father’s education level (junior high school and below, high school / technical secondary school, bachelor's degree and above, associate degree), mother’s education level (junior high school and below, high school / technical secondary school, bachelor's degree and above, associate degree), and monthly living expenses (<1500, 1500-2000, >2000). 2) Lifestyle behaviors: including smoking status (yes, no), alcohol consumption (yes, no), takeaway frequency (<1 time/week, 1-3 times/week, 4-6 times/week, ≥1 time/day), off- dining frequency (<1 time/week, 1-3 times/week, 4-6 times/week, ≥1 time/day), and daily step count (<5000, 5000-10000, 10000-15000, >15000).

Chronotype was assessed using the morningness-eveningness questionnaire (MEQ) item: "People are often described as 'morning' or 'evening' types. Which best describes you?" Responses categorized participants into five chronotypes: “definite morning” type, “moderate morning” type, “intermediate” type, “moderate evening” type and “definite evening” type [35] . In this study, the correlation coefficient (rs) between the MEQ-5 total score and the single-question score was 0.68, similar to previous findings (r=0.72) [36], suggesting that a single question has good validity in evaluating chronotype. Test-retest reliability (rs) was 0.61, with 63.2% consistency in chronotype classification across the two tests. The weighted coefficient κ was 0.45, suggesting moderate reliability. Therefore, using this question can concisely reflect the circadian rhythm status of an individual.

DATA PROCESSING AND ANALYSES

Data Processing

To ensure data integrity, the completed questionnaires underwent a rigorous double data entry procedure into a customized electronic database using EpiData software (version 3.1, The EpiData Association, Odense, Denmark). Two independent data clerks (Yadan Deng, Haiyi Zhao) performed data entry, with EpiData automatically highlighting discrepancies between the two entries for verification. All data points identified as anomalous or outside expected ranges during the entry phase were systematically flagged and recorded in a dedicated log file for subsequent review. Missing values encountered in the dataset were addressed through single imputation. Specifically, missing values were addressed via single imputation: continuous variables used median imputation, while categorical variables employed modal imputation (most frequent category).

Latent Classes of Temporal Eating Patterns

Latent classes analysis (LCA) was conducted using R 4.2.2. LCA identifies latent categories based on categorical variables. The classification of individuals according to their temporal eating patterns was based on the probabilities of class membership (unconditional probability or average posterior probability), considering that each individual belongs to only one latent class, and the probability of item response (conditional probability), that is, the probability that the individual reports each item that constitutes the latent class [37, 38]. The decision on the number of classes (temporal eating patterns) in the model is a central element of LCA and is commonly based on statistical measures of base model fit that consider the statistical quality of the model (parsimony) and the interpretability of the classes, which is based on the underlying theory of the latent construct that is being identified (temporal eating patterns) [37]. In this study, four multiple categorical variables, including breakfast, lunch, dinner and snack, were created as input variables for LCA by dividing the participants into different meal periods. The LCA process involved initially testing models with two potential categories, followed by the gradual addition of more categories until determining the optimal number of potential categories. The final number of categories was determined through: (1) Evaluation of model fit metrics, including Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), with a smaller value indicating a better model fit. (2) Lo-Mendell-Rubin Likelihood Ratio Test (LMR-LRT), comparing k and k-1 class models, where k is the number of potential classes. (3) Model Interpretability [39]. These criteria collectively guided the selection of the most appropriate number of categories in the LCA model [38].

Statistical Analysis

Statistical analysis and plotting were performed using R4.2.2 software. Continuous variables were expressed as means and standard deviations and categorical variables were expressed as percentages. Kruskal-Walli method and chi-square tests were used to compare the differences in descriptive characteristics between different genders. Univariate logistic regression analysis was used to explore the associations between temporal eating pattern and chronotype with overweight and obesity. Subgroup analysis among males and females, which model was adjusted for gender, age, grade, monthly living expense, father's education, mother's education, frequency of takeaway orders, frequency of dining out of school, smoke status, alcohol status and daily steps. All statistical tests were two-sided, with P<0.05 indicating statistical significance. Furthermore, based on the PBF, sensitivity analysis was conducted to explore the stability between temporal eating patterns and overweight and obesity among the university students.

RESULTS

Participants Selection

A total of 1214 individuals initially participated in this study. After the exclusion of participants with incomplete questionnaire information, incomplete physical examination data, abnormal data entries, or duplicate involvement. 1101 participants were included in the final analysis (91%). The flowchart outlining the inclusion and exclusion of the study subjects is presented in Figure 1.

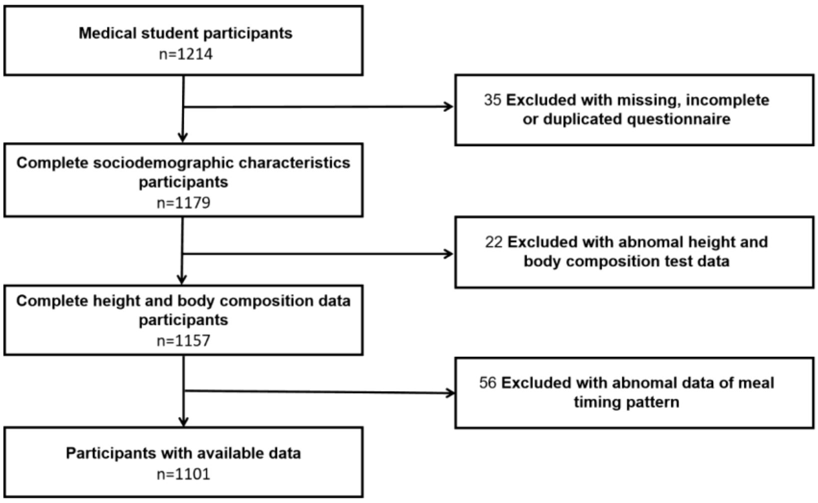

Figure 1: Flow diagram of inclusion and exclusion of study participants.

A total 1214 participants were assessed for eligibility. Of these, 113 were excluded for missing, incomplete, duplicated questionnaire and abnormal data. The remaining 1101 participants were enrolled in the study.

General Characteristics of Participants

Among the 1101 university students, who had a mean age of 19.95 ± 1.41 years and 59.13% (n=651) were females. Additionally, 28.88% (n = 318) were classified as having overweight and obesity. In comparison to the normal group, participants with overweight and obesity were more likely to be older (20.22 vs. 19.83 years), predominantly male (60.69% vs. 32.82%), junior (30.19% vs. 20.95%) and more often came from urban areas (64.78% vs. 56.70%). This group also exhibited lower parental educational attainment and a higher prevalence of smoking (P < 0.05). The essential demographic characteristics of the participants are summarized in Table 1.

Table 1: Descriptive characteristics of the demographic of the university students with different BMI levels.

	Total	Normal	Overweight/ obesity	P-values
n	**1101**	**783**	**318**	
Age, years	19.95 ± 1.41	19.83 ± 1.36	20.22 ± 1.50	<0.001*
Gender, n (%)				<0.001*
Male	450 (40.87)	257 (32.82)	193 (60.69)	
Female	651 (59.13)	526 (67.18)	125 (39.31)	
Residence, n (%)				0.016*
Town	650 (59.04)	444 (56.70)	206 (64.78)	
Country	451 (40.96)	339 (43.30)	112 (35.22)	
Ethnicity, n (%)				0.677
Han	964 (87.56)	683 (87.23)	281 (88.36)	
The others	137 (12.44)	100 (12.77)	37 (11.64)	
Grade, n (%)				<0.001*
Freshman	361 (32.79)	285 (36.40)	76 (23.90)	
Sophomore	354 (32.15)	248 (31.67)	106 (33.33)	
Junior	260 (23.61)	164 (20.95)	96 (30.19)	
Senior or above	126 (11.44)	86 (10.98)	40 (12.58)	
Monthly living expenses, n (%)				0.598
<1500	381 (34.60)	275 (35.12)	106 (33.33)	
1500-2000	535 (48.59)	373 (47.64)	162 (50.94)	
>2000	185 (16.80)	135 (17.24)	50 (15.72)	
Father's educational level, n (%)				0.015*
Junior high school and below	451 (40.96)	342 (43.68)	109 (34.28)	
High school / Technical secondary school	300 (27.25)	211 (26.95)	89 (27.99)	
Associate degree	106 (9.63)	67 (8.56)	39 (12.26)	
Bachelor's degree and above	244 (22.16)	163 (20.82)	81 (25.47)	
Mother's educational level, n (%)				<0.001*
Junior high school and below	501 (45.50)	385 (49.17)	116 (36.48)	
High school / Technical secondary school	309 (28.07)	204 (26.05)	105 (33.02)	
Associate degree	111 (10.08)	70 (8.94)	41 (12.89)	
Bachelor's degree and above	180 (16.35)	124 (15.84)	56 (17.61)	
Smoking, n (%)	47 (4.27)	24 (3.07)	23 (7.23)	0.003*
Drinking, n (%)	195 (17.71)	127 (16.22)	68 (21.38)	0.052
Exercise, n (%)	767 (69.66)	547 (69.86)	220 (69.18)	0.881
Chronotype, n (%)				0.61

Intermediate Type	95 (8.63)	64 (8.17)	31 (9.75)	
Definite Morning Type	58 (5.27)	41 (5.24)	17 (5.35)	
Moderate Morning Type	239 (21.71)	178 (22.73)	61 (19.18)	
Moderate Evening Type	493 (44.78)	352 (44.96)	141 (44.34)	
Definite Evening Type	216 (19.62)	148 (18.90)	68 (21.38)	

*: Stands for significant results. Continuous or categorical variables are used the Kruskal-Walli or chi-square test as methods. BMI, body mass index.

Latent Classes of Temporal Eating Patterns

The model fit indices for LCA are provided in Table 2. Each categorization demonstrated statistical significance surpassing the previous one, and the model with four (4) latent class was chosen (BIC = 9,017.860; BIC-Adjusted = 8,855.872; LMR-LRT = −83.47; $p > 0.05$, Entropy = 0.784) to represent the temporal eating patterns among young adults in this study. After careful evaluation, the four-class solution was determined to be more parsimonious and provided better interpretability for identifying distinct temporal eating patterns.

Table 2: Model fit indices for latent class models of temporal eating patterns [a].

	2 classes	3 classes	4 classes	5 classes	6 classes
AIC	8,893.176	8,819.635	8,762.657	8,747.102	8,738.968
BIC	9,018.275	9,009.787	9,017.860	9,067.356	9,124.274
BIC-Adjusted	8,938.869	8,889.090	8,855.872	8,864.077	8,879.703
Entropy	0.931	0.750	0.784	0.749	0.714
LMR-LRT	-322.72; $p > 0.05$	-100.13; $p > 0.05$	-83.47; $p > 0.05$	-41.80; $p > 0.05$	-34.34; $p > 0.05$

[a]: AIC Akaike Information Criterion, BIC Bayesian Information Criterion; LMR-LRT, Vuong–Lo–Mendell–Rubin Likelihood Ratio Test.

The class labels were derived according to the typical timing of breakfast, lunch, dinner, and snack consumption during a typical day. Detailed characteristics of the four identified temporal eating patterns are presented in Table 3.

The first pattern, labeled “Conventional” pattern, was observed in 41.05% of participants. This group exhibited three distinct peaks for breakfast (8:00-9:00), lunch (12:00-13:00) and dinner (16:00-18:00), along with a high probability (> 0.7) of no snacking, aligning with traditional meal times. Both Class 2 and Class 3 showed a very high probability (> 0.9) of skipping breakfast and a relatively high probability (> 0.8) of lunch consumption during the conventional lunch period (11:00-13:00), with no distinct snacking characteristics. These two classes differed mainly in dinner timing: Class 2 displayed a high probability of an earlier dinner and was labeled “Early dinner”, whereas Class 3 showed a later dinner and was termed “Late dinner”. In contrast, Class 4 was characterized by the absence of distinct features during main meal periods, except for a high probability (> 0.9) of snacking in the afternoon and evening, leading to its designation as the “Later snack” pattern.

Table 3: Conditional probabilities of meal times considering four temporal eating patterns, derived from latent class analysis, in young adults.

Meal Times	**Temporal Eating Patterns**			
	Conventional (n =452)	**Earlier Dinner (n =306)**	**Later Dinner (n =268)**	**Later snack (n =75)**
Breakfast				
Skipping breakfast	0.1	91.7	100	44.2
6:00~8:00	13.5	5.7	0	13
8:00~9:00	76.9	2.6	0	35.3
9:00~10:00	9.6	0	0	7.5
Lunch				
Skipping lunch	0.6	5.5	1.3	10.5
11:00~12:00	25	38.9	12.7	32.2
12:00~13:00	72	55.6	75.7	53
13:00~14:00	2.4	0	10.3	4.3
Dinner				
Skipping dinner	0	0.8	1.7	36.4
16:00~18:00	58.3	82.1	10.3	34.7
18:00~20:00	36.9	17.1	61.8	16.2
20:00~23:59	4.8	0	26.2	12.7
Snack				
No snacking	71.9	15.1	37.9	8.8
Before lunch	0	34.5	29.5	0
Between lunch and dinner	1.5	0	8.7	66.5
After dinner	26.6	50.4	23.9	24.7

Note: The highest probabilities defined dominant meal time groups for each cluster and are shown in bold.

Table 4 presents the distribution of meal times and temporal eating patterns among university students by BMI category. Participants with overweight or obesity exhibited significantly later dinner times compared to those with normal BMI (51.25% vs. 41.89%).

Although no significant differences were observed in the overall distribution of temporal eating patterns, students with overweight and obesity were more likely to exhibit non-traditional meal patterns (38.68% vs. 42.02%) and later dinner patterns (27.99% vs. 22.86%) than those with normal BMI.

Collectively, these findings indicated a temporal shift in eating behaviors among university students with overweight and obesity, characterized by later snack consumption and less regular meal timing, as detailed in Table 4.

Table 4: Descriptive characteristics of meal times and temporal eating patterns of the university students with different BMI levels.

	Total	Normal	Overweight/ obesity	P-values
n	1101	783	318	
Breakfast, n (%)				0.157
Skipping breakfast	583 (52.95)	413 (52.75)	170 (53.46)	
6:00~8:00	89 (8.08)	72 (9.20)	17 (5.35)	
8:00~9:00	380 (34.51)	266 (33.97)	114 (35.85)	
9:00~10:00	49 (4.45)	32 (4.09)	17 (5.35)	
Lunch, n (%)				0.717
Skipping lunch	32 (2.91)	22 (2.81)	10 (3.14)	
11:00~12:00	293 (26.61)	209 (26.69)	84 (26.42)	
12:00~13:00	735 (66.76)	526 (67.18)	209 (65.72)	
13:00~14:00	41 (3.72)	26 (3.32)	15 (4.72)	
Dinner, n (%)				<0.001*
Skipping dinner	38 (3.45)	26 (3.32)	12 (3.77)	
16:00~18:00	572 (51.95)	429 (54.79)	143 (44.97)	
18:00~20:00	391 (35.51)	249 (31.80)	142 (44.65)	
20:00~23:59	100 (9.08)	79 (10.09)	21 (6.60)	
Snack, n (%)				0.466
No snacking	472 (42.87)	331 (42.27)	141 (44.34)	
Before lunch	184 (16.71)	139 (17.75)	45 (14.15)	
Between lunch and dinner	86 (7.81)	63 (8.05)	23 (7.23)	
After dinner	359 (32.61)	250 (31.93)	109 (34.28)	
Temporal eating pattern, n (%)				0.145
Conventional	452 (41.05)	329 (42.02)	123 (38.68)	
Earlier dinner	306 (27.79)	226 (28.86)	80 (25.16)	
Later dinner	268 (24.34)	179 (22.86)	89 (27.99)	
Later snack	75 (6.81)	49 (6.26)	26 (8.18)	

*: Stands for significant results. Continuous or categorical variables are used the Kruskal-Walli or chi-square test as methods. BMI, body mass index.

Logistic Regression Analysis of Associations Between Temporal Eating Patterns, Chronotype and Overweight/Obesity

In univariate logistic regression analysis, no significant differences were observed. However, when using Class 1 ("Conventional") as the reference category in a multivariable model adjusted for age, gender, grade, monthly living expenses, parental education, frequency of takeaway orders, eating out, smoking, alcohol use, and daily steps, significant associations emerged between certain temporal eating patterns and overweight/obesity. Specifically, Class 4 ("Later Snack") demonstrated a significantly elevated risk (OR = 2.02, 95% CI: 1.15–3.56). In contrast, neither Class 2 ("Early Dinner") nor Class 3 ("Late Dinner") showed statistically significant associations. Furthermore, no significant association was observed between chronotype and overweight/obesity in the fully adjusted model (Table 5).

Table 5: Odds ratios (OR) and 95% confidence intervals (CI) for overweight or obesity according to temporal eating patterns and chronotype.

	Model 1		Model 2	
	OR (95% CI)	**P-value**	**OR (95% CI)**	**P-value**
Temporal eating patterns				
Conventional	Ref		Ref	
Earlier dinner	0.95(0.68-1.32)	0.745	0.97(0.68-1.39)	0.872
Later dinner	1.33(0.96-1.85)	0.089	1.10(0.76-1.61)	0.610
Later snack	1.42(0.84-2.39)	0.186	2.02(1.15-3.56)	0.015*
Chronotype				
Intermediate Type	Ref		Ref	
Definite Morning Type	0.86(0.42-1.74)	0.668	1.03(0.46-2.33)	0.935
Moderate Morning Type	0.71(0.42-1.19)	0.191	0.82(0.47-1.42)	0.473
Moderate Evening Type	0.83(0.52-1.33)	0.429	0.95(0.57-1.59)	0.856
Definite Evening Type	0.95(0.57-1.59)	0.841	0.97(0.55-1.73)	0.924

*: Stands for significant results. Model 1: unadjusted; Model 2: adjusted by age, gender, grade, monthly living expense, father's education, mother's education, frequency of takeaway orders, frequency of dining out of school, smoke status, alcohol status and daily steps.

Analysis of the relationships between temporal eating patterns and chronotype revealed negative associations of the "Definite Morning Type" chronotype with the "Early Dinner", "Later Dinner", and "Later Snack" patterns. Similar negative associations were also observed for the "Moderate Morning Type" chronotype (Table 6). These findings suggest that young adults with morning chronotype are more likely to adopt the "Conventional" temporal eating pattern. Conversely, both "Moderate Evening Type" and "Definite Evening Type" chronotypes showed strong positive associations with the "Later Dinner" pattern. However, neither evening chronotype was significantly associated with the "Later Snack" pattern, as detailed in Table 6.

Table 6: Associations between temporal eating patterns, chronotype, gender and BMI category in a sample of young adults.

Variables	Temporal Eating Patterns					
	Earlier Dinner		Later Dinner		Later snack	
	Univariate OR (95% CI)	Multivariate OR (95% CI)	Univariate OR (95% CI)	Multivariate OR (95% CI)	Univariate OR (95% CI)	Multivariate OR (95% CI)
Gender						
Male	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Female	1.58(1.16 -2.14) *	1.62(1.15-2.29) *	0.77(0.57-1.04)	0.73(0.51 - 1.06)	2.11(1.22 -3.63) *	2.30(1.24-4.24) *
BMI Category						

Normal	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Overweight and obesity	0.95(0.68 -1.32)	0.97(0.68-1.39)	1.33(0.96-1.85)	1.10(0.76-1.61)	1.42(0.84 -2.39)	2.02(1.15-3.56) *
Chronotype						
Intermediate Type	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Definite Morning Type	0.45(0.20 -0.98) *	0.56(0.25-1.28)	0.15(0.03-0.73) *	0.17(0.04-0.83) *	0.09(0.01-0.74) *	0.08(0.01-0.69) *
Moderate Morning Type	0.51(0.29 -0.91) *	0.52(0.29-0.94) *	0.55(0.26-1.17)	0.59(0.27-1.28)	0.39(0.17 -0.91) *	0.37(0.15-0.91) *
Moderate Evening Type	1.27(0.75 -2.14)	1.18(0.63-2.03)	2.49(1.29-4.84) *	2.45(1.23-4.87) *	0.89(0.42 -1.89)	0.76(0.34-1.73)
Definite Evening Type	1.80(0.98 -3.28)	1.59(0.84-2.99)	6.20(3.05-12.63) *	5.20(2.48-10.89) *	0.61(0.22 -1.66)	0.50(0.17-1.44)

*: Stands for significant results. BMI, body mass index. Adjusted for all other variables in the table.

Subgroup Analysis

To evaluate the consistency of primary findings, we conducted stratified analyses by gender. Among male participants, no temporal eating pattern showed a statistically significant association with overweight/obesity. Conversely, in females, the “Later snack” type pattern - characterized by irregular eating intervals and having snack later - was significantly associated with increased risk of overweight/obesity (OR = 2.11; 95% CI: 1.11-4.02). This association remained consistent after adjusting for confounding factors (adjusted OR = 2.62; 95% CI: 1.30-5.21), indicating that females with this temporal eating pattern had 2.62 times higher odds of developing overweight and obesity compared to those with traditional meal times. No other temporal eating patterns showed significant associations in the female subgroup, suggesting that irregular eating timing may represent a sex-specific risk factor for adiposity in female university students (Table 7).

Table 7: Subgroup analysis between overweight and obesity according to temporal eating patterns.

Subgroup	Temporal eating patterns	Model 1		Model 2	
		OR (95% CI)	P-value	OR (95% CI)	P-value
Male (n=450)	Conventional	Ref		Ref	
	Earlier dinner	1.32(0.81-2.15)	0.265	1.25(0.74-2.10)	0.408
	Later dinner	1.52(0.97-2.37)	0.066	1.42(0.88-2.30)	0.149
	Later snack	1.08(0.42-2.76)	0.879	1.20(0.43-3.23)	0.714
Female (n=651)	Conventional	Ref		Ref	
	Earlier dinner	0.89(0.55-1.44)	0.625	0.82(0.49-1.35)	0.434
	Later dinner	0.95(0.55-1.63)	0.839	0.80(0.44-1.43)	0.459
	Later snack	2.11(1.11-4.02)	0.024*	2.62(1.30-5.21)	0.006*

*: Stands for significant results. Model 1: unadjusted; Model 2: adjusted by age, grade, monthly living expense, father’s education, mother’s education, frequency of takeaway orders, frequency of dining out of school, smoke status, alcohol status and daily steps. CI, confidence interval; OR = Odds Ratios.

Sensitive Analysis

In sensitivity analysis examining the robustness of our primary findings, we redefined overweight/obesity using PBF instead of BMI. As presented in Table 8, the “Later snack” temporal eating pattern remained significantly associated with PBF-defined overweight/obesity in the overall cohort (adjusted OR = 1.94; 95% CI: 1.15–3.26), while no other patterns exhibited significant associations. Univariate sensitivity analysis revealed that the “Definite Morning Type” chronotype was significantly negatively associated with overweight/obesity, though this association became non-significant after adjusting for confounding factors. Overall, the sensitivity analysis results are consistent with the main findings, confirming the robustness of the primary conclusions.

Table 8: Sensitivity analysis of logistic regression between meal times and overweight/obesity based on PBF.

	Model 1		Model 2	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Temporal eating patterns				
Conventional	Ref		Ref	
Earlier dinner	1.03(0.77-1.39)	0.83	0.90(0.65-1.23)	0.492
Later dinner	1.13(0.83-1.54)	0.427	1.05(0.75-1.48)	0.773
Later snack	2.13(1.29-3.50)	0.003*	1.94(1.15-3.26)	0.013*
Chronotype				
Intermediate Type	Ref		Ref	
Definite Morning Type	0.46(0.23-0.92)	0.029*	0.55(0.27-1.16)	0.117
Moderate Morning Type	0.80(0.50-1.29)	0.358	0.82(0.50-1.34)	0.427
Moderate Evening Type	0.92(0.59-1.43)	0.702	0.97(0.61-1.54)	0.891
Definite Evening Type	0.87(0.54-1.42)	0.58	0.88(0.52-1.49)	0.644

*: Stands for significant results. Model 1: unadjusted; Model 2: adjusted by age, grade, monthly living expense, father’s education, mother’s education, frequency of takeaway orders, frequency of dining out of school, smoke status, alcohol status and daily steps. PBF, percentage of body fat; CI, confidence interval; OR = Odds Ratios.

DISCUSSION

The present study employed LCA, introducing a novel approach to investigate, for the first time, the relationships between temporal eating patterns, chronotype and overweight/obesity among young adults, primarily university students. Using LCA, we identified four distinct temporal eating patterns, namely “Conventional,” “Early dinner,” “Later dinner,” and “Later snack,” were identified among university adults in this study through LCA. The “Later snack” pattern, characterized by indistinct main meal periods and late-time snacking, was associated with a significantly elevated risk of overweight or obesity. In contrast, the “Early dinner” and “Late dinner” patterns, though differing by approximately two hours in dinner timing, showed no significant associations with overweight/obesity in adjusted models. This cross-sectional analysis further revealed that the “Later snack” pattern increased the risk of overweight or obesity particularly among females. Although no direct association was observed between chronotype and overweight/obesity, morning chronotypes were more likely to follow a “Conventional” eating pattern, while evening chronotypes tended toward the “Later dinner” pattern. These findings provided valuable insights into the associations between overall temporal eating patterns, chronotypes, and overweight/obesity risk in the young adults, mainly university students population.

Irregular eating is known to disrupt circadian metabolic regulation through two primary pathways. First, extended eating windows (>10 hours) have been shown to increase ad libitum energy intake by 8–20% [40]. Additionally, late eating can impair nocturnal lipid oxidation and promote insulin resistance [41]. Our results align with prospective cohort studies indicating that fragmented eating occasions elevate BMI trajectories in young adults [42]. Japanese cohort data further corroborate that bedtime snacking is associated with obesity in women (OR: 1.47) [43], and clinical research links nighttime eating to accelerated weight gain [44]. Contrary to our initial hypotheses, neither “Early dinner” nor “Later dinner” patterns predicted overweight/obesity risk. Our results consistent with meta-analyses linking breakfast skipping to obesity [45]. This might reflect that the energy intake during dinner compensates for the energy not consumed during breakfast. Correspondingly, evidence suggests that breakfast or dinner omission may increase subsequent caloric intake [46, 47], thereby potentially affecting long-term weight trajectory. Our analysis revealed a significant difference: compared with the traditional three-meal pattern, neither the "Earlier dinner" nor the "Later dinner" pattern was significantly associated with overweight/obesity when breakfast was skipped. This may indicate that, under conditions of breakfast absence, the specific timing of dinner does not independently contribute to obesity risk within the university population.

Chronotype serves as a subjective indicator reflecting an individual's circadian rhythm preference and has been previously associated with physical activity and sleep-wake cycles [48]. Our findings corroborate previous research, evening chronotypes exhibited a strong preference for “Later dinner” patterns (all $p<0.05$), consistent with delayed peripheral circadian rhythms in late sleepers [49]. Morning types, by contrast, were more likely to consume main meals at conventional times of three meals a day and less likely to skip breakfast or snack late. These results are consistent with Japanese data indicating that later sleep midpoints predict delayed dinner timing [50]. However, no direct association was observed between circadian type and overweight/obesity. This aligns with a cross-sectional study among Chinese college students that used the same single-item chronotype measure and also found no associations between chronotype and body weight [51]. One possible explanation for this observation is that single-item chronotype assessment may lack the sensitivity to detect subtle metabolic associations. Although previous studies have validated this measure, a single question may may not fully capture an individual's circadian rhythm. Genetic studies have revealed significant associations between variants in clock genes (e.g., Per1 and Clock) and both late chronotypes and obesity risk [52]. Moreover, circadian influences on body weight may operate not only through meal timing but also through dietary composition [53-55].

Our study identified the “Later snack” pattern as a significant risk factor for overweight/obesity compared to the conventional three-meal pattern. In nutritional epidemiology, a “snack” refers to any eating or drinking occasion outside main meals [56].

Relative to main meals, snacking is often irregular in both timing and composition [57], and typically involves casual consumption of smaller food quantities [58]. Regardless of whether it is fried or fresh, or consumed in the morning or at midnight, in all cases, food ingested while snacking, as with meals, influences overall energy and nutrient balance [57, 59]. Frequent consumption of energy-dense snacks has been linked to the rising prevalence of overweight/obesity among college-aged individuals [60]. The timing of energy intake during the day may have different effects on fat oxidation and energy expenditure. As socioeconomic changes drive the replacement of whole foods with processed snacks [61], the timing of consumption may become metabolically critical [26, 62]. Thereby, the significant impact on body weight cannot be ignored. In our study, as an important source of energy intake outside of regular meals, snacks included both caloric beverages and prepackaged or natural foods typically consumed in small portions. The timing of energy intake influences fat oxidation and energy expenditure, and evening is a common snacking period in China, with peak consumption around 9:00 p.m. [63]. Although snacks are usually lower in calories and portion size than main meals, several studies have shown that the late timing of snack may increases overweight/obesity risk. For example, snacking after dinner was associated with obesity among Japanese women [64]. A longitudinal study linked nighttime eating to weight gain in Chinese adults [65]. Consistent with these findings, our study concluded that snacking after dinner is associated with increased overweight/obesity risk among university students. By contrast, a cross-sectional study of 409 Malaysian students showed no significant difference was observed between snacking after the last meal across BMI categories [66], this discrepancy may stem from limited sample size and low rates of nighttime eating. Randomized crossover trials have demonstrated that evening snacking reduces fat oxidation [67], potentially increasing obesity risk. Additionally, afternoon snacking has been associated with higher BMI and obesogenic dietary patterns [68], while nighttime snacking is often driven by hedonic factors with less regard for weight control [69]. Morning snacking has been linked to higher fruit and vegetable intake, whereas evening snacking correlates with higher BMI and consumption of fast food, French fries, and soft drinks [70]. Thus, late-day snacking may elevate obesity risk partly due to poorer snack choices. Our data support Asian population studies in which Japanese women who snack after dinner show a 3.02-fold higher obesity risk [64], and Chinese adults with nighttime eating habits gain more weight [65]. The null result from the Malaysian study [66] likely reflects methodological limitations—such as small sample size and low event rates—rather than biological irrelevance.

The absence of significant associations between chronotype and overweight/obesity in this university cohort contrasts with some previous reports. Several methodological factors may explain this discrepancy: 1) the cross-sectional design precludes observation of longitudinal weight trajectories; 2) single-item chronotype assessment may lack sensitivity to detect metabolic relationships; 3) Population heterogeneity within university setting may introduce confounding variables; and 4) unmeasured dietary quality factors could modulate weight outcomes. Crucially, our null finding aligns with emerging evidence that genetic polymorphisms in circadian regulators (e.g., CLOCK, PER3) may confer metabolic adaptations to delayed eating in evening types, thereby decoupling chronotype from obesity risk. This supports a mediation model in which chronotype influences obesity primarily through temporal eating behaviors. The nutritional composition and timing of intake serve as critical regulators for peripheral circadian clocks [71]. When misaligned with endogenous rhythms — as occurs during nocturnal snacking — metabolic desynchronization may promote weight gain and impaired glucose regulation over time. Supporting this, Japanese data show that later sleep midpoints predict delayed dinner timing in female students [50], and longitudinal evidence links delayed sleeping patterns to weight gain in young populations [72]. although chronotype itself may not directly associate with adiposity in young adults, it can establish behavioral patterns in which delayed eating—particularly later snacking—independently elevates obesity risk. This pathway explains both the observed associations with the "Later snack" pattern and broader epidemiological evidence that nocturnal energy intake disproportionately affects metabolic health.

Interestingly, subgroup analyses revealed that the "Later snack" pattern was not associated with overweight/obesity in males. A recent study reported that a "grazing" pattern was associated with overweight or obesity (OR: 1.57; 95% CI: 1.15, 2.13) and central overweight or obesity (OR: 1.73; 95% CI: 1.19, 2.50) among women [73]. The heightened obesity susceptibility among females with "Later snack" patterns may stem from sex-specific endocrine responses. Several mechanisms may explain this association. First, oestrogen enhances insulin sensitivity in adipose tissue [74, 75], but irregular eating may disrupt this effect. Second, late-night eating may cause circadian misalignment, reduce energy expenditure (e.g., via lower leptin levels), increase appetite sensations, and promote weight gain [70]. Beyond behavioral chronodisruption, circadian gene variants have been linked to altered metabolism and adverse health outcomes. For example, carriers of minor alleles in clock genes exhibited resistance to weight loss after a 12–14-week intervention, along with shorter sleep duration, higher ghrelin levels, and a preference for delayed mealtimes [76]. Energy expenditure is typically lower at night than during the day [77, 78]. Thus, compared to daytime snacking, nighttime snacking has been associated with reduced fat oxidation [79] and may promote fat accumulation, as nutrients consumed at night are less likely to be used for glycogen synthesis in muscle and live [80]. Previously described as "grazing"—frequent eating episodes across multiple daytime periods—this pattern has been linked to overweight/obesity in women. Our findings corroborate this association and extend it using LCA-derived temporal eating patterns, which treat meal timing as an integrated variable rather than a single or multiple methodologies, offering a more holistic view of mealtime characteristics in young adults.

Unlike most previous studies that mainly focused solely on breakfast, lunch, and dinner times, this research represents the first investigation of the associations between temporal eating patterns, chronotype, and overweight/obesity in university students. The study held several strengths: Firstly, with a novel approach providing an overall temporal eating pattern rather than analyzing single meals in isolation, which rendered the results more objective and a comprehensive understanding of mealtime characteristics in this population. Secondly, Second, we incorporated snack timing in pattern classification, acknowledging its potential role in weight status among young adults, particularly in university students who are prone to circadian disruption and irregular eating due to academic demands. Thirdly, the meal pattern questionnaire enabled efficient capture of multi-dimensional meal timing variables, simplifying the classification of daily eating patterns and reducing the burden of dietary assessment However, several limitations should be noted. First, self-reported dietary data are subject to recall bias. Second, as a cross-sectional study, the observed associations cannot support causal inference. Thirdly, although LCA offered advantages as a relative novel method, its exploratory nature may limit generalizability to other populations. As O'Hara et al. [81] emphasized that the extent to which different classification methods affect results remains unclear, and cross-method comparisons should be made cautiously. For this reason, we did not compare different temporal pattern derivation methods. Future studies should apply multiple methodologies to help clarify methodological influences on pattern definition and interpretation.

DISCUSSION

In conclusion, this study indicated significant associations between temporal eating patterns identified through the LCA method and overweight/obesity risk among young adults. Irregular meals and later snacking were associated with increased risk of overweight/obesity. These findings underscore the importance of promoting regular mealtimes and reducing late-evening snack consumption, especially among populations such as university students who are vulnerable to circadian rhythm disruption and irregular eating habits.

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Supplementary Table 1: Content of four different meal types.

Meal type	Explanation
Main Meal	A substantial eating occasion typically characterized by the presence of at least one staple food portion (e.g., rice, bread, noodles) and at least two separate side dishes. It may also commonly include soup, beverages (including alcoholic drinks if consumed), fruit, or snacks as additional components. This represents a primary, more complete meal.
Light Meal	A convenient and generally smaller or less complex eating occasion focused on satisfying hunger efficiently. It typically consists of a single, combined dish or item that provides both staple food and protein/vegetable components. Examples include: a bowl of noodles, a plate of fried rice, a sandwich, a hamburger, a wrap, or a single serving of pizza.
Snack meal	An eating occasion primarily involving a single item or portion of food, consumed between main meals. This typically includes: Pre-packaged food items: Such as biscuits/cookies, cake/pastry, an energy bar, a bag of crisps/chips, sweets/candy, or yogurt. Also, single portions of natural/minimally processed foods: Such as a piece of fruit, a small serving of nuts or seeds, or a single potato/sweet potato.
Drink meal	An occasion where caloric intake comes predominantly or exclusively from liquids, consumed on its own and not accompanied by substantial solid food (like a snack or meal). Examples include: coffee (with milk/sugar), tea (with milk/sugar), fruit juice, milk, plant-based milk drinks, soft drinks/soda, or a standalone smoothie. Plain water or unsweetened black coffee/tea are not typically reported as distinct eating occasions unless they contribute significant calories.

Supplementary Table 2: Meal time division criteria and contents of four different meal periods.

Meal period	Meal time division criteria and contents	Reference
Breakfast	Main/light meal consumed 06:00–10:00. Aligns with first-meal convention ≤10:00 and 20–35% daily calories. Classification: 6:00-8:00, 8:00-9:00, 9:00-10:00 and skipping breakfast.	[30]
Lunch	Main/light meal consumed 11:00–14:00. Based on medical university cafeteria hours, addressing cultural inconsistencies. Classification: 11:00-12:00, 12:00-13:00, 13:00-14:00 and skipping lunch.	[31] [32]
Dinner	Main/light meal consumed 16:00–23:59 Reflecting university cafeteria operations and pre-sleep consumption. Classification: 16:00-18:00, 18:00-20:00, 20:00-23:59 and skipping dinner.	-
Snack	Snack/drink meal consumed outside main meals time. Excluding water/unsweetened black coffee/tea. Classification: pre-lunch, lunch-dinner interval, post-dinner and no snacking.	[33]