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ORIGINAL RESEARCH

The Association Between Chronotype and Weight Change Among Medical Students: A Cross-Sectional Study

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Purpose: This study analyzed the differences in weight change among medical students with different chronotypes and evaluated the association between chronotype and weight change after controlling for confounders.

Methods: Using proportional stratified cluster random sampling, 1300 medical students (excluding freshmen) were selected from April to September 2021. Chronotype was assessed with the Chinese version of MEQ-5 questionnaire, categorized into five groups: definite morning, moderate morning, intermediate, moderate evening, and definite evening. The primary outcome was weight change value (kg), the difference between current weight and weight at admission; the secondary outcome was weight gain (≥10% increase from admission weight). Multiple linear and logistic regression models were used to analyze the independent association between chronotype, weight change value, and weight gain, respectively.

Results: Among the 1300 medical students, the proportion of definite morning, moderate morning, intermediate, moderate evening, and definite evening chronotype were 14.08%, 12.38%, 28.92%, 31.46%, 13.15%, respectively. Definite evening-type students had worse sleep quality, shorter sleep duration, more late-night snacks, higher satiety, and lower breakfast frequency ($P<0.05$). Compared to definite morning-type medical students, those with moderate morning, intermediate, moderate evening and definite evening chronotype showed an increasing trend of weight change ($P=0.044$), with definite evening-type students gaining 0.88 kg on average (95% CI: 0.10, 1.65), consistent after adjusting for confounders. The association between chronotype and weight gain was similar although not statistically significant (OR=1.96, 95% CI: 0.72, 5.36). Evening chronotype with dinner ≥ 6 PM had the highest odds of weight gain compared to morning chronotype with dinner before 6 PM (OR=2.43, 95% CI: 1.07, 5.50).

Conclusion: Definite evening chronotype was associated with greater weight increase and higher odds of weight gain among medical students, especially when dinner ≥ 6 PM. These findings highlight the importance of morning chronotype and early dinner for weight control.

Keywords: chronotype, weight change, overweight, obesity, medical students

Introduction

Overweight and obesity represent a growing global public health challenge. Globally, obesity prevalence has more than tripled since 1975.[1] Currently, these conditions affect approximately 42% of adults and 22% of children and adolescents,[2] significantly increase the risk of cardiovascular disease, cancer, and contribute to 25% of venous thromboembolism events.[3–5] In China, obesity rates have increased significantly in recent decades. The China Chronic Disease and Risk Factors Surveillance (CCDRFS) program reports that obesity among adults more than doubled from 3.1% in 2004 to 8.1% in 2018, affecting an estimated 85 million people.[6] Moreover, 34.8% of adults in China are classified as overweight.[7] A survey of university students revealed that 22% were overweight or

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obese, highlighting the need for targeted health interventions.[8] Among medical students, the prevalence of overweight and obesity can reach up to 38%.[9] Therefore, identifying the factors contributing to weight increase among medical students and implementing effective countermeasures is crucial.

Health behaviors, encompassing diet,[10,11] physical activity,[12] and sleep,[13] have been shown to significantly influence weight management. Unhealthy eating behaviors, such as binge eating,[14] late-night snacking,[15] and alcohol consumption,[16] substantially contribute to overweight and obesity. Smoking is also associated positively with body mass index (BMI) and fat-mass percentage.[17,18] Lack of exercise is also a contributing factor to overweight or obesity.[19] Sleep behavior significantly affects weight status, with studies consistently showing that shorter sleep duration[20,21] and poorer sleep quality[22] are associated with an increased risk of overweight and obesity. However, the research on the association between chronotype and weight change is limited, especially among college students.

Chronotype refers to an individual's preference for sleep-wake patterns within a 24-hour period, regulated by the biological clock. It can be mainly divided into three types: morning type (early lark type), intermediate type (intermediate type) and evening type (night owl type).[23] Evening-typed individuals often exhibit poorer health outcomes, including reduced sleep quality[24,25] and increased susceptibility to obesity.[26] Chronotype can also influence eating behavior, with evening types exhibiting more frequent unhealthy eating behaviors and a higher risk of obesity compared to morning types.[27,28]

College students, transitioning between late adolescence and young adulthood, exhibit different chronotype distributions and influences compared to adults. While more than half of the middle-aged population are morning types,[29] college students tend to be evening types,[30] often due to academic pressure or other factors that lead to staying up late. Therefore, it is not feasible to directly infer the chronotype patterns and their impacts on college students from adult data. Medical students, facing high academic pressure, workload, and clinical training demands, may experience altered health behaviors and physiological functions, particularly in sleep and eating habits, compared to other college students. Prolonged late-night studying increases late-night snacking, while insufficient sleep elevates ghrelin and reduces leptin, contributing to overeating and weight increase.[31] Additionally, stress-induced cortisol elevation is positively correlated with BMI,[32] a factor to which medical students are particularly vulnerable due to their high stress levels. Further investigation into the association between chronotype and weight change specifically in medical students is urgently needed.

Therefore, this study aims to compare the health behaviors and weight status among medical students with different chronotypes, and to examine the independent association between chronotype and weight change after controlling for various confounding factors.

Materials and Methods

Participants

A proportional stratified cluster random sampling method was used to select undergraduates of medical majors from a medical university in eastern China from April to September 2021. The questionnaires were designed by experts in epidemiology, medical statistics, sociology and other fields with reference to sleep-related research literature.[33,34] Questionnaires were distributed through the Questionnaire Star software.

Inclusion criteria required that the students are sophomores and above, and they should be medical majors including clinical medicine, preventive medicine, nursing, anesthesiology, medical laboratory science, and others. Exclusion criteria included students with missing data on variables, those without weight change information, and individuals with excessive weight changes (absolute value of weight change more than 15kg).

The study protocol was approved by the Ethics Committee of Wenzhou Medical University (ethics approval number: 2021-022) and was conducted in accordance with the Declaration of Helsinki. All participants signed written informed consent.

Measures

Chronotype

The chronotype was evaluated by the question "One hears about 'morning' and 'evening' types of people. Which one of these types do you consider yourself to be?" in the Chinese version of MEQ-5 (Morningness-Eveningness

Questionnaire). The chronotype is divided into five groups, which are "definite morning" type, "moderate morning" type, "intermediate" type, "moderate evening" type and "definite evening" type.[35] In this study, the correlation coefficient (r_s) 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 (r_s) 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.

Weight Change

According to recent studies,[37] the consistency between self-reported weight and objectively measured weight is strong, so the students' weight data were obtained by the question "What is your current weight?" and the question "What was your weight when you enrolled in freshman year?" While recall bias may be a concern, it's noteworthy that all freshmen undergo a physical examination at enrollment, during which their weight is recorded and accessible. The primary outcome was absolute weight change (kg), defined as current weight – weight at admission. Therefore, negative values indicate that college students are losing weight, and positive values indicate that college students are gaining weight. Body mass index (BMI) is a student's weight in kilograms divided by the square of height in meters, and was classified into four groups using the WS/T 428-2013 (China) standard:[38] underweight (<18.5 kg/m^2), normal (18.5~ <24.0 kg/m^2), overweight (24~ <28.0 kg/m^2) and obese (≥28.0 kg/m^2).

The secondary outcome was weight gain, defined as an increase in weight of at least 10% compared to the weight upon entrance in the freshman year.[39]

Covariates

Covariates in this study included sociodemographic and behavioral characteristics, which were collected through self-administered questionnaire.

Sociodemographic characteristics included gender (male, female), grade (sophomore, junior, senior or above), major, birthplace (city, town, countryside), parental education level (primary school or below, junior high school, high school, university or above), and only-child (yes, no). Major was classified as clinical (clinical medicine) and non-clinical (including preventive medicine, nursing, anesthesiology, medical laboratory science, and others).

Behavioral characteristics, including naps, smoking, alcohol consumption, late-night snacks, dinner time, breakfast frequency, and satiety rating, were collected using a self-edited general information questionnaire. Dinner time was categorized as before or after 6 PM (≥6 PM). Satiety was rated on a scale from 1 (least full) to 10 (most full). Sleeping behavior was assessed using the Pittsburgh Sleep Quality Index (PSQI), which evaluated sleep quality (very good, good, general, poor), sleep duration (≤6 hours, 7 hours, ≥8 hours), and sleep latency. Physical activity and sedentary behavior were assessed using the International Physical Activity Questionnaire (IPAQ). Moderate to vigorous physical activity was categorized into two groups (<2 hours, ≥2 hours), and sedentary behavior was divided into two groups (<9 hours, ≥9 hours).[40,41]

Statistical Analysis

The measurement data were tested for normality and expressed as mean ± standard deviation (SD) if they conformed to a normal distribution, or median and interquartile range if they did not, and the count data were expressed as frequency and proportions (n, %). Analysis of variance, χ^2 test, or rank sum test were used to compare the basic information, behaviors among different chronotype groups. The association between chronotype and weight change and weight gain were analyzed by multiple linear regression models and logistic regression models after controlling for confounding factors. The model I adjusted for demographic including gender, grade, parental education, birthplace, only child. The model II further controls the potential confounding of biorhythmic and lifestyle variables: sleep duration, sleep quality, late night snack, highest intake at dinner, physical activity time, sedentary behavior.

When exploring the joint effect of chronotype and eating dinner ≥ 6 PM, to ensure the test efficacy, five groups of chronotypes were combined into morning, intermediate and evening type,[25] and the three combined groups of chronotypes were combined with whether to eat dinner ≥ 6 PM to form six subgroups. The morning type and eating dinner before 6 PM groups were used as reference to analyze the remaining various combinations of weight change value and the odds ratio (OR) of weight gain.

Sensitivity analyses consisted of two parts: (1) the sample was restricted to medical students who did not smoke, drink alcohol, eat snacks after dinner, or were underweight/normal weight; and (2) major was further adjusted as a confounding factor in the full sample analysis to account for its potential influence on the results. A two-sided test was used, and $P<0.05$ was considered a statistically significant difference. Statistical analyses were conducted using SPSS 26 and Empower (R) (https://www.empowerstats.net/cn/, X & Y solutions, inc. Boston MA).

Results

Sample Characteristics

A total of 1479 medical students participated in this study. Among them, we excluded 24 students with most variables missed, 150 people with no information on weight change, and 5 people with excessive weight change (absolute value of weight change more than 15kg). So, 1300 medical students (61.2% female) were included in the final analysis. Among them, 551 (42.4%) gained weight, and the mean of weight change value was 0.38 kg (SD=3.72kg). In terms of chronotype distribution, the most prevalent type was the moderate evening type, with a total of 409 individuals (31.5%), followed by the intermediate type (376, 28.9%), definitive morning type (183, 14.1%), definitive evening type (171, 13.1%), and moderate morning type (161, 12.4%).

Table 1 shows the comparison of basic characteristics of medical students with different chronotypes. There were no statistically significant differences in sociodemographic characteristics such as gender, grade, only child, parental education level, and birthplace; and there was no statistically significant difference in body shape at baseline as well.

The comparison of behaviors of medical students with different chronotype mainly focuses on three aspects: sleeping behavior, eating habits and physical activity. The results of univariate analysis (Table 2) showed that definite evening type students had worse sleep quality, shorter sleep duration, a higher proportion of eating late night snacks, a lower proportion of eating breakfast, and had higher satiety rating ($P<0.05$). Definite evening-type students tended to be less active, although no significant difference was found.

Table 1 Basic Characteristics of Participants by Chronotype

Basic Characteristics	Definite Morning Type (n=183)	Moderate Morning Type (n=161)	Intermediate Type (n=376)	Moderate Evening Type (n=409)	Definite Evening Type (n=171)	*P*
Female, n (%)	109 (59.56)	109 (67.70)	237 (63.03)	244 (59.66)	96 (56.14)	0.210
Grade, n (%)						0.757
Sophomore	96 (52.46)	79 (49.07)	184 (48.94)	214 (52.32)	89 (52.05)	
Junior	57 (31.15)	49 (30.43)	119 (31.65)	129 (31.54)	59 (34.50)	
Senior or above	30 (16.39)	33 (20.50)	73 (19.41)	66 (16.14)	23 (13.45)	
Only child, n (%)	97 (53.01)	62 (38.51)	169 (44.95)	182 (44.50)	85 (49.71)	0.069
Parental education, n (%)						0.899
Primary school or below	15 (8.20)	16 (9.94)	36 (9.57)	32 (7.82)	15 (8.77)	
Junior high school	71 (38.80)	69 (42.86)	138 (36.70)	154 (37.65)	68 (39.77)	
High school	61 (33.33)	43 (26.71)	122 (32.45)	127 (31.05)	46 (26.90)	
University or above	36 (19.67)	33 (20.50)	80 (21.28)	96 (23.47)	42 (24.56)	
Birthplace, n (%)						0.631
City	66 (36.26)	64 (39.75)	131 (34.84)	148 (36.27)	71 (41.76)	
Town	44 (24.18)	33 (20.50)	76 (20.21)	97 (23.77)	37 (21.76)	
Rural	72 (39.56)	64 (39.75)	169 (44.95)	163 (39.95)	62 (36.47)	
Body type, n (%)						0.563
Normal or underweight	160 (87.43)	144 (89.44)	339 (90.16)	354 (86.55)	149 (87.13)	
Overweight or obesity	23 (12.57)	17 (10.56)	37 (9.84)	55 (13.45)	22 (12.87)	

Note: The Chi-square test was used for nominal data and the Kruskal–Wallis test was used for ordinal data.

Table 2 Behavioral Characteristics of Participants by Chronotype

Behavioral Characteristics	Definite Morning Type (n=183)	Moderate Morning Type (n=161)	Intermediate Type (n=376)	Moderate Evening Type (n=409)	Definite Evening Type (n=171)	*P*
SLEEPING BEHAVIOR						
Sleep quality, n (%)						**0.003**
Very good	43 (23.50)	30 (18.63)	58 (15.43)	77 (18.87)	28 (16.47)	
Good	80 (43.72)	74 (45.96)	161 (42.82)	139 (34.07)	59 (34.71)	
General	50 (27.32)	52 (32.30)	129 (34.31)	160 (39.22)	61 (35.88)	
Poor	10 (5.46)	5 (3.11)	28 (7.45%)	32 (7.84)	22 (12.94)	
Sleep duration/h, n (%)						0.166
≤6	26 (14.21)	31 (19.25)	80 (21.28)	88 (21.52)	34 (19.88)	
7	90 (49.18)	76 (47.20)	191 (50.80)	216 (52.81)	91 (53.22)	
≥8	67 (36.61)	54 (33.54)	105 (27.93)	105 (25.67)	46 (26.90)	
Sleep latency, min	10.00 (5.00–20.00)	10.00 (7.75–20.00)	15.00 (10.00–30.00)	20.00 (10.00–30.00)	15.00 (10.00–30.00)	**0.021**
Nap, n (%)	140 (76.50)	127 (78.88)	280 (74.47)	320 (78.24)	128 (74.85)	0.677
Nap duration, min/day	30.00 (30.00–45.00)	30.00 (30.00–45.00)	30.00 (30.00–57.50)	30.00 (30.00–60.00)	40.00 (30.00–60.00)	**<0.001**
EATING HABITS						
Late night snacks, n (%)	20 (10.93)	22 (13.66)	47 (12.50)	81 (19.80)	41 (23.98)	**<0.001**
Dinner ≥ 6 PM, n (%)	33 (18.13)	19 (11.80)	71 (18.93)	81 (19.80)	35 (20.47)	0.217
Highest intake at dinner, n (%)	24 (13.19)	17 (10.83)	82 (21.81)	112 (27.52)	52 (30.41)	**<0.001**
Frequency of breakfast, day/week	7.00 (6.00–7.00)	7.00 (5.00–7.00)	6.00 (5.00–7.00)	6.00 (5.00–7.00)	5.00 (4.00–6.00)	**<0.001**
Satiety rating	7.67 (1.24)	7.84 (1.15)	7.88 (1.07)	7.91 (1.04)	8.13 (1.16)	**0.004**
MOVEMENT BEHAVIOR						
Sedentary time, hours/day	8.00 (2.85)	7.86 (2.78)	7.67 (2.95)	7.84 (2.98)	8.07 (3.00)	0.576
Physical activity, hours/day	1.00 (0.50–1.50)	1.00 (0.50–2.00)	1.00 (0.50–2.00)	1.00 (0.50–1.50)	1.00 (0.50–1.50)	0.089

Notes: The bold values indicated statistical significance $P<0.05$. Quantitative variables are represented by mean (standard deviation) if they meet the normal distribution, and by median (P25-P75) if they do not meet the normal distribution. There were 2 cases of missing data on sleep quality, 331 cases of missing data on nap duration, 112 cases of missing data on sleep latency, 8 cases of missing data on sedentary time and 38 cases of missing data on physical activity time.

Association Between Chronotype and Weight Change

As shown in Table 3, the weight changes among medical students with different chronotypes were different, F=2.45, P=0.044. The weight of participants with the definite morning type decreased 0.36 kg; however, the weight of the other four groups all increased, especially the group with definite evening type had a mean increase of 0.73 kg (Figure 1 and Table 3).

When weight gain was analyzed as the outcome variable, we found that the proportion of people who gained weight ≥10% among the definite morning type is the lowest.

The multiple linear regression model was used to control confounding factors (Table 4). It was found that compared with the definite morning type, the weight change value of the moderate morning type, intermediate type, moderate evening type and the definite evening type gradually increased; and the results were consistent after adjusting for various confounding factors. Especially, the weight change value and the 95% confidence interval (CI) was 0.88 (0.10, 1.65) kg for the definite evening type.

Similarly, logistic regression model was used to control confounding factors, and the independent effect of chronotype on weight gain was analyzed. Although the results were not statistically significant, there was a similar trend.

Table 3 Weight Change of Participants With Different Chronotypes

Weight Status	Definite Morning Type (n=183)	Moderate Morning Type (n=161)	Intermediate Type (n=376)	Moderate Evening Type (n=409)	Definite Evening Type (n=171)	*P*
Baseline weight, kg	59.73 (12.03)	57.19 (11.27)	57.10 (10.83)	57.65 (10.17)	57.40 (11.53)	0.096
Current weight, kg	59.37 (11.24)	57.46 (11.11)	57.58 (10.51)	58.16 (10.36)	58.14 (11.65)	0.412
Weight change, kg	−0.36 (3.67)	0.27 (3.80)	0.48 (3.79)	0.51 (3.65)	0.73 (3.66)	**0.044**
Weight gain, n (%)	7 (3.83)	11 (6.83)	27 (7.18)	31 (7.58)	13 (7.60)	0.528

Notes: The bold values indicated statistical significance $P<0.05$. Weight change (kg) = current weight − enrollment weight; Weight gain (≥10% increase from admission weight). Baseline weight, current weight and weight change were normally distributed and expressed as Mean (SD).

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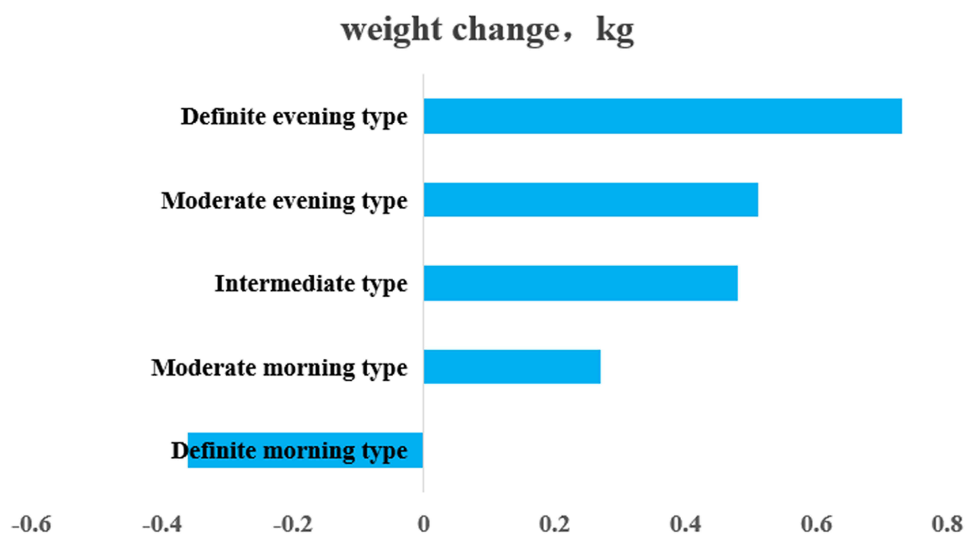

Figure 1 Weight changes with different chronotypes. Weight change (kg) = current weight - enrollment weight.

Compared with the definite morning type, the OR of weight gain in the definite evening type was significantly higher; and the results remain consistent after adjusting for various confounding factors. The OR and the 95% CI were 1.96 (0.72, 5.36) for the definite evening type.

Joint Effect of Chronotype and Dinner Time

In comparison with medical students who had morning chronotype and had dinner before 6 PM, the medical students who had evening chronotype and had dinner ≥ 6 PM had the largest weight increase (b=1.03kg, 95% CI: 0.22, 1.84, Figure 2a and Table 5), and had the highest odds of weight gain (OR=2.43, 95% CI: 1.07, 5.50, Figure 2b and Table 5).

Table 4 Association Between Chronotype, Weight Change and Weight Gain, n=1300

Outcome	**Effect size (95% CI) *P***		
	Non-adjusted	**Model I**	**Model II**
Weight change	**β (95% CI) *P***		
Definite morning type	0	0	0
Moderate morning type	0.63 (−0.15, 1.42) 0.115	0.70 (−0.06, 1.47) 0.073	0.60 (−0.19, 1.39) 0.136
Intermediate type	**0.84 (0.19, 1.50) 0.012**	**0.85 (0.22, 1.49) 0.009**	**0.74 (0.09, 1.39) 0.025**
Moderate evening type	**0.87 (0.23, 1.52) 0.008**	**0.93 (0.30, 1.56) 0.004**	**0.70 (0.06, 1.35) 0.033**
Definite evening type	**1.10 (0.32, 1.87) 0.006**	**1.10 (0.35, 1.85) 0.004**	**0.88 (0.10, 1.65) 0.027**
Weight Gain	**OR (95% CI) *P***		
Definite morning type	1	1	1
Moderate morning type	1.84 (0.70, 4.87) 0.217	2.09 (0.76, 5.74) 0.154	2.12 (0.74, 6.08) 0.160
Intermediate type	1.95 (0.83, 4.55) 0.125	1.98 (0.82, 4.78) 0.131	2.01 (0.82, 4.97) 0.129
Moderate evening type	2.06 (0.89, 4.77) 0.091	2.20 (0.92, 5.26) 0.076	1.87 (0.76, 4.57) 0.173
Definite evening type	2.07 (0.81, 5.31) 0.131	2.23 (0.84, 5.96) 0.109	1.96 (0.72, 5.36) 0.190

Notes: The bold values indicated statistical significance P<0.05. Model I adjusted for: gender (male, female), grade (sophomore, junior, senior or above), parental education (primary school or below, junior high school, high school, university or above), birthplace (city, town, countryside), only child (yes, no); Model II additionally adjusted for: sleep duration (≤6h, 7h, ≥8h), sleep quality (very good, good, general, poor), late night snack (yes, no), highest intake at dinner (yes, no), physical activity time (<2h, ≥2h), sedentary behavior (<9h, ≥9h).
Abbreviations: β, partial regression coefficient; CI, confidence interval; OR, odds ratio.

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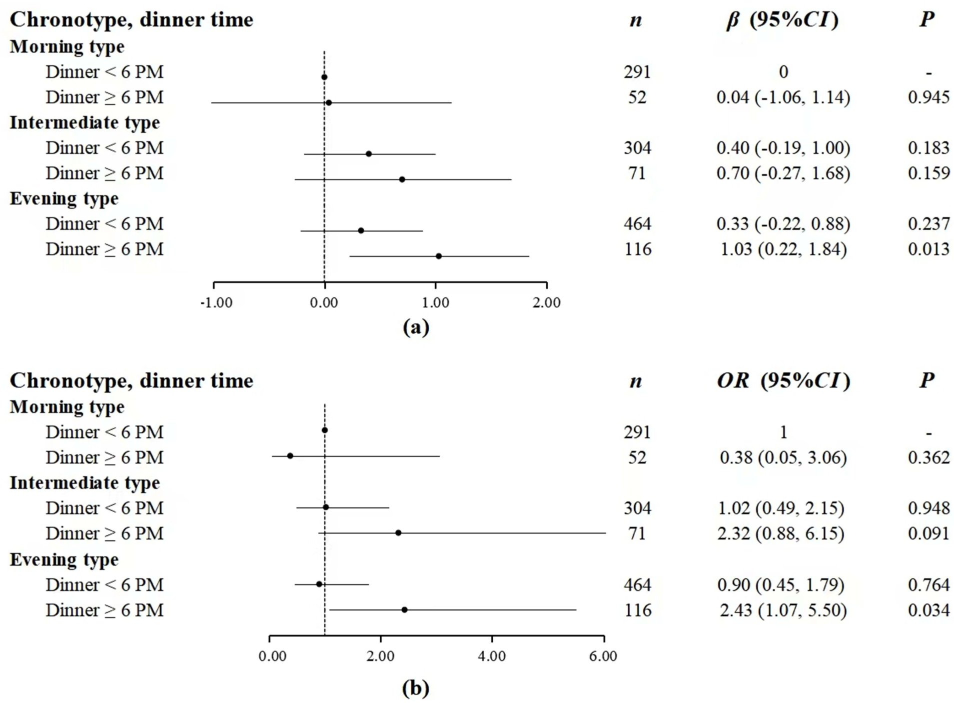

Figure 2 (**a**) Joint effect of chronotype and dinner time on weight change value; (**b**) Joint effect of chronotype and dinner time on weight gain. Model was adjusted for gender (male, female), grade (sophomore, junior, senior or above), parental education (primary school or below, junior high school, high school, university or above), birthplace (city, town, countryside), only child (yes, no), sleep duration (≤6h, 7h, ≥8h), sleep quality (very good, good, general, poor), late night snack (yes, no), highest intake at dinner (yes, no), physical activity time (<2h, ≥2h), sedentary behavior (<9h, ≥9h).

Sensitivity Analysis

In order to control the influence of confounding factors such as smoking, drinking, and eating late night snacks, we further limited the population to medical students who did not smoke, drink alcohol, eat late night snacks, or were underweight/normal, and the results remained unchanged. We additionally included the major as the confounding factor and the results remained stable (Table 6): compared with the definite morning type, the weight change value of the moderate morning type, intermediate type, moderate evening type and the definite evening type showed an increasing trend.

Similarly, taking weight gain as the outcome variable for analysis, although the results are not statistically significant, there is a similar trend.

Table 5 Joint Effect of Chronotype and Dinner Time on Weight Change

Chronotype	Dinner ≥ 6 PM	N	Outcome	Effect Size (95% CI) *P*		
				Non-Adjusted	Model I	Model II
			Weight change, mean (SD)	β (95% CI) *P*		
Morning type	No	291	−0.05 (3.82)	0	0	0
Intermediate type	No	304	0.42 (3.65)	0.47 (−0.12, 1.07) 0.120	0.46 (−0.12, 1.04) 0.119	0.40 (−0.19, 1.00) 0.183
Evening type	No	464	0.41 (3.62)	0.46 (−0.08, 1.01) 0.096	0.48 (−0.05, 1.01) 0.075	0.33 (−0.22, 0.88) 0.237
Morning type	Yes	52	−0.04 (3.17)	0.01 (−1.08, 1.11) 0.983	−0.02 (−1.08, 1.05) 0.976	0.04 (−1.06, 1.14) 0.945
Intermediate type	Yes	71	0.71 (4.37)	0.76 (−0.20, 1.72) 0.122	0.67 (−0.27, 1.61) 0.165	0.70 (−0.27, 1.68) 0.159
Evening type	Yes	116	1.23 (3.74)	**1.28 (0.48, 2.08) 0.002**	**1.20 (0.42, 1.97) 0.003**	**1.03 (0.22, 1.84) 0.013**
$P_{\text{for interaction}}$				0.444	0.473	0.581

(*Continued*)

Table 5 (Continued).

Chronotype	Dinner ≥ 6 PM	N	Outcome	Effect Size (95% CI) *P*		
				Non-Adjusted	Model I	Model II
			Weight gain, n (%)	**OR (95% CI) *P***		
Morning type	No	291	291 (5.84)	1	1	1
Intermediate type	No	304	304 (5.92)	1.01 (0.51, 2.01) 0.967	0.95 (0.46, 1.94) 0.882	1.02 (0.49, 2.15) 0.948
Evening type	No	464	464 (6.03)	1.04 (0.56, 1.93) 0.913	1.01 (0.52, 1.93) 0.985	0.90 (0.45, 1.79) 0.764
Morning type	Yes	52	52 (1.92)	0.32 (0.04, 2.43) 0.268	0.30 (0.04, 2.37) 0.253	0.38 (0.05, 3.06) 0.362
Intermediate type	Yes	71	71 (12.68)	2.34 (1.00, 5.49) 0.051	2.30 (0.91, 5.81) 0.078	2.32 (0.88, 6.15) 0.091
Evening type	Yes	116	116 (13.79)	**2.58 (1.26, 5.30) 0.010**	**2.64 (1.22, 5.69) 0.014**	**2.43 (1.07, 5.50) 0.034**
***P* for interaction**				0.0549	**0.049**	0.110

Notes: The bold values indicated statistical significance *P*<0.05. Model I adjusted for: gender (male, female), grade (sophomore, junior, senior or above), parental education (primary school or below, junior high school, high school, university or above), birthplace (city, town, countryside), only child (yes, no); Model II additionally adjusted for: sleep duration (≤6h, 7h, ≥8h), sleep quality (very good, good, general, poor), late night snack (yes, no), highest intake at dinner (yes, no), physical activity time (<2h, ≥2h), sedentary behavior (<9h, ≥9h).
Abbreviations: β, partial regression coefficient; CI, confidence interval; OR, odds ratio.

Table 6 Sensitivity Analysis

	Effect Size (95% CI) *P*				
	Limiting Population to:				Further Adjustment* (n=1300)
	Non-Smoker (n=1283)	Non-Drinkers (n=1266)	No Late Night Snacks (n=1089)	Underweight/ Normal (n=1146)	
Weight change	**β (95% CI) *P***				
Definite morning type	0	0	0	0	0
Moderate morning type	0.58 (−0.19, 1.36) 0.138	0.55 (−0.23, 1.33) 0.165	**0.86 (0.04, 1.68) 0.041**	0.30 (−0.47, 1.07) 0.447	0.61 (−0.18, 1.40) 0.1276
Intermediate type	**0.75 (0.11, 1.39) 0.021**	**0.70 (0.06, 1.34) 0.033**	**0.92 (0.24, 1.59) 0.008**	**0.67 (0.04, 1.31) 0.038**	**0.74 (0.09, 1.39) 0.0249**
Moderate evening type	**0.75 (0.12, 1.39) 0.020**	0.60 (−0.04, 1.24) 0.067	**0.80 (0.12, 1.47) 0.021**	0.55 (−0.08, 1.19) 0.089	**0.70 (0.06, 1.35) 0.0326**
Definite Night type	**0.77 (0.01, 1.54) 0.047**	**0.83 (0.06, 1.60) 0.035**	0.82 (−0.01, 1.66) 0.052	**1.02 (0.26, 1.79) 0.009**	**0.88 (0.10, 1.65) 0.0265**
Weight Gain	**OR (95% CI) *P***				
Definite morning type	1	1	1	1	1
Moderate morning type	2.06 (0.72, 5.90) 0.178	2.08 (0.72, 5.96) 0.173	2.47 (0.76, 8.07) 0.133	1.38 (0.44, 4.38) 0.582	2.13 (0.74, 6.09) 0.1607
Intermediate type	2.00 (0.81, 4.96) 0.133	1.99 (0.80, 4.92) 0.139	2.45 (0.88, 6.86) 0.087	1.37 (0.53, 3.52) 0.520	2.03 (0.82, 5.01) 0.1252
Moderate evening type	1.84 (0.75, 4.53) 0.184	1.65 (0.66, 4.11) 0.280	1.73 (0.60, 4.99) 0.310	1.36 (0.53, 3.50) 0.524	1.84 (0.75.4.53) 0.1815
Definite Night type	1.71 (0.61, 4.81) 0.310	1.94 (0.70, 5.38) 0.205	1.32 (0.37, 4.71) 0.670	2.02 (0.72, 5.70) 0.183	1.93 (0.70, 5.30) 0.2006

Notes: The bold values indicated statistical significance *P*<0.05. Adjusted for gender (male, female), grade (sophomore, junior, senior or above), parental education (primary school or below, junior high school, high school, university or above), birthplace (city, town, countryside), only child (yes, no), sleep duration (≤6h, 7h, ≥8h), sleep quality (very good, good, general, poor), late night snack (yes, no), highest intake at dinner (yes, no), physical activity time (<2h, ≥2h), sedentary behavior (<9h, ≥9h); *Further adjusted for major (clinical, non-clinical).
Abbreviations: β, partial regression coefficient; CI, confidence interval; OR, odds ratio.

Discussion

In this cross-sectional study of medical students, we observed that high prevalence of moderate evening chronotype among medical students. Significant differences were found in weight change among medical students with different chronotypes, with definite evening chronotype students showing more pronounced weight increase, while definite morning chronotype students experienced weight decrease. Compared to the definite morning type, the proportions of weight gain were higher in the other chronotype groups, though the differences were not statistically significant. A joint effect was observed between chronotype and dinner time, with evening-type students eating dinner ≥ 6 PM exhibiting the greatest weight change and highest likelihood of weight gain.

This study found that 31.5% and 13.1% of medical students had moderate evening and definite evening chronotypes, respectively. This proportion is higher than the 36% of evening-type students reported in a Canadian study of university

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students.[42] However, the prevalence of evening chronotype is generally higher among university students than in the general population,[43] regardless of whether they are medical students. Medical students, in particular, may be more inclined toward evening chronotype due to additional pressures such as clinical practice and academic demands. In modern society, factors such as academic pressure,[30] reduced parental supervision,[44] and social factors[45] likely contribute to the shift of college students' chronotype toward evening type. This highlights the need to address chronotype-related health behaviors in this population.

In this study, 42.38% of medical students experienced an increase in weight during their university studies, with a mean weight change of 0.38 kg. A dose-response relationship was observed between chronotype and weight change: compared to the definite morning type, the odds of weight gain progressively increased for the moderate morning type, intermediate type, moderate evening type, and definite evening type. Previous studies have reported mixed results regarding the association between chronotype and weight change. For example, a study in Turkey found higher BMI levels in morning types among university students, which contrasts with our findings.[46] This study differed from ours by focusing on addictive eating behaviors and not considering the effects of physical activity on BMI. Additionally, the authors suggested that morning-evening preferences may not directly align with decisions about bedtime and wake-up times. However, a study of 661 healthy students at Ankara University reported higher BMI in evening-type students, mediated by reduced sleep quality.[47] Similarly, a prospective study of US college freshmen found no significant association between chronotype and initial weight, but evening types experienced a significant increase in weight over time, potentially due to the adoption of unhealthy behaviors after gaining autonomy away from home.[44] Additionally, a study of Australian school-aged children found higher BMI levels in late chronotypes.[30] While these findings align with our results, they did not focus on medical students or did not control some important confounding factors such as breakfast frequency, dinner time, and midnight snacking.

Moreover, it is worth noting that chronotype showed no significant association with weight gain, but evening-type students who eating dinner ≥ 6 PM had the greatest weight change and highest likelihood of weight gain. While previous studies on this topic are limited, a study of US retirees investigated the association between meal time and BMI in different chronotypes, with those who consumed more energy at night had higher odds of being overweight or obese, particularly evening-type individuals.[48] Based on our findings, it is particularly important for evening-type medical students to have an earlier dinner and avoid late-night energy intake to promote better health. As medical students often face irregular schedules during clinical work, maintaining a morning chronotype can be challenging. However, by adopting these eating habits, they can better manage their weight and reduce the risk of overweight and obesity.

The mechanism by which chronotype affects weight change remains unclear, but may involve physiological, psychological and behavioral factors. First, chronotype may affect multiple physiological systems. Evening chronotypes are associated with unfavorable metabolic outcomes, which contribute to obesity. Second, chronotype may impact health by influencing the inflammatory response.[49] Behaviorally, studies have shown that individuals with an evening chronotype are more likely to consume high-energy foods and beverages than their morning or intermediate counterparts.[50,51] They also tend to have a higher alcohol intake.[52] Research indicates that evening-type individuals may experience alcohol-induced eating, contributing to a 25% increase in overweight status.[53] Additionally, they typically have higher daily caffeine consumption and poorer sleep quality.[47,54] Also, evening-type individuals are 80% more likely to be physically inactive than morning-type ones and 190% more likely to spend extra time on electronic screens,[30] leading to low energy expenditure. Sedentary behavior and high-calorie food consumption in later chronotypes often result in an energy imbalance, as they may not burn enough calories through daily activities, resulting in weight increase.[55] Prolonged screen time further reduces physical activity and disrupts circadian rhythms.[56] These disruptions can exacerbate weight increase by misaligning the body's internal clock with external schedules for work and social activities.[57]

This study investigated the independent effects of chronotype on weight change among young medical students, controlling for various confounding factors. Comprehensive data on behaviors and lifestyle factors were collected, enabling detailed analysis of potential influences. For example, dinner timing was investigated for each participant, with dinner ≥ 6 PM included as a key variable in the statistical analysis. The results revealed a joint effect of chronotype and late dinner timing on weight changes, a finding rarely reported in previous studies.

However, as a cross-sectional study, the association between chronotype and weight change cannot be explained as a causal relationship. And this study did not account for light exposure, which is a crucial factor influencing both chronotype and weight changes.[58] Excessive nighttime lighting, particularly blue light, is associated with dysregulation in circadian rhythms and metabolic disorders, potentially leading to weight increase.[59,60] Future research should incorporate different light exposure related behaviors, such as daily outdoor activity time and night time screen time, to explore their potential mediating roles in the relationship between chronotype and weight changes. Moreover, incorporating psychological factors such as anxiety and depression, along with conducting longitudinal follow-up studies on medical students, will provide a more comprehensive and reliable scientific basis for understanding these complex interactions.

Conclusion

In conclusion, this study, from the perspective of biological clock, found that the chronotype was related to the weight change of medical students. Evening-type medical students may gain more weight than morning-type students. Moreover, there was a joint effect between evening chronotype and eating dinner ≥ 6 PM on weight change value and weight gain. Therefore, college students should maintain regular sleep schedules to prevent excessive weight increase. Evening-type medical students, in particular, may benefit from eating dinner earlier and avoiding late-night calorie intake to better manage their weight and reduce the risk of obesity.

Ethics Approval and Consent to Participate

The study protocol was approved by the Ethics Committee of Wenzhou Medical University (ethics approval number: 2021-022) and was conducted in accordance with the Declaration of Helsinki. All participants signed written informed consent.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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