ORIGINAL ARTICLE

The effects of individual circadian rhythm differences on insomnia, impulsivity, and food addiction

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Abstract

Purpose Individuals can generally be divided into morning, neither and evening types according to behavioral, psychological, and biological variables including appetite levels, usual meal times, sleep times, and melatonin secretion. These factors together identify a person as being part of a certain chronotype, i.e., as feeling more efficient either in the morning (morning type) or later in the day (evening type). Food addiction is defined as addictive behavior toward palatable foods and is thought to be one of the underlying risk factors for obesity. Our aim in this study was to investigate the relationship between circadian rhythm differences and food addiction via insomnia and impulsivity in university students.

Method Participants were 1323 university students, filled out a package of psychological tools, including the Morningness–Eveningness Questionnaire, Insomnia Severity Index, Barratt Impulsiveness Scale Short Form, and Yale Food Addiction Scale. Logistic regression analysis was used to investigate direct relation of food addiction with insomnia, impulsivity and obesity, and mediation regression analysis was used to investigate the indirect effect of circadian rhythm differences on food addiction.

Results Our findings indicated that evening types were more prone to insomnia and impulsivity, and also insomnia and impulsivity significantly contributed to the variance of food addiction. Although there was no significant linear relationship between circadian rhythm differences and food addiction, evening-type circadian preferences were indirectly associated with higher food addiction scores mediated by insomnia and impulsivity.

Conclusion The most remarkable result of our work was that circadian rhythm differences seem to indirectly effect on food addiction through elevated insomnia and impulsivity.

Level of evidence Level V, descriptive cross-sectional survey.

Keywords Circadian rhythm · Chronotype · Food addiction · Impulsivity · Insomnia · Obesity

This article is part of topical collection on Sleep and Obesity.

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Introduction

In healthy individuals, the sleep/wake cycle, which is regulated by endogenous (e.g., circadian pacemaker, peripheral oscillators, clock genes) and exogenous factors (e.g., light, feeding, social behavior, work and school schedules), is defined as circadian rhythm [1, 2]. Chronotypes can generally be divided into three types as morning types, neither types and evening types which differ in accordance with a number of psychological, behavioral, and biological variables including usual meal times, performance, mood, alertness and appetite. Morning types wake up earlier, go to sleep at night earlier, and have less variable sleep times than evening types. Morning types tend to start earlier in the morning with regard to their activities, while evening types are more

efficient later in the day. In addition, evening types are more associated with having insomnia [3–7].

Recently, in studies conducted on the relationship between chronotypes and personality traits, it has been reported that evening-time individuals are characterized as being more outward-looking, high sensation seeking, risk-taking, and independent and having lower avoidance habits, perseverance, and self-direction [8–12]. In a study conducted on individuals who attempted suicide, it was determined that the evening types tended to be more impulsive and more prone to suicide [13].

A mammal's feeding time is the most important time adjuster for the peripheral clock, although it is organized by the biological clock with the suprachiasmatic nucleus in the central frontal hypothalamus, such as the sleep–wake cycle (Zeitgeber) [14, 15]. Mammals often feed during active phases. Studies have shown that mice fed during passive phases gain more weight than mice fed during active phases [16]. In another study, rats fed a high-fat diet were fed only during active phases for 18 weeks, which resulted in less weight gain, decreased cholesterol levels, and increased insulin sensitivity [17]. Epidemiological investigations have suggested that the results of circadian misalignment such as eating at the wrong time of the day, skipping breakfast, and eating at night are associated with obesity and metabolic syndrome [18].

In studies on circadian preferences and eating behaviors, morning types had better control over food intake, while evening types were more likely to skip breakfast [19, 20]. This finding suggests that staying up late at night can lead to excessive feeding [21]. After daily and consistent snack access has been interrupted, ongoing search and expectation suggest that stimuli representing a reward for the individual can affect the circadian system and sustain daily behavioral rhythms and neuronal activity. In addition, it is believed that various arousal-seeking behaviors existing primarily at certain times of the day are the result of the underlying mechanisms of addictive behaviors [1].

Food addiction comprised the idea that certain foods (usually processed, palatable and high calorie foods) may have an addictive potency and that overeating these foods represents addictive behavior [22]. The proliferation of high-processed foods that can fuel addictive behavior in the twenty-first century and the continued growth of obesity as a public health problem have made food addiction a focus of scientists [23]. Consequently, research studies on food addiction have been increasing in recent years; recent animal studies and human brain imaging studies have demonstrated the neurobiological and behavioral similarities between drug addiction and food addiction [24]. In 2009, studies concerning the prevalence of food addiction began with the creation of the Yale Food Addiction Scale developed by Gearhardt et al. [25] and Luczak et al. [26].

In a study conducted by university students who observed the relationship between obesity and impulsivity, it was found that impulsivity increases obesity by increasing food addiction [27]. In addition, in a study comparing impulsivity, food addiction, and BMI, a significant relationship was found between impulsivity and food addiction and BMI [27]. According to another recent study, food addiction was found to be related to impulsivity independent of obesity and/or binge eating disorder [28].

Sleep deprivation, one of the consequences of the social jet lag or business world, is increasing in Western society [29]. It is defined as "Insufficient Sleep Syndrome" in the International Classification of Sleep Disorders 3 [30]. Studies have shown that sleep deprivation can increase food intake and appetite. The brain functional magnetic resonance imaging study by Benedict et al. showed that acute sleep deprivation increases the reward response to food clue, regardless of weight and blood sugar level [31].

Evidence suggests that a model of food addiction underlies obesity [32]. Insomuch as sleep–wake cycles and food intake are known to be directed by the circadian system, circadian differences in relation to food addiction have not been studied as far as we know. In addition, insomnia and impulsivity seem to have a mediating role for the relationships between circadian rhythm differences and food addiction. Our aim in this study was to investigate the effects of individual circadian rhythm differences on insomnia, impulsivity, and food addiction. Our hypotheses were as follows: (1) evening-type circadian preferences will be associated with insomnia and impulsivity, (2) insomnia and impulsivity will contribute to food addiction, and (3) evening-type circadian preferences will increase food addiction through elevated insomnia and impulsivity.

Method

Participants and procedures

This research was a cross-sectional study aiming to analyze the relation between circadian rhythm differences and food addiction in university students. Research population consisted of 1323 university students. By accepting the prevalence of some sleep problems including circadian rhythm as 46.4% and estimating the real value of this ratio in 0.08 points with 99% confidence level, the required sample size was found to be 1268 [33, 34]. In the study, cluster sampling method was used. Every class faculties and high schools were accepted as a cluster and total 45 clusters were chosen. The faculties as medicine, engineering, health science and communication elected by lot from these clusters were included in the study. The data in the research was collected using a package of psychological

tools including the personal questionnaire, the Morningness–Eveningness Questionnaire (MEQ), Insomnia Severity Index (ISI), Barratt Impulsiveness Scale Short Form (BIS-11-SF), and Yale Food Addiction Scale (YFAS). The personal questionnaire asked about age, height, weight, gender, alcohol and cigarette use, and prior psychiatric disorder. The data were gathered in the classrooms by the researcher.

University students aged 16 and older were included in the study. Exclusion criteria for the participants were as follows: (a) having any current functional or organic mental disorder; (b) the presence of the psychoactive substance or alcohol abuse or dependence; (c) working in shift work. Students were informed before the study and their consent was obtained. To carry out the study, permission was obtained from the Non-Invasive Ethical Committee of Selcuk University, Faculty of Medicine (the decision number: 2016/116).

Measures

Morningness–Eveningness Questionnaire

The MEQ is the most commonly used measure to determine circadian rhythm differences. This 19-item self-report scale is used for screening purposes and yields scores ranging from 16 to 86. Participants who score between 16 and 41 are classified as evening type, who score between 42 and 58 are classified as neither type, and who score between 59 and 86 are classified as morning type [35]. The validity and reliability of the Turkish version of the MEQ was performed by Agargun et al. The Cronbach's α coefficient of this study was $\alpha = 0.81$ for 19 items and showed good validity and reliability [36].

Insomnia Severity Index

The ISI is a reliable, valid, easily applicable self-report scale designed to assess the severity of insomnia. Participants are asked to rate seven self-reported items on difficulty in falling asleep, difficulty staying asleep, waking up too early, satisfaction from sleep patterns, deterioration in daily functionality, awareness of sleep-induced deterioration, and level of stress caused by sleep problems [37]. The total score the scale is calculated by summing the scores from each item. The lowest point to be taken from the scale is 0, the highest score is 28. Higher scores are associated with more severe insomnia. The validity and reliability of the Turkish version of the ISI was performed by Boysan et al. and was demonstrated to have good psychometric properties. In this study, internal reliability was $\alpha = 0.79$ and 2-week test–retest reliability was $r = 0.82$ [38].

Barratt Impulsiveness Scale Short Form

Tamam et al. shortened the Turkish adaptation of the 30-item scale by factor analyzing the items of the scale and taking the 5 items with the highest loadings for each of the subscales [39, 40]. The internal consistency reliability coefficients (Cronbach's α) were 0.70 for motor impulsiveness, 0.64 for attentional impulsiveness, 0.80 for nonplanning impulsiveness; and 0.82 for the total 15-item scale in the adaptation study. BIS-11-SF is a 4-point, multiple-choice Likert-type measure of 15 items [40].

Yale Food Addiction Scale

The YFAS is a 25-item measure which assesses addictive eating behavior such as reduced involvement in social, occupational and recreational pursuits due to addictive eating and food tolerance. Responses are used to calculate a symptom count of food addiction symptoms ranging from 0 to 7. According to this scale, in order for the food addiction to be met, the participant has to meet three or more symptoms and indicated clinically significant impairment [25]. Sevincer et al. conducted the validity and reliability study of the Turkish version of YFAS among bariatric surgery patients. The internal consistency analyzed by Kuder Richardson 20 formula was found to be 0.822 [41].

Analyses

SPSS-22 statistical package program was used when evaluating the data. First, descriptive statistics were evaluated. Two strategies have been identified for filling the missing data. If the missing data obtained from scales form, we excluded the participant from this study. In addition, for only four values, the group means values were entered when the descriptive data were missing but the scale forms were full. To test hypothesis 1, one-way analysis of variance was used to investigate the differences between scale scores according to circadian rhythm differences. To test hypothesis 2, risk factors for food addiction were assessed by logistic regression analysis enter model. Finally, to test hypothesis 3, mediation regression analysis was used to investigate the indirect effect of circadian rhythm differences on food addiction through insomnia and impulsivity. Mediation analyses were performed with the macro for SPSS Indirect [42]. The models were bootstrapped 5000 times to avoid non-normality. In addition, the bootstrap bias corrected and accelerated procedure was preferred to obtain more reliable results [43]. Demographic data such as age, sex, BMI, prior psychiatric disorder, use of cigarette and alcohol were used as covariates in multiple mediation analysis model. The risk values are calculated within the 95% confidence interval. The significance threshold was determined as $p < 0.05$.

Results

Preliminary analyses

The mean age of the participants was 20.8 (SD ± 1.9), ranging between 16 and 33. 65.8% of the sample were females ($n = 870$). 16.1% of the sample reported cigarette use, and 10.4% of the sample reported alcohol use. Demographic characteristics, and means and standard deviations of the MEQ, ISI, YFAS and BIS-11-SF are reported in Table 1.

Pearson correlation coefficients were calculated to examine the associations between the BMI, subscale scores of the BIS-11-SF and other scale scores. There was a strong correlation between all scale scores except correlations between BMI and sleep parameters. The results of Pearson correlations are presented in Table 2.

Table 1 Participant characteristics and descriptive statistics of the measured variables

Participant characteristics ($N = 1323$)	%/M (SD); range
Gender	
Female	65.8%
Male	34.2%
Age	20.83 (1.98); 16–33 years
Prior psychiatric disorder	
Yes (91)	6.9%
No (1232)	93.1%
Body Mass Index	21.96 (3.03); 14.61–41.38
Underweight	9% (BMI < 18.5)
Normal weight	75.4% (BMI 18.5–24.9)
Overweight	14.3% (BMI 25.0–29.9)
Obese	1.4% (BMI ≥ 30)
YFAS scores	3.41 (1.46); 0–7 symptoms
Met criteria (241)	18.2%
Did not criteria (1082)	81.8%
MEQ scores	50.15 (8.95); 18–76
Morning type (204)	15.4%
Mix type (926)	70.0%
Evening type (193)	14.6%
ISI scores	9.67 (5.28); 0–28
No insomnia (509)	38.5%
Subthreshold (570)	43.1%
Moderate (212)	16.0%
Severe (32)	2.4%
BIS-11-SF scores	29.81 (6.22); 16–57
Motor impulsivity	8.09 (2.14); 4–16
Attention impulsivity	11.21 (2.95); 6–24
Nonplanning impulsivity	10.51 (2.91); 5–20

Table 2 Pearson product–moment correlation coefficients

	1	2	3	4	5
1. BMI	1.00				
2. MEQ	0.00	1.00			
3. ISI	− 0.03	− 0.16**	1.00		
4. YFAS	0.11**	− 0.10**	0.14**	1.00	
5. BIS-11-SF	0.11**	− 0.21**	0.23**	0.28**	1.00

BMI Body Mass Index, *MEQ* Morningness Eveningness Questionnaire, *ISI* Insomnia Severity Index, *YFAS* Yale Food Addiction Scale, *BIS-11-SF* Barrat Impulsiveness Scale 11 Short Form

*$p < 0.05$; **$p < 0.01$

Differences on scale scores according to chronotypes

One-way analysis of variance was used to compare all scale scores and BMI according to chronotypes. Subsequently, significant differences were determined between the groups using the LSD multiple comparison test. Statistically significant differences were found between the groups in the MEQ, ISI, YFAS and BIS-11-SF scores excluding BMI. As shown in Table 3, evening-type individuals had more insomnia, impulsivity and food addiction scores than the other two chronotypes ($p < 0.01$).

Logistic regression analyses for food addiction

Risk factors for food addiction were evaluated via logistic regression analysis (enter model). According to this analysis, having prior psychiatric disorder (OR 1.69, Cl 1.01–2.82), obesity (OR 1.48, Cl 1.25–1.91), all subscale scores of BIS-11-SF (NI: OR 1.06, Cl 1.01–1.13; motor impulsiveness: OR 1.12, Cl 1.04–1.19; AI: OR 1.11, Cl 1.04–1.19) and insomnia score (OR 2.24, Cl 1.58–3.17) were risk factors for food addiction. Age, sex, tobacco use, alcohol use and having morning or evening types on MEQ were determined as non-risk factors (Table 4).

Mediation analysis of circadian rhythm differences on food addiction

According to logistic regression analysis, there was no significant relationship between food addiction and circadian preferences. Hence, mediation regression analysis was used to investigate the indirect effect of circadian rhythm differences on food addiction through insomnia and impulsivity. It was found out that those who reported a lower MEQ score reported significantly higher ISI and BIS-11-SF scores ($\beta = - 0.08$; $p < 0.01$ and $\beta = - 0.12$; $p < 0.01$) (*a* paths). In addition, having a higher ISI score and BIS-11-SF score predicted significantly more severe

Table 3 Comparison of scale scores between chronotypes

	Morning–evening type						$F(2,1320)$	p	η^2	Post hoc[‡]
	Evening type (A)		Neither type (B)		Morning type (C)					
	Mean	SD	Mean	SD	Mean	SD				
MEQ	34.66	6.59	50.66	4.40	62.48	3.24	1803.546	< 0.001	0.732	A = B = C
ISI	11.02	6.09	9.65	4.99	8.48	5.48	11.659	< 0.001	0.017	A > C > B
YFAS	3.64	1.53	3.44	1.45	3.06	1.35	8.532	< 0.001	0.013	C > A > B
BIS-11-SF	31.85	6.81	29.89	5.99	27.46	5.84	26.120	< 0.001	0.038	A = B = C
BMI	22.02	4.31	22.02	3.03	22.05	2.73	0.005	0.995	0.000	–

BMI Body Mass Index, *MEQ* Morningness Eveningness Questionnaire, *ISI* Insomnia Severity Index, *YFAS* Yale Food Addiction Scale, *BIS-11-SF* Barrat Impulsiveness Scale 11 Short Form

[‡]Post hoc comparisons were carried out using the LSD multiple group comparison test ($p < 0.05$)

Table 4 Logistic regression analysis enter model for food addiction

	B	ODDS	95% CI	p
Age	− 0.169	0.85	0.62–1.15	0.282
Sex	0.011	1.58	0.73–1.41	0.950
Tobacco use	− 0.305	0.74	0.46–1.19	0.209
Alcohol use	0.25	1.23	0.76–2.17	0.347
Prior psychiatric disorder	0.52	1.69	1.01–2.82	0.047*
Obesity (BMI)	0.74	1.48	1.25–1.91	0.024*
Morning type (MEQ)	− 0.02	0.98	0.63–1.53	0.941
Evening type (MEQ)	0.11	1.12	0.74–1.69	0.591
Nonplanning impulsivity	0.06	1.06	1.01–1.13	0.033*
Motor impulsivity	0.18	1.12	1.03–1.23	0.008**
Attention impulsivity	1.10	1.11	1.04–1.19	0.002**
Insomnia	0.81	2.24	1.58–3.17	< 0.001**

*$p < 0.05$; ** $p < 0.01$

food addiction ($\beta = 0.02$; $p = 0.002$ and $\beta = 0.06$; $p < 0.01$) (*b* paths). When the indirect effects were examined, it was found that the MEQ scores were inversely contributed to the food addiction score through increasing the ISI ($\beta = -0.002$; $p < 0.01$ bias corrected and accelerated 95% CI − 0.004 to − 0.001) and BIS-11-SF scores ($\beta = -0.007$; $p < 0.01$ bias corrected and accelerated 95% CI − 0.01 to − 0.004). The important point is that the direct effect of MEQ scores on food addiction scores was not significant ($\beta = -0.01$; $p = 0.07$) (*c′* path), but the total effect of MEQ scores on the food addiction through the ISI and the BIS-11-SF was statistically significant ($\beta = -0.02$; $p < 0.01$ bias corrected and accelerated 95% CI − 0.013 to − 0.006) (*c* path). The results of the mediation analysis are presented in Table 5. The meditational model is illustrated in Fig. 1.

Discussion

In our study, we examined the relationship between circadian differences and food addiction as well as the impact of impulsivity and insomnia on this process. To our knowledge, this is the first study to examine the relationship between circadian preferences and food addiction, which is an important predictor of obesity.

It has been shown that people with evening-type chronotypes tend to sleep later, tend to get up later, and are predictive of insomnia [7]. It is also known that being an evening type and having insomnia is a risk factor in terms of impulsivity [44]. In our study, it was also found that having an evening-type circadian rhythm significantly predicted insomnia and impulsivity.

Table 5 Mediation analysis of circadian rhythm differences on food addiction

	B	SE	t	p
Direct effect				
a paths				
MEQ to ISI	− 0.08	0.02	− 4.89	< 0.001**
MEQ to BIS 11-SF	− 0.12	0.02	− 6.54	< 0.001**
b paths				
ISI to YFAS	0.02	0.01	3.12	0.002**
BIS 11-SF to YFAS	0.06	0.01	8.56	< 0.001**
c′ path				
MEQ to YFAS	− 0.01	0.004	− 1.79	0.07
Total effect				
c paths				
MEQ to YFAS	− 0.02	0.005	− 3.70	0.002**
	B (BC and % 95 CI)*	SE	p	
Indirect effect				
Through ISI	− 0.002 (− 0.004 to − 0.001)	0.001	< 0.01	
Through BIS 11-SF	− 0.007 (− 0.01 to − 0.004)	0.001	< 0.01	

*Bootstrap results (bias corrected and accelerated 95% confidence interval); **$p < 0.01$

MEQ Morningness–Eveningness Questionnaire, *ISI* Insomnia Severity Scale, *BIS-11-SF* Short Form of Barratt Impulsiveness Scale, *YFAS* Yale Food Addiction Scale
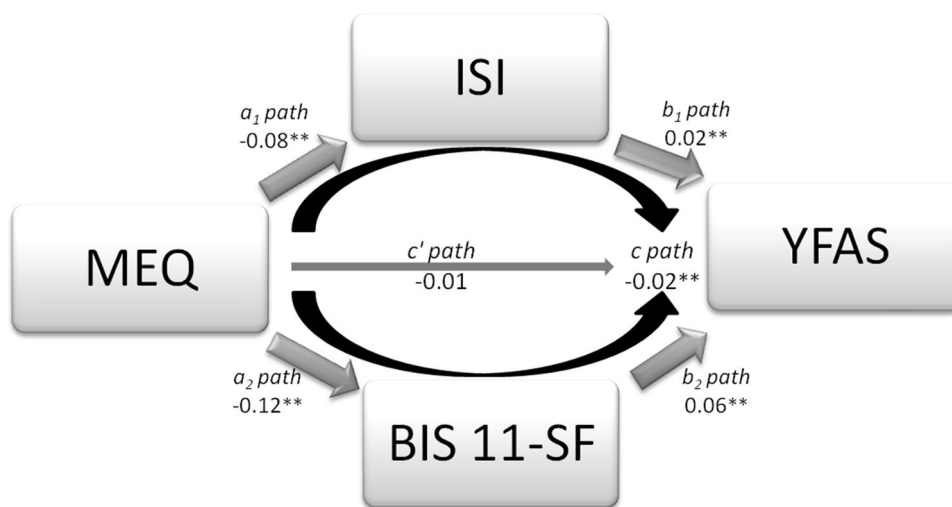

Fig. 1 Mediational model of circadian rhythm differences on food addiction. The figure represents direct and indirect associations between morningness–eveningness and food addiction mediated by insomnia and impulsivity. Curved black arrows line plotted from the MEQ to the Food Addiction through the ISI and BIS-11-SF refers to the total effect of the MEQ through the ISI and BIS-11-SF on the YFAS (*c* path). In the multiple mediation model age, sex, body mass index, prior psychiatric disorder, use of cigarette and alcohol were covariates which were not illustrated in the diagram (*$p < 0.05$; **$p < 0.01$). *MEQ* Morningness–Eveningness Questionnaire, *ISI* Insomnia Severity Scale, BIS-11-SF Short Form of Barratt Impulsiveness Scale, *YFAS* Yale Food Addiction Scale

One hundred and forty-three patients who applied for bariatric surgery were examined in a single study that previously analyzed the association between impulsivity subscales and food addiction. It is understood that motor impulsiveness and attentional impulsiveness predispose a person to food addiction, but there is no known relation between nonplanning impulsiveness and food addiction [45]. In our study, however, there were more obvious results in accordance with this literature. A Pearson correlation analysis showed a significant correlation between each subscale of the BIS-11-SF scale and food addiction. In a logistic risk analysis, motor impulsiveness and attentional impulsiveness

also predicted food addiction more significantly than non-planning impulsiveness. This result can be explained by the fact that the number of samples in our study was higher.

Many studies have examined the relationship between the circadian system and eating attitudes. It has been demonstrated that food intake is a peripheral oscillator for the circadian system [46]. A study by Yasumoto et al. on mice have shown that mice fed at unusual times of day led to a desynchronization of their peripheral clocks and led to metabolic disturbances in the forms of leptin resistance, hyperphagia, physical inactivity, and fatty liver [18]. In addition, it has been reported that certain palatable foods snacked upon at certain times of the day stimulate the reward system, including the corticolimbic system and nucleus accumbens, and lead to intensity-seeking behaviors and lay the foundation for food addiction In a cross-sectional study conducted by Harb et al. on a clinical sample examining the relationship between chronotype and night eating syndrome and binge eating disorder, it was found that evening-type circadian preference was more related to these two clinical disorders [47]. In a study conducted by Kervran et al. involving 333 volunteers who applied for treatment for addiction, it was found that being an evening type was more associated with poly-problematic addictions and non-substance addictions [48]. Based on the totality of the literature, it can therefore be reasonably assessed that evening-type circadian preferences may increase the risk of food addiction. In our study, impulsivity subscales and insomnia were strong predictors of food addiction according to a logistic risk analysis, but circadian preferences did not represent a significant risk. According to the multiple mediator analysis performed afterwards, it was found that having the evening-type circadian preference increased the likelihood of food addiction significantly by increasing the chances of insomnia and impulsivity scores.

Although there was no relationship found between circadian preferences and BMI in both our study and another study with similar sampling, there are studies that suggest that evening-type circadian preference is a predictor of obesity [49]. In a study conducted among 115 children, it was determined that the frequency of food intake was positive predictive of BMI and the total sleep duration was negative predictive of BMI [50]. There is a need for wider age range sampling and prospective observational studies to examine the relationship between circadian preferences and obesity.

The first limitation of our study was the narrow age range of our sample; all of the volunteers were undergraduates. This situation limits the generalization of the findings. Another limitation of our study was the cross-sectional method of our study. In addition, the lack of use of a tool to assess both depression and anxiety symptoms that may affect both insomnia and food addiction in our study and the lack of evaluation of general eating pathology symptoms

that are closely related to food addiction may be a limitation. Longitudinal studies of clinical samples will provide a better understanding of the relationship between circadian preferences and obesity.

In summary, we found that insomnia and impulsivity were directly related to food addiction. In addition, our study showed that evening-type circadian preferences predicted food addiction by increasing impulsivity and insomnia scores. Our study identified important common phenomena such as insomnia and impulsivity in relation to circadian rhythm differences and food addiction. The scientific importance of circadian rhythm studies is increasing [51]. In humans, promising findings of circadian rhythm and eating behaviors have been obtained. Longitudinal studies of clinical samples are needed to better understand the direct relationship between circadian rhythm, food addiction and obesity.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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