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# The role of chronotype, sleep quality, and physical activity in food cravings: a cross-sectional study

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## Abstract

**Introduction** Food cravings contribute to unhealthy eating behaviors, increased energy intake, and metabolic disturbances. However, the interplay between chronotype, sleep quality, and physical activity in shaping food cravings remains unclear. This study explores these associations in adults attending fitness centers.

**Methods** A cross-sectional study was conducted with 201 participants (80 females, 121 males) aged 19–64 years in İzmir, Türkiye. Validated tools, including the Food Craving Questionnaire-Trait (FCQ-T), Morningness–Eveningness Questionnaire (MEQ), and Pittsburgh Sleep Quality Index (PSQI), were used to assess food cravings, chronotype, and sleep quality, respectively.

**Results** Regular physical activity was significantly associated with lower FCQ-T scores ( $p < 0.05$ ). Poor sleep quality was linked to higher food craving levels ( $p < 0.05$ ). Evening chronotypes showed higher food craving scores than morning types, though this was not statistically significant ( $p > 0.05$ ). However, evening chronotypes exhibited significantly poorer sleep quality (higher PSQI scores) compared to morning types ( $p < 0.05$ ).

**Conclusion** This cross-sectional study suggests that regular physical activity and good sleep quality may be associated with lower food craving levels. Although chronotype differences were observed, further research is needed to clarify the underlying mechanisms. Given the limitations of the study design and potential selection bias, causal interpretations should be approached with caution. Nevertheless, interventions focusing on improving sleep and promoting physical activity may help reduce unhealthy eating tendencies in similar populations.

**Keywords** Food cravings, Sleep quality, Chronotype, Physical activity, Behavioral nutrition, Public health

## 1 Introduction

Food craving is defined as a strong and irresistible urge to consume specific foods [1]. Derived from the Old English word “crafiān,” meaning “to beg,” the concept of craving is also recognized in the Diagnostic and Statistical Manual of Mental Disorders, 5th



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Edition, as a key criterion for substance use disorders [2, 3]. Cravings often occur without hunger, driving consumption of highly palatable, energy-dense foods like processed snacks and desserts [4]. The easy availability and affordability of these foods exacerbate their overconsumption, influenced further by environmental cues like advertisements [5]. Such patterns are linked to rising obesity rates, emphasizing the need to regulate food cravings as a public health priority [6].

Regular physical activity induces beneficial physiological changes and is associated with improved appetite control and energy balance [7]. Sleep quality, too, affects appetite and cravings through homeostatic and hedonic mechanisms [8, 9]. Evening chronotypes are linked to unhealthy eating habits, including delayed meals, skipping breakfast, and increased consumption of sugary foods, while morning chronotypes tend to exhibit better dietary behaviors and fewer emotional eating patterns [10–12].

Chronotype, sleep quality, and physical activity are interconnected through neuroendocrine and behavioral mechanisms. For instance, evening chronotypes tend to exhibit poorer sleep quality due to circadian misalignment, which may lead to increased fatigue and reduced physical activity levels. Both poor sleep and insufficient physical activity have been independently associated with greater food cravings, possibly through hormonal imbalances (e.g., ghrelin, leptin) and impaired self-regulation [7, 13, 14]. Although chronotypes and food cravings are connected, findings remain inconsistent. Understanding how sleep patterns, eating behaviors, and chronotypes intersect is essential to developing targeted interventions for healthier lifestyles and future research.

Therefore, this study aimed to examine the associations between chronotype, sleep quality, physical activity, and food cravings in adults attending fitness centers. Additionally, exploratory analyses were conducted on sociodemographic and lifestyle variables such as biological sex, dietary patterns, and anthropometric indicators to provide a more comprehensive understanding of factors related to food cravings.

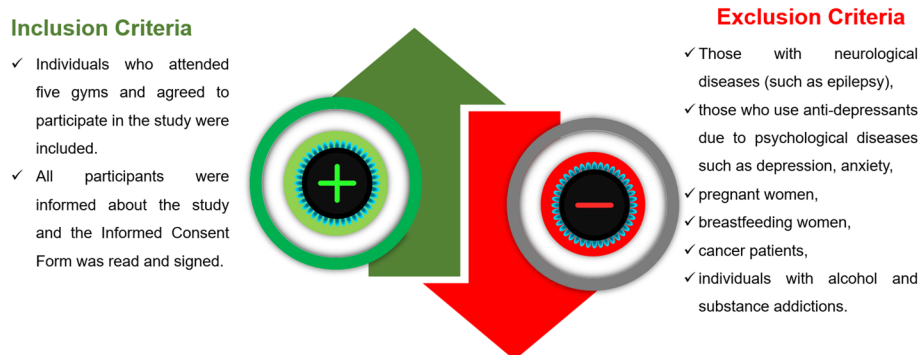
## 2 Methods

### 2.1 Study design

This descriptive, cross-sectional study was carried out between April and June 2022, involving 201 participants (80 women and 121 men) aged 19–64 years, who were recruited from five fitness centers in İzmir. The probability cluster sampling method was employed among 32 fitness centers located within the Konak and Karabağlar districts. Sample size determination was based on G-Power analysis, requiring at least 159 participants to detect significant differences across three groups at a 5% type I error level, with 80% power and a medium effect size ( $cf. = 0.25$ ) using one-way ANOVA. This study was approved by the Non-Interventional Clinical Research Ethics Committee of Izmir Democracy University (Decision No: 2022/04-12, dated June 4, 2022) and conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent prior to participation. Inclusion and exclusion criteria for the participants are presented in Fig. 1.

### 2.2 Questionnaire and data collection

General demographic and lifestyle information, including age, biological sex, marital status, education level, chronic illnesses, smoking, and alcohol consumption, was collected. Dietary habits and daily intake of energy, macronutrients, and micronutrients



**Fig. 1** Inclusion and exclusion criteria of the study participants

were assessed using a 24-h food recall conducted through face-to-face interviews the day before training.

Anthropometric measurements such as body weight (kg), height (cm), waist circumference, and hip circumference were recorded. These values were used to calculate body mass index (BMI,  $\text{kg}/\text{m}^2$ ), waist-to-hip ratio, and waist-to-height ratio. Body weight was measured before exercise, with participants wearing light clothing and no shoes, using a portable digital scale (Tanita BC-730, Japan) provided by the researcher. Height was measured with a non-elastic tape measure, while participants stood upright, heels together, back against the wall, and head in the Frankfurt horizontal plane. Measurements were recorded in centimeters. Waist circumference was measured at the mid-point between the lowest rib and the iliac crest, and hip circumference was measured at the widest point of the buttocks, using a flexible but non-elastic tape measure. All measurements were performed prior to participants' training sessions by the researcher.

Participants were also asked about their physical activity history, including the duration of previous and regular physical activities and their preferred types of gym exercises. Physical activity records for 24 h were gathered, and basal metabolic rate (BMR) was calculated using World Health Organization equations based on age, biological sex, and BMI. Physical activity levels (PALs) were estimated by multiplying the activity durations by their respective activity ratios [15]. Total energy expenditure was then derived by dividing the BMR by 1440 min and multiplying it by the total activity duration.

### 2.3 Assessment tools

**Chronotype:** Chronotypes were determined using the Morningness-Eveningness Questionnaire developed by Horne and Östberg [16], which includes 19 items consisting of both Likert-type questions and time-scale items. The Turkish adaptation of this tool was validated by Pündük et al. [17] Scores of 59–86 indicate a morning type, 42–58 an intermediate type, and 16–41 an evening type.

**Sleep quality:** Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), developed by Buysse et al. [18] and validated for the Turkish population by Ağargün et al. [19]. This 24-item questionnaire evaluates sleep patterns over the past month across seven components. Total scores of  $\leq 5$  indicate good sleep quality, while scores  $> 5$  indicate poor sleep quality.

**Food cravings:** Food cravings were assessed using the Food Craving Questionnaire-Trait (FCQ-T), originally developed by Cepeda-Benito et al. [20] and validated in Turkish by Müftüoğlu et al. [21]. The questionnaire comprises 39 items divided into nine

subdimensions. These are: (1) intent and planning to eat, (2) expectation of positive reinforcement from eating, (3) relief from negative emotions through eating, (4) lack of control over eating, (5) preoccupation with food-related thoughts, (6) physiological cravings, (7) emotional experiences during or around eating, (8) stimuli triggering food cravings, and (9) guilt or inability to resist food cravings.

#### 2.4 Data analysis

The data were analyzed using SPSS version 22.0. Descriptive statistics, including means, standard deviations, frequencies, and percentages, were used to summarize the data. The normality of the data distribution was confirmed, allowing for parametric tests. Comparisons between two independent groups were conducted using the Independent Samples t-Test, while differences among three or more groups were analyzed using One-Way ANOVA. Post-hoc analyses, such as Tukey's test, were applied where necessary to determine specific group differences. Multivariate analysis of variance (MANOVA) was performed to evaluate the impact of sleep quality and chronotype on the subcomponents of food cravings. Statistical significance was set at  $p < 0.05$ .

### 3 Results

A total of 201 individuals participated in the study, comprising 80 females and 121 males, with mean ages of  $28.3 \pm 8.7$  years and  $27.3 \pm 9.1$  years, respectively. The marital status distribution showed that 28.8% of women and 18.2% of men were married, while 71.2% of women and 81.8% of men were single. Smoking was reported by 37.5% of women and 35.5% of men, and alcohol consumption was noted among 43.8% of women and 33.9% of men. Detailed sociodemographic characteristics are presented in Table 1.

Table 2 summarizes the relationship between food craving scores and sociodemographic characteristics. Women had significantly higher food craving scores than men ( $p < 0.05$ ). No significant differences were observed in food craving scores across marital status, education level, smoking status, or alcohol consumption ( $p > 0.05$ ). Participants who skipped main meals tended to have higher food craving scores compared to those who did not; however, this difference was not statistically significant ( $p > 0.05$ ). Among meal skippers, individuals who skipped breakfast tended to have higher food craving scores than those who skipped other meals; however, these results were also not significant ( $p > 0.05$ ). On the other hand, participants adhering to a special diet had significantly lower food craving scores compared to those who did not follow a diet ( $p < 0.05$ ). Analysis of dietary records revealed that women had a daily energy intake of 1800.7 kcal, while men had an intake of 2499.4 kcal. Women's macronutrient intake included 74.1 g of protein (17.1% of energy), 88.2 g of fat (43.2%), and 173.1 g of carbohydrates (39.6%). For men, protein intake was 126.1 g (20.9%), fat intake was 108.7 g (39.2%), and carbohydrate intake was 249 g (40.1%).

The relationship between physical activity, anthropometric measurements, and food cravings is detailed in Table 3. Individuals who had previously engaged in physical activity and those who had maintained regular physical activity for the last three months had significantly lower food craving scores compared to those who had not ( $p < 0.05$ ). No significant differences in food craving scores were observed across physical activity level (PAL) categories ( $p > 0.05$ ). Food craving scores increased with higher BMI in both men and women, but the relationship was statistically significant only in women ( $p < 0.05$ ).

**Table 1** Descriptive sociodemographic characteristics of the study population

	Female (N = 80)		Male (N = 121)		Total (N = 201)	
<b>Mean age (years)</b>	28.29±8.73		27.27±9.06		27.68±8.92	
$\bar{X} \pm SD$ (min-max)	(18–52)		(18–56)		(18–56)	
<b>Marital status</b>	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>
Married	23	28.8	22	18.2	45	22.4
Single	57	71.2	99	81.8	156	77.6
<b>Total</b>	80	100	121	100	201	100
<b>Education status</b>	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>
Compulsory education (primary, secondary, or senior high school)	24	30	48	39.7	72	35.8
University (associate, undergraduate, or graduate)	56	70	73	60.3	129	64.2
<b>Total</b>	80	100	121	100	201	100
<b>Smoking status</b>	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>
No, I never drank	45	56.3	64	52.9	109	54.2
I drank, I quit	5	6.3	14	11.6	19	9.5
I still drink	30	37.5	43	35.5	73	36.3
<b>Total</b>	80	100	121	100	201	100
Duration of smoking (years)	6.34±7.38		8.12±7.66		12.05±8.74	
$\bar{X} \pm SD$						
Amount of cigarettes smoked (pcs/day)	8.32±6.74		14.69±9.10		7.34±7.55	
$\bar{X} \pm SD$						
<b>Alcohol consumption</b>	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>
No	45	56.2	80	66.1	125	62.2
Yes	35	43.8	41	33.9	76	37.8
<b>Total</b>	80	100	121	100	201	100
Frequency of alcohol consumption (month)	3.41±2.36		3.17±2.28		3.28±2.31	
$\bar{X} \pm SD$						
Alcohol consumption (ml)	524.60±625.47		765.49±980.05		651.22±834.58	
$\bar{X} \pm SD$						

Similarly, in women, increased waist circumference, waist-to-hip ratio, and waist-to-height ratio were associated with higher food craving scores ( $p < 0.05$ ), while no significant relationships were observed for these measurements in men ( $p > 0.05$ ).

The total Pittsburgh Sleep Quality Index (PSQI) score was  $5.34 \pm 3.21$  for women and  $4.93 \pm 2.10$  for men. Among participants, 123 were classified as having good sleep quality, while 78 had poor sleep quality. Chronotype distribution showed that 26 participants were morning types, 139 were intermediate types, and 36 were evening types (Fig. 2). Evening chronotypes had significantly higher PSQI scores compared to morning types ( $p < 0.05$ ). Additionally, participants with good sleep quality had a higher proportion of morningness compared to those with poor sleep quality ( $p < 0.05$ ).

Multivariate analysis of variance (MANOVA) results examining food cravings based on chronotypes and sleep quality are shown in Table 4. A significant difference was observed in Factor 9 of the FCQ-T (guilt or inability to resist food cravings) across chronotypes, with a moderate effect size ( $p < 0.05$ ). Additionally, Factor 8 (stimuli triggering food cravings) and the total FCQ-T score differed significantly by sleep quality ( $p < 0.05$ ). No significant relationships were found for other FCQ-T factors ( $p > 0.05$ ).

#### 4 Discussion

This study investigated the associations between chronotype, sleep quality, physical activity, and food cravings in a sample of physically active adults. In addition to these primary behavioral variables, exploratory analyses were conducted to assess the influence of sociodemographic factors and biological sex on food cravings. These findings may offer valuable insights into how these interconnected factors contribute to craving behavior and may guide future research. Consistent with prior research, females exhibited significantly higher food craving scores than males, indicating sex-specific differences [4, 22]. Biological and hormonal factors—such as fluctuations in estrogen and progesterone levels during the menstrual cycle—are known to influence appetite and food cravings [23, 24]. While social and cultural factors may also contribute to these patterns, our findings highlight the importance of considering biological sex in developing targeted public health interventions to manage food cravings.

While meal skipping was associated with higher food craving scores in this study, the differences were not statistically significant. Breakfast skippers exhibited the highest scores, aligning with previous research that prolonged eating intervals increase cravings at subsequent meals. For instance, Taetzsch et al. and Reichenberger et al. found that irregular eating patterns heightened cravings, particularly for sweet and salty foods [25, 26]. These findings highlight the importance of maintaining consistent meal patterns to regulate food cravings.

Food cravings have been consistently linked to obesity, a major global health issue associated with increased morbidity and mortality risks [27–29]. Factors such as restricted eating, emotional triggers, and hunger disruptions contribute to unhealthy eating behaviors and weight gain [30]. In this study, women with higher BMI, waist-to-hip ratio, and waist-to-height ratio exhibited elevated food craving scores, whereas no significant associations were observed in men. This sex-based difference may reflect biological differences in food preferences, with women favoring sweet foods and men opting for protein-rich options [31]. Addressing these preferences could guide personalized interventions for managing food cravings and obesity.

**Table 2** Food craving scores based on sociodemographic characteristics and dietary habits

Variable	Groups	N	%	Mean $\pm$ SD	F/t Value	p-value
Biological Sex	Male	121	60.2%	104.06 $\pm$ 39.75	t = -2.065 <sup>‡</sup>	0.041*
	Female	80	39.8%	117.04 $\pm$ 45.98		
Marital Status	Married	45	22.4%	111.00 $\pm$ 44.07	t = 0.316 <sup>‡</sup>	0.752
	Single	156	77.6%	108.71 $\pm$ 42.44		
Education Status	Compulsory Education	72	35.8%	112.51 $\pm$ 49.53	t = 0.760 <sup>‡</sup>	0.449
	University	129	64.2%	107.39 $\pm$ 38.47		
Smoking Status	Non-smokers	128	63.7%	111.73 $\pm$ 42.20	t = 1.104 <sup>‡</sup>	0.271
	Smokers	73	36.3%	104.82 $\pm$ 43.52		
Alcohol Consumption	Non-drinkers	125	62.2%	109.35 $\pm$ 42.90	t = 0.054 <sup>‡</sup>	0.957
	Drinkers	76	37.8%	109.01 $\pm$ 42.68		
Skipping Main Meals	No	77	38.3%	110.31 $\pm$ 45.83	F = 0.378 <sup>†</sup>	0.686
	Yes	55	27.4%	112.09 $\pm$ 41.32		
	Sometimes	69	34.3%	105.72 $\pm$ 40.51		
Skipped Meal	Breakfast	61	29.9%	112.17 $\pm$ 40.28	F = 0.522 <sup>†</sup>	0.594
	Lunch	55	27.4%	105.62 $\pm$ 41.15		
	Dinner	8	4.0%	101.80 $\pm$ 45.44		
Use of Nutritional Supplements	No	134	66.7%	110.81 $\pm$ 44.64	t = 0.742 <sup>‡</sup>	0.459
	Yes	67	33.3%	106.06 $\pm$ 38.69		
Special Diet Applied	No	178	88.6%	111.52 $\pm$ 42.84	t = -2.136 <sup>‡</sup>	0.034*
	Yes	23	11.4%	91.48 $\pm$ 38.02		

<sup>†</sup>One-way ANOVA was performed

<sup>‡</sup>Independent Samples t-test was performed

p < 0.05 indicates statistically significant differences between groups

Participants engaged in regular physical activity for at least three months reported significantly lower craving scores. This aligns with findings from Bergouignan et al., who demonstrated that moderate-intensity walking reduced cravings in sedentary individuals [32]. Moreover, integrating physical activity into daily routines, such as using sit-and-stand desks, has been shown to curb appetite and decrease caloric intake [33, 34]. These results suggest that physical activity may play a role in supporting energy balance and appetite regulation, although further longitudinal research is needed to clarify the direction of this relationship.

Individuals with poor sleep quality exhibited significantly higher food craving scores. Sleep deprivation can influence food-related behavior through several biological and psychological mechanisms. Neurocognitive pathways such as the prefrontal cortex—responsible for self-control—may be impaired during sleep deprivation, which increases hedonic responses to food. In addition, homeostatic regulation may be disrupted via hormonal changes; for instance, Broussard et al. (2016) reported that sleep restriction increased ghrelin and decreased leptin levels, while Markwald et al. (2013) found the opposite pattern [8, 35]. Experimental studies further support these effects. Yang et al. (2019) demonstrated that even a single night of sleep restriction increased hunger and portion size selection in non-obese women [36]. Tasali et al. (2014) observed that extending sleep from less than 6.5 h to 8.5 h for two weeks led to a 62% reduction in cravings for sweet and salty foods [37].

Subjective sleepiness may also modulate flavor perception and food cravings. In a study by Lv et al. (2018), individuals who reported higher sleepiness rated flavors more intensely and reported stronger cravings for high-fat and sweet foods [14]. Kracht et al. (2019) found that greater sleep efficiency among adolescents was associated with reduced cravings for multiple food categories, though cravings for fast food and fruits/

**Table 3** Food craving scores based on anthropometric measurements, physical activity

BMI Classification	Groups	N	%	Mean ± SD	F Value	p-value
Male	Underweight	60	30.0%	98.68 ± 40.29	F = 2.251 <sup>†</sup>	0.110
	Normal	47	23.5%	105.19 ± 35.91		
	Overweight	14	7.0%	123.29 ± 43.60		
Female	Underweight	7	5.8%	74.00 ± 31.72 <sup>a</sup>	F = 9.775 <sup>†</sup>	< 0.001*
	Normal	50	41.7%	107.00 ± 41.03 <sup>b</sup>		
	Overweight	14	11.7%	148.35 ± 42.58 <sup>b</sup>		
	Obese	9	7.5%	157.55 ± 32.47 <sup>c</sup>		
Waist circumference		<b>N</b>	<b>%</b>	<b>Mean ± SD</b>	<b>F Value</b>	<b>p-value</b>
Male	Normal	85	70.2%	102.60 ± 39.14	F = 0.192 <sup>†</sup>	0.826
	Low Risk	22	18.2%	107.86 ± 49.68		
	High Risk	14	11.6%	106.93 ± 25.57		
Female	Normal	71	88.8%	112.37 ± 45.64 <sup>a</sup>	F = 3.969 <sup>†</sup>	0.023*
	Low Risk	6	7.5%	164.00 ± 31.12 <sup>b</sup>		
	High Risk	3	3.7%	133.67 ± 19.76 <sup>c</sup>		
Waist-to-Hip Ratio		<b>N</b>	<b>%</b>	<b>Mean ± SD</b>	<b>t Value</b>	<b>p-value</b>
Male	Normal	59	48.8%	103.37 ± 40.60	t = -0.184 <sup>‡</sup>	0.854
	Risk	62	51.2%	104.71 ± 39.25		
Female	Normal	68	85.0%	111.57 ± 45.59 <sup>a</sup>	t = -2.622 <sup>‡</sup>	0.010*
	Risk	12	15.0%	148.00 ± 35.99 <sup>b</sup>		
Waist-to-Height Ratio		<b>N</b>	<b>%</b>	<b>Mean ± SD</b>	<b>F Value</b>	<b>p-value</b>
Male	Normal	75	62.0%	102.05 ± 39.87	F = 0.274 <sup>†</sup>	0.761
	Risk	40	33.1%	107.85 ± 41.89		
	High Risk	6	4.9%	103.83 ± 23.15		
Female	Risk	15	18.8%	89.47 ± 31.05 <sup>a</sup>	F = 7.878 <sup>†</sup>	< 0.001*
	Normal	48	60.0%	111.83 ± 45.11 <sup>b</sup>		
	Risk	10	12.5%	162.60 ± 38.99 <sup>c</sup>		
	High Risk	7	8.8%	146.71 ± 27.66 <sup>c</sup>		
Previous Physical Activity		<b>N</b>	<b>%</b>	<b>Mean ± SD</b>	<b>F Value</b>	<b>p-value</b>
	No, recently started	47		122.40 ± 46.37	t = 2.447 <sup>‡</sup>	0.015*
	Yes	154		105.20 ± 40.84		
Regular Physical Activity		<b>N</b>	<b>%</b>	<b>Mean ± SD</b>	<b>F Value</b>	<b>p-value</b>
	New starters	64		119.98 ± 42.37	t = 2.466 <sup>‡</sup>	0.014*
	Regular	137		104.19 ± 42.08		
Physical Activity Level (PAL)		<b>N</b>	<b>%</b>	<b>Mean ± SD</b>	<b>F Value</b>	<b>p-value</b>
	Mild	66		106.35 ± 43.34	F = 0.239 <sup>†</sup>	0.788
	Moderate	98		110.20 ± 41.13		
	Vigorous	37		111.76 ± 46.48		

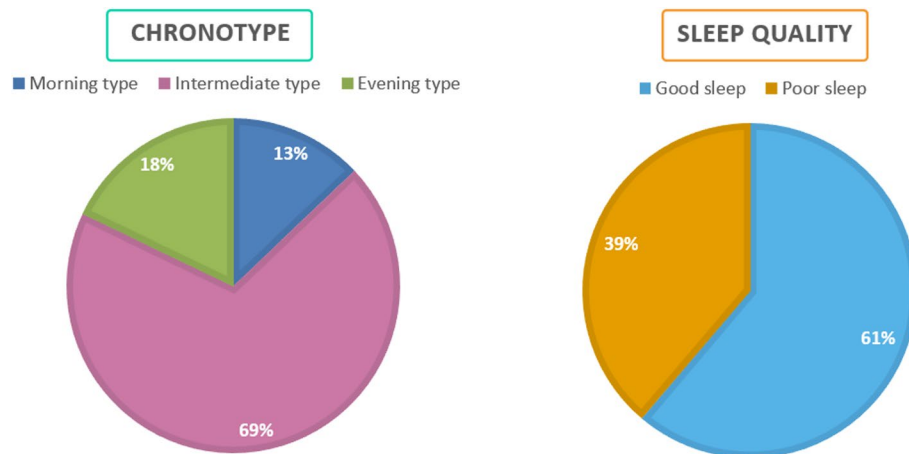
<sup>†</sup>One-way Anova was performed. <sup>‡</sup>t-test was performed.

\*  $p < 0.05$  indicates statistical significance.

Superscript letters (a, b, c) indicate significant differences between groups based on post-hoc Tukey HSD test.s

vegetables were less affected [38]. The PSQI used in our study evaluates sleep quality over the past month, and thus reflects more chronic patterns. While acute sleep deprivation has been shown to intensify food cravings and reward-driven eating behavior [39, 40], chronic poor sleep may elicit adaptive responses that moderate this effect. This distinction between acute and chronic sleep impacts should be further investigated in future research.

Chronotype also appears to play a role in dietary behaviors and food cravings. Evening chronotypes exhibited higher food craving scores than morning types, consistent with prior research linking evening types to less healthy eating patterns, such as increased consumption of sugary snacks and emotional eating [10–12, 41]. Meule et al. further associated evening chronotypes with heightened cravings for palatable foods during



**Fig. 2** Proportion of individuals according to chronotype and sleep quality classification

**Table 4** Multivariate analysis of variance results for food cravings based on chronotype and sleep quality

	Factor	Sum of Squares	df	Mean Squares	F	p	η <sup>2</sup>
<b>Chronotype</b>	Factor 1	19.082	2	9.541	0.588	0.556*	–
	Factor 2	3.106	2	1.553	0.038	0.963*	–
	Factor 3	3.999	2	1.999	0.113	0.893*	–
	Factor 4	108.380	2	54.190	0.974	0.379*	–
	Factor 5	175.373	2	87.686	1.038	0.356*	–
	Factor 6	24.881	2	12.441	0.489	0.614*	–
	Factor 7	38.120	2	19.060	0.478	0.621*	–
	Factor 8	7.826	2	3.913	0.143	0.867*	–
	Factor 9	116.012	2	58.006	3.818	<b>0.024*</b>	0.037
	FCQ-T score	7.948,994	2	3.974,497	2.205	0.113*	–
<b>Sleep quality</b>	Factor 1	19.214	1	19.214	1.190	0.277*	–
	Factor 2	82.249	1	82.249	2.042	0.155*	–
	Factor 3	15.004	1	15.004	0.854	0.357*	–
	Factor 4	39.576	1	39.576	0.710	0.400*	–
	Factor 5	212.645	1	212.645	2.536	0.113*	–
	Factor 6	73.669	1	73.669	2.941	0.088*	–
	Factor 7	23.251	1	23.251	0.584	0.446*	–
	Factor 8	149.830	1	149.830	5.666	<b>0.018*</b>	0.028
	Factor 9	3.115	1	3.115	0.199	0.656*	–
	FCQ-T score	22379.412	1	22379.412	13.005	<b>0.000*</b>	0.061

Multivariate analysis of variance was performed. Differences between groups were evaluated using Wilks' Lambda value.

\*  $p < 0.05$  indicates statistical significance.

FCQ-T factors refer to the following subdimensions: (1) intent and planning to eat, (2) expectation of positive reinforcement from eating, (3) relief from negative emotions through eating, (4) lack of control over eating, (5) preoccupation with food-related thoughts, (6) physiological cravings, (7) emotional experiences during or around eating, (8) stimuli triggering food cravings, and (9) guilt or inability to resist food cravings.

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), where scores > 5 indicate poor sleep quality.

late-night hours [42]. In a study conducted among pregnant women using the FCQ-T, Teixeira et al. found that evening chronotype was significantly associated with various food craving dimensions, reinforcing the link between circadian preference and hedonic eating behavior [43]. In addition, eveningness has been associated with poorer overall health outcomes, including an increased risk of metabolic disorders and obesity. These

findings underline the potential value of chronotype-specific interventions to mitigate food cravings and promote healthier eating behaviors.

This study has several limitations. First, its cross-sectional design limits the ability to infer causal relationships between chronotype, sleep quality, physical activity, and food cravings. Second, participants were recruited from fitness centers, which may introduce selection bias and restrict the generalizability of the findings to the broader population. Individuals attending fitness centers may have distinct lifestyle behaviors, such as higher motivation for health and fitness, compared to the general population. Future studies with more diverse samples are needed to validate these findings. Another limitation is the lack of standardized timing for questionnaire administration. As data collection was conducted prior to participants' training sessions at various times of the day, variations in hunger levels or recent food intake may have influenced responses, particularly those related to food cravings. Due to the cross-sectional design and recruitment strategy, causal inferences should be interpreted with caution. Furthermore, we did not adjust for potential confounders such as BMI, age, or biological sex in the MANOVA analyses, which may have influenced the observed associations. Future studies employing multivariate regression models could provide more precise estimates by accounting for these variables. Additionally, while the interplay between chronotype, sleep quality, and physical activity was explored in the full thesis using interaction analyses, these results were not included in the current manuscript due to space limitations and to maintain focus on primary associations. Future studies should further investigate these interrelationships to better understand their combined impact on food cravings.

Despite these limitations, the study also possesses several strengths. These include the use of validated assessment tools (FCQ-T, PSQI, MEQ), the inclusion of multiple behavioral predictors (physical activity, sleep quality, and chronotype), and a relatively diverse age range among participants. By examining the interplay of these variables in an active adult population, the study contributes meaningful insights into the complex behavioral mechanisms underlying food cravings. Future longitudinal or experimental studies can build on these findings to inform evidence-based interventions.

## 5 Conclusion

This cross-sectional study highlights associations between biological sex, physical activity, sleep quality, and food cravings. Our findings suggest that individuals with better sleep quality and regular physical activity may experience fewer food cravings. Although participants with an evening chronotype tended to report higher food craving scores, this relationship was not statistically significant.

Given the limitations of the cross-sectional design and potential for selection bias, causal interpretations should be made with caution. These associations may serve as a basis for generating hypotheses in future longitudinal or interventional studies. Tailored strategies that consider sleep patterns and physical activity habits may contribute to managing food cravings and promoting healthier eating behaviors.

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### Author contributions

TT, KEKÇ, and FÇK participated in developing the hypothesis and planning the research. TT collected and analyzed the data as part of his master's thesis. All authors interpreted the data. TT prepared the first draft. All authors edited and reviewed the text for scientific content. All authors read and approved the final version of the manuscript.

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**Data availability**

The datasets generated during the current study are available from the corresponding author on reasonable request.

**Declarations****Ethics approval and consent to participate**

This study was performed in line with the principles of the Declaration of Helsinki and was approved by the Non-Interventional Clinical Research Ethics Committee of Izmir Democracy University, with the decision dated June 4, 2022, numbered 2022/04–12. All participants were informed about the study, and the Informed Consent Form was read and signed.

**Competing interests**

The authors declare no competing interests.

**Clinical trial number**

Not applicable.

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