ATATÜRK ÜNİVERSİTESİ YAYINLARI
ATATURK UNIVERSITY PUBLICATIONS

Research Article/*Araştırma Makalesi* DOI: 10.51621/aws.1615581

Effect of Menstrual Cycle on Resting Energy Expenditure and Food Preferences

Menstrual Döngünün Dinlenme Enerji Harcaması ve Besin Tercihi Üzerindeki Etkisi

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ABSTRACT

Objective: It was aimed to evaluate the participants' resting energy expenditure, nutrient intake, food preferences, mindful eating and body composition in the follicular and luteal phase.

Method: The study included 58 participants between the ages of 18-45 years, who had a stable menstrual cycle for a minimum of six months and normal body mass index (BMI). Participants were invited for resting energy expenditure, body weight and body composition analysis in both the follicular and luteal phases. Nutrient intake and food preferences were evaluated, and Mindful Eating Scale was applied in both phases.

Results: Oxygen consumption (VO_2) and resting energy expenditure (REE) were significantly higher in the luteal phase ($p < .05$). There was no significant difference between measurements of body weight and body composition analysis and nutrient intakes in both phases ($p > .05$). Although the preference for high-protein/low-fat foods, fatty foods and sugary foods tended to increase in the luteal phase, there was no significant difference between the phases ($p > .05$). Finally, it was shown that the mean score of Disinhibition subscale of Mindful Eating Scale was noticeably higher during the luteal period ($p = .004$).

Conclusion: Changes in hormone levels during the menstrual cycle phases are an important factor to consider that may affect REE and impulsive eating. However, mindful eating strategies, dietary interventions and education programs are important in preventing the development of obesity and eating behavior disorders in predisposed individuals.

Keywords: Follicular, food intake, luteal, menstrual cycle, resting energy expenditure

ÖZ

Amaç: Bu çalışmada katılımcıların foliküler ve luteal fazdaki dinlenme enerji harcaması, besin alımı, besin tercihleri, yeme farkındalığı ve vücut kompozisyonlarının değerlendirilmesi amaçlanmıştır.

Yöntem: Çalışmaya, en az 6 aydır düzenli menstrual döngüye sahip ve beden kütle indeksi (BKİ)'ne göre normal, 18-45 yaş aralığındaki 58 katılımcı dahil edilmiştir. Katılımcılar hem foliküler hem de luteal fazlarda dinlenme enerjisi harcaması ölçümü, vücut ağırlığı ve vücut kompozisyonu analizi için davet edilmiştir. Ayrıca, besin tüketimi ve besin tercihleri değerlendirilmiş ve her iki fazda da Yeme Farkındalığı Ölçeği uygulanmıştır.

Bulgular: Oksijen tüketimi (VO_2) ve dinlenme enerji harcaması (DEE) ölçümleri luteal fazda foliküler faza göre anlamlı olarak yüksektir ($p < ,05$). Foliküler ve luteal fazlarda vücut ağırlığı ölçümleri, vücut kompozisyon analizi ve besin alımları arasında anlamlı bir fark bulunmamıştır ($p > ,05$). Yüksek proteinli/düşük yağlı besinler, yağlı besinler ve şekerli besin tercihleri luteal fazda artma eğiliminde olsa da fazlar arasında anlamlı bir fark bulunmamıştır ($p > ,05$). Son olarak, Yeme Farkındalığı disinhibisyon alt ölçeğinin ortalama puanı luteal fazda anlamlı olarak daha yüksek bulunmuştur ($p = ,004$).

Sonuç: Menstrual döngünün farklı evrelerindeki hormonal dalgalanmalar, DEE ve dürtüsel yemeyi etkileyebilecek önemli bir faktördür. Ancak yeme farkındalığı, diyet müdahaleleri ve eğitim programları, yatkın bireylerde obezite ve yeme davranışı bozukluklarının gelişmesini önlemede önemlidir.

Anahtar Kelimeler: Besin alımı, dinlenme enerji harcaması, foliküler, luteal, menstrual döngü

Geliş Tarihi/Received 08.01.2025
Kabul Tarihi/Accepted 22.04.2025
Yayın Tarihi/Publication Date 23.06.2025

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Cite this article: Atabilen, B., Uyduran, E. B., Kabak, M., Taşdemir, V. Ş., & Akdevelioğlu, Y. (2025). Effect of menstrual cycle on resting energy expenditure and food preferences. *Advances in Women's Studies, 7*(1), 1-11. Doi: 10.51621/aws.1615581

Introduction

For the regular menstrual cycle, the hypothalamic-pituitary-ovarian axis must work simultaneously. Follicle-stimulating hormone (FSH) and luteinizing hormone (LH) are released from the pituitary gland in response to gonadotropin-releasing hormone (GnRH), which is released in the hypothalamic pathway. While FSH and LH provide follicle growth, ovulation and corpus luteum formation in the ovary, they are also responsible for the coordinated release of hormones such as estrogen, progesterone and inhibin from the follicles (Öktem & Urman, 2012). The menstrual cycle is a complex control process. However, obesity and nutrition are one of the factors that can affect the menstrual cycle (Jahangir, 2018; Silvestris et al., 2018). Apart from the impact of diet on the menstrual cycle, variations in ovarian hormones (progesterone and estrogen) can cause differences in food consumption (Kammoun et al., 2017; Matsuura et al., 2020; Nowak et al., 2020) and stimulate the development of eating behavior disorders such as emotional eating and binge eating (Klump et al., 2013; Ma et al., 2020; Racine et al., 2013). Studies have found that food intake tends to decrease during the follicular phase (Frank et al., 2014), while it increases during the luteal phase (Arnoni-Bauer et al., 2017; Buffenstein et al., 1995). This increase is often accompanied by stronger cravings for sugary, salty, and high-fat foods (Gorczyca et al., 2016; Souza et al., 2018).

Effect of the menstrual cycle on REE has also been the subject of studies. According to the results of a meta-analysis study, it was stated that the luteal phase showed a notable rise in REE (Benton et al., 2020). The reason for the increase in REE through the luteal phase is explained by the increase in progesterone level. Progesterone functions as a metabolic stimulant by acting directly on the thermoregulatory center in the hypothalamus (Davidsen et al., 2007). When the increase in REE and food intake in the luteal phase is evaluated together, it is also necessary to take into consideration body weight and body composition analysis. However, body weight and body composition did not significantly alter across periods (Cumberledge et al., 2018; Thompson et al., 2021; Türkoğlu & Pekcan, 2013).

As a result, although there is an increase in REE in the luteal phase, there may also be an increase in food intake and food preferences because of progesterone. This may stimulate the development of eating behavior disorders in susceptible patients, resulting in long-term weight gain. The goal of this study was to assess the participants' REE, nutrient intake, food preferences, mindful eating and body composition in the follicular and luteal phase with a holistic approach. In this way, it is aimed to raise awareness of the risk of obesity due to hormonal changes during the menstrual cycle and to reduce the prevalence of obesity, which is among the health targets in the Twelfth Development Plan.

The following hypotheses form the basis of our study:

H1: Participants' resting energy expenditure is higher in the luteal phase than in the follicular phase.

H2: Participants' energy intake is higher in the luteal phase.

H3: Participants' dietary energy, carbohydrate and fat intake is higher in the luteal phase.

H4: Participants' tendency to consume fatty foods and sugary foods is higher in the luteal phase.

H5: Participants' Mindful Eating Scale score is higher in the follicular phase.

H6: There is no significant difference between the luteal phase and the follicular phase in terms of body weight, waist circumference measurement and body composition.

Method

This research was planned as a descriptive cross-sectional study. The study included women aged 18-45 years, who had a stable menstrual cycle for a minimum of six months (22-32 days) and had normal body mass index (BMI) according to the World Health Organization classification (BMI: 18.5-24.9 kg/m^2). The mean menstrual cycle duration is 28 days. However, this period may vary due to individual differences. In 82% of women, the period takes between 22-32 days (Patricio & Sergio, 2019). In addition, since a menstrual cycle duration of less than 21 days is defined as polymenorrhea and a duration of more than 35 days is defined as oligomenorrhea (Reed & Carr, 2015), the regular menstrual cycle criterion for this study was determined as 22-32 days.

The exclusion criteria were as follows:

- Hormonal contraception and corticosteroid therapy
- Diagnosis of disease that affects eating habits
- Use of medications that affect appetite
- Following an energy restricted diet
- Pregnancy and breastfeeding

When the power analysis was performed with 95% power and 5% margin of error using data from a similar study evaluating the effect of the menstrual cycle on energy balance in Chinese women (effect size = 0.75), the number of samples of 26 was found sufficient (Elliott et al., 2015). A total of 63 participants were included in this study, but since follicular or luteal phase measurements could not be performed in some of the participants, the study was completed with 58 participants. Study data was collected between December 2022 and February 2024. Students and academic staff from the Gazi University faculty of health sciences participated in the study.

Study Design

A structured questionnaire was used to collect data on the general characteristics of the participants. The questionnaire includes questions about general information, health information, lifestyle and dietary habits, and the short form of the International Physical Activity Questionnaire (IPAQ). There are four distinct sections and seven questions in the IPAQ-short form. The number of days in the past week and the duration of each for walking, moderate, and intense physical activity were determined. Each activity duration should be at least 10 minutes. The last question asks about the daily free time (sitting, lying, etc.) activities. The heavy physical activity value was determined as 8 metabolic equivalents (METs), moderate physical activity as 4 METs, and walking as 3.3 METs (Arabacı & Çankaya, 2007). One metabolic equivalent (MET) is defined as the amount of oxygen consumption while sitting at rest and equal to 3.5 ml O_2 per kg body weight x min (Jetté et al., 1990). For each activity, the MET value is multiplied by the number of physically active days and duration (minute). The total score is obtained by summing up the values for heavy, moderate physical activity and walking. If the calculated value was <600 MET/min/week, the physical activity level was classified as sedentary, between 600-3000 MET/min/week, it was classified as minimally active, and if >3000 MET/min/week, it was classified as active (Arabacı & Çankaya, 2007).

Menstrual cycle phases were calculated for each participant. Since menstrual cycle length varies among women, the total duration for each cycle was considered 100%. The first day of menstrual bleeding is expressed as 0%, and the last day before the next menstrual bleeding is expressed as 100%. Considering that ovulation corresponds to approximately 50%, the calculation was made to represent 25-49% follicular phase and 51-100% luteal phase (Elliott et al., 2015). The determination of phases for a participant with a mean menstrual cycle duration of 28 days was summarized in Figure 1. Participants were invited for REE, body weight and body composition analysis in both the follicular and luteal phases. Also, nutrient intake and food preferences were evaluated, and Mindful Eating Scale was applied in both phases.

Evaluation of Resting Energy Expenditure

Cosmed Fitmate Pro device was used to measure REE. Fitmate is an indirect calorimeter used in clinical settings. Its validity has been shown by studies (Nieman et al., 2006; Vandarakis et al., 2012). REE was performed separately in both phases. Conditions for measurement was fasting for at least 10 hours, not using stimulants such as cigarettes, alcohol, caffeine, or medication until 4 hours ago, and not performing any physical activity until at least 12 hours ago (Nieman et al., 2006). Measurement was started after the individuals rested in a supine position for 20 minutes. The measurement took a total of 15 minutes in a quiet environment, with the room temperature at 20-25°C. For adaptation, the first 5 minutes of the measurement was neglected, and the middle 5-minute test value of the next 10 minutes was used.

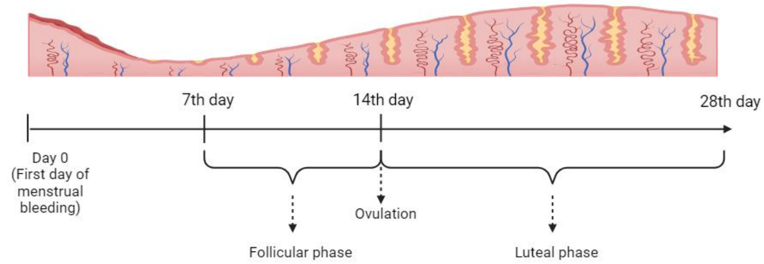

Figure 1.

Representation of Menstrual Cycle Phases on the Timeline

Evaluation of Nutrient Intake and Food Preferences

Food consumption records were taken from the participants in both phases, two days on weekdays and one day on the weekend. "Nutrition Information Systems Package Program (BEBİS)" was used to examine the energy and nutrient consumption. Dietary reference intake (DRI) levels were used for comparison with daily requirements for macro and micro nutrients (NIH, 2001).

In the luteal and follicular phases, high-protein/low-fat foods (low-fat/fat-free dairy products, grilled or baked chicken and fish, lean red meat), high-protein/high-fat foods (steak, fried chicken, fried fish, whole dairy products), high fat foods (hamburgers, pizza, French fries, chips, nuts, some sauces such as mayonnaise), starchy foods (bread, rice, pasta, boiled potatoes) and sugary foods (cake, cookies, cake, ice cream, desserts, sugary snacks, chocolate, sugary drinks) were evaluated with a visual analog scale (Harvey et al., 1993). Participants were asked to number their desires for the specified foods from 1 (indicating "not at all") to 10 (indicating "extremely"). Visual analog scale is used to obtain numeric data on variables that cannot be measured numerically. Visual analog scale is a reliable and easily applicable test that has been used for a long time (Hayzaran, 2018). There have been previous studies using visual analog scales to assess food cravings (Harris et al., 2023; Ledoux et al., 2013).

Mindful Eating Scale

Mindful Eating Scale is a measurement tool developed by Framson et al. in 2009 (Framson et al., 2009). The scale consists of 7 sub-scales such as disinhibition, emotional eating, eating control, focus, eating discipline, awareness and interference. The scale's validity and reliability in Türkiye were investigated by Köse and colleagues in 2016 (Köse et al., 2016). In the study, the Mindful Eating Scale was applied to participants in both phases.

Evaluation of Body Composition

Body composition analysis was also performed on the same day that participants' REE were measured. Tanita BC 418 device was used for body weight and body composition evaluation. Bioelectrical impedance analysis (BIA) is utilized to determine lean tissue mass and total body water in individuals without fluid-electrolyte imbalance. Because the equipment is portable and safe, the process is easy and non-invasive, and the results are quick and repeatable, body composition analysis carried out under appropriate conditions is considered valid and reliable (Kyle et al., 2004a).

It is advised to fast and no alcohol for at least eight hours and refrain from physical activity for eight hours prior to body composition analysis (Kyle et al., 2004b). These recommendations have already been provided prior to REE measurement. Furthermore, precautions were taken to guarantee that no metal jewelry was present and participants has voided before measurement (Kyle et al., 2004b). Since the body composition analysis was repeated, care was also taken to perform measurements at the same time of day and under the same environmental conditions. Height measurement was made with a stadiometer in accordance with the recommendations (Pekcan, 2008). Analysis of participants' body weight and body composition was repeated in both phases.

Statistical Analysis

The SPSS (IBM SPSS Corp., Armonk, NY, USA) 22.0 software was used to evaluate the data using proper statistical techniques. Number (n), percentage (%), arithmetic mean ($\bar{x}$), standard deviation (SD), median, and IQR (interquartile range) are all used to express descriptive values. The Kolmogorov-Smirnov/Shapiro-Wilk tests were used to analyze the variables' suitability for normal distribution. Paired Samples t-test or Wilcoxon Signed Ranks test was used in comparisons of REE, energy and nutrient intake, body weight and body composition analysis values, Mindful Eating Scale score and food preference scores between the luteal phase and follicular phase. Pearson correlation analysis was used to evaluate the relationship between food preference and BMI. The significance level for hypothesis testing was determined as $p < .05$.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Gazi University (Date: November 08, 2022, Decision Number: 2022 – 1161). Written consent was obtained from all the participants.

Results

The mean age of the participants was 23.2±3.72 years. Since most of the participants were university students, the education level of 75.9% of the participants was high school. According to physical activity level, only 20.7% of participants were recorded as active. According to menstrual cycle characteristics, the mean duration between menstrual cycles of the participants was 27.4±2.71 days, and the mean menstrual bleeding duration was 5.9±1.27 days. Socio-demographic, health information and menstrual cycle characteristics of the subjects were given in Table 1.

Table 1.

Socio-demographic, Health Information and Menstrual Cycle Characteristics of the Subjects

Variables	n	%
Age (year)		
$\bar{x}$±SD	23.2±3.72	
Median (IQR)	22.0 (2.0)	
Education status		
High school	44	75.9
Bachelor's degree	5	8.6
Postgraduate	9	15.5
Working status		
Yes	9	15.5
No	49	84.5
Chronic disease		
Yes	10	17.2
No	48	82.8
Smoking		
Yes	11	19.0
No	47	81.0
Alcohol		
Yes	15	25.9
No	43	74.1
Supplement use		
Yes	9	15.5
No	49	84.5
Physical activity level		
Sedentary	8	13.8
Minimal active	38	65.5
Active	12	20.7
Duration between menstrual cycles (days)		
$\bar{x}$±SD	27.4±2.71	
Median (IQR)	28.0 (4.0)	
Menstrual bleeding duration (days)		
$\bar{x}$±SD	5.9±1.27	
Median (IQR)	6.0 (2.0)	

IQR= Interquartile range; SD= Standard deviation

The mean, standard deviation and median (IQR) values of the anthropometric measurements, REE and Mindful Eating Scale in the follicular and luteal phases were given in Table 2. The follicular and luteal phases did not significantly differ in terms of body weight and body composition ($p > .05$). Similarly, there was no significant difference in Mindful Eating Scale total score ($p = .057$). Only the mean score from the "Disinhibition" sub-scale was significantly higher in the luteal phase ($p = .004$). In addition, oxygen consumption (VO_2-ml/dk), mean ventilation rate (Ve-l/dk) and REE (kcal) were significantly higher in the luteal phase ($p < .05$). No significant difference was found between the physical activity groups in terms of REE in the follicular and luteal phases ($p < .05$).

Table 2.

The Descriptive Values of the Anthropometric Measurements, Resting Energy Expenditure and Mindful Eating Scale in Both Phases

Anthropometric measurements	Follicular Phase		Luteal Phase		p
	$\bar{x}$±SD	Median (IQR)	$\bar{x}$±SD	Median (IQR)	
Body weight (kg)	57.7±6.60	58.6 (9.20)	57.7±6.63	58.3 (9.48)	.577*
Body fat percentage (%)	24.0±5.62	24.2 (6.50)	23.9±5.67	24.1 (6.45)	.445*
Body fat mass (kg)	14.2±4.59	13.7 (5.07)	14.1±4.61	14.0 (5.78)	.542*
Fat-free mass (kg)	43.5±2.72	43.6 (3.50)	43.6±2.69	43.6 (3.65)	.309*
Muscle mass (kg)	41.3±2.59	41.4 (3.30)	41.4±2.56	41.4 (3.45)	.330*
Body water percentage (%)	52.6±4.81	52.9 (4.28)	53.2±3.52	53.1 (3.92)	.375†
Mindful Eating Scale					
Total score	89.0±13.85	84.0 (19.0)	93.5±14.87	93.5 (20.0)	.057†
Disinhibition	13.9±4.21	14.0 (6.25)	15.4±4.54	15.0 (6.25)	**.004***
Emotional eating	14.4±4.95	14.0 (7.0)	15.6±6.39	16.0 (7.0)	.420†
Eating control	11.2±3.75	10.0 (5.25)	11.8±4.00	12.0 (7.0)	.090†
Focusing	17.5±2.77	17.0 (3.25)	18.1±4.65	18.0 (3.25)	.621†
Eating discipline	12.8±2.50	13.0 (4.0)	12.7±2.52	12.5 (4.0)	.850*
Mindfulness	13.6±2.78	13.0 (3.25)	14.1±2.80	14.0 (3.25)	.110*
Interference	5.6±2.14	5.5 (3.0)	5.7±1.88	5.0 (3.0)	.544†
Indirect calorimetric measurement					
VO_2 (Oxygen consumption-ml/dk)	195.8±24.29	197.0 (32.50)	201.1±22.33	200.5 (32.75)	**.037***
Ve (Mean ventilation rate-l/dk)	6.4±1.18	6.3 (1.33)	6.7±0.96	6.7 (1.55)	**.012†**
REE (Resting energy expenditure-kcal)	1363.4±169.76	1374.5 (224.75)	1400.5±155.71	1393.5 (232.0)	**.038***
Classification of REE based on physical activity level					
REE (kcal)-sedentary	1049.0±67.88	1049.0 (-)	1294.0±45.25	1294.0 (-)	.201*
REE (kcal)-moderately active	1360.6±155.29	1364.0 (216.50)	1362.5±156.68	1353.5 (175.75)	.927*
REE (kcal)-active	1454.0±134.41	1401.0 (183.0)	1430.4±124.22	1372.0 (191.0)	.536*

IQR= Interquartile range; SD= Standard deviation

*Paired samples t-test

†Wilcoxon signed ranks test

Statistically significant p values were written in bold ($p < .05$)

The participants' food preferences assessed using an analog visual scale and their correlation with BMI were given in Table 3. Although the desire for high-fat foods and sugary foods tended to increase more than other food groups in the luteal phase, there was no significant difference between the phases ($p > .05$). When the relationship between food preference and BMI was evaluated, a positive relationship was found between BMI and sugary food preference in the luteal phase (r=0.404; $p = .020$) a negative relationship was found between BMI and starchy foods in the follicular phase (r=-0.350; $p = .046$).

The mean, standard deviation and median (IQR) values of the nutrient intake in the follicular and luteal phases were given in Table 4. Regarding energy and nutrient intake, there was no significant difference between the phases. ($p > .05$). However, although no significant difference was found, energy intake in the luteal phase is approximately 200 kcal higher than in the follicular phase for sedentary participants. When the percentages of meeting nutrient requirements according to DRI were evaluated, it was noted that at least 50% of the requirements for all nutrients were met (estimated average requirement (EAR) level). However, in both phases, the percentage of dietary fat is above the recommended range (>35%).

Table 3.

The Descriptive Values of the Participants' Food Preferences and Their Correlation with BMI in Both Phases

Food groups	Follicular phase		Luteal phase		*p*
	x̄±SD	Median (IQR)	x̄±SD	Median (IQR)	
High protein/low fat foods	17.2±7.71	19.0 (13.0)	18.2±7.43	19.0 (12.0)	.435*
High protein/high fat foods	25.7±10.71	24.0 (14.0)	26.3±9.80	24.0 (15.75)	.573†
High fat foods	30.6±12.56	28.0 (19.0)	32.4±12.32	32.5 (16.25)	.198†
Starchy foods	19.2±8.07	17.5 (11.50)	18.9±7.54	18.5 (10.25)	.656†
Sugary foods	34.8±10.95	35.0 (16.0)	36.9±12.59	37.5 (18.25)	.119†
Correlation between BMI and food preferences	**Follicular phase**		**Luteal phase**		
	r	p‡	r	p‡	
High protein/low fat foods	-0.130	.470	-0.212	.236	
High protein/high fat foods	0.096	.593	-0.010	.956	
High fat foods	-0.086	.633	0.068	.706	
Starchy foods	**-0.350**	**.046**	-0.109	.545	
Sugary foods	0.137	.448	**0.404**	**.020**	

IQR= Interquartile range; SD= Standard deviation; BMI: Body mass index
*Wilcoxon signed ranks test
†Paired samples t-test
‡Pearson correlation analysis

Discussion

This study, completed with a total of 58 participants, aimed to assess the participants' REE, nutrient intake, food preferences, mindful eating and body composition in the follicular and luteal phase with a holistic approach. The major findings from the study were briefly summarized: Participants had significantly higher REE in the luteal phase than in the follicular phase (p = .038). There was no significant difference between measurements of body weight and body composition analysis, nutrient intakes and food preferences in both phases. However, mean score of Disinhibition subscale of Mindful Eating Scale was noticeably higher during the luteal period (p = .004).

Estrogen is important in regulating energy metabolism as well as regulating reproductive function. Estrogen achieves this effect by reducing food intake and promoting the thermogenesis of brown adipose tissue (Xu & López, 2018). Possible mechanisms for the effect of estrogen on food intake are: widespread estrogen receptors in the ventromedial nucleus, arcuate nucleus, and paraventricular nucleus of the hypothalamus, which stimulate a reduction in food intake; increasing leptin and insulin sensitivity (Frank et al., 2014); increasing the effect of cholecystokinin (Asarian & Geary, 1999); and weakening the effects of orexigenic peptides such as ghrelin and neuropeptide Y (Santollo & Eckel, 2008). On the contrary, progesterone increases storage of triglycerides and hence adipose tissue in the body. This may cause a decrease in plasma free fatty acid levels and an increase in the intake of high-fat foods (Buffenstein et al., 1995). In addition, rising progesterone levels may stimulate the endogenous opioid control system and increase the release of opioid peptides, which can, in turn, lead to greater consumption of high-fat foods (Buffenstein et al., 1995). Therefore, during the menstrual cycle, a decrease in food intake is expected in the follicular phase, when estrogen levels are high, and an increase in food intake is expected in the luteal phase, when progesterone levels are higher than estrogen.

Table 4.

The Descriptive Values of the Nutrient Intake in Both Phases

Nutrients	Follicular phase			Luteal phase			p[†]
	x̄±SD	Median (IQR)	DRI (%)	x̄±SD	Median (IQR)	DRI (%)	
[*]Energy (kcal/day) (Sedentary)	1659.0±512.0	1560.1 (764.64)	86.0	1842.3±737.64	1831.9 (991.17)	95.3	.779
[*]Energy (kcal/day) (Moderately active)	1633.6±499.13	1582.5 (742.11)	73.4	1560.2±590.52	1581.0 (654.08)	70.3	.141
[*]Energy (kcal/day) (Active)	1704.0±531.91	1898.7 (856.18)	69.4	1729.5±529.36	1723.7 (909.23)	69.8	1.000
Protein (g)	62.7±22.92	64.0 (22.10)	136.2	61.5±22.28	56.2 (25.30)	133.7	.443
Protein (%)	15.9±3.90	15.5 (4.25)	Rec.: 10-35%	16.0±3.84	15.5 (4.0)	Rec.: 10-35%	.593
Dietary fat (%)	38.6±6.74	39.0 (7.50)	Rec.: 20-35%	38.5±5.32	39.0 (6.25)	Rec.: 20-35%	.932
Carbohydrate (%)	45.4±7.27	45.0 (8.0)	Rec.: 45-65%	45.6±6.00	45.5 (8.0)	Rec.: 45-65%	.850
Dietary fiber (g)	18.3±5.69	18.1 (8.06)	73.1	18.3±7.59	17.5 (7.88)	73.0	.355
Antioxidant content (mmol)	1.9±1.53	1.6 (1.21)	-	2.7±5.50	1.7 (1.26)	-	.487
Vitamin A (mcg)	929.8±784.24	810.9 (590.25)	132.8	827.1±513.44	697.3 (533.36)	118.1	.220
Vitamin E (mg)	16.1±8.89	14.5 (11.09)	107.2	14.5±7.35	14.3 (8.95)	96.9	.214
Thiamine (mg)	0.8±0.28	0.8 (0.30)	77.5	0.8±0.29	0.8 (0.31)	74.0	.165
Riboflavin (mg)	1.3±0.50	1.2 (0.44)	114.8	1.2±0.39	1.1 (0.46)	108.1	.796
Niacin (mg)	13.0±5.78	12.3 (6.20)	92.7	13.0±6.28	12.2 (5.76)	93.0	.757
Folic acid (mcg)	264.3±104.46	254.8 (116.96)	66.1	253.2±93.31	247.8 (121.78)	63.3	.477
Vitamin B_{12} (mcg)	4.1±3.04	3.5 (2.95)	171.3	3.7±2.00	3.3 (2.87)	154.8	.477
Vitamin C (mg)	98.3±58.35	87.0 (69.74)	131.0	90.8±49.77	86.5 (66.76)	121.1	.334
Potassium (mg)	2221.9±668.15	2304.4 (882.51)	85.4	2244.9±780.41	2142.8 (1048.12)	86.3	.965
Calcium (mg)	592.3±233.07	582.2 (195.40)	59.2	569.0±208.94	536.6 (225.21)	56.9	.359
Magnesium (mg)	237.4±74.49	235.8 (93.21)	76.1	239.3±87.36	226.5 (79.79)	76.7	.766
Phosphorus (mg)	1033.6±340.22	977.6 (419.56)	147.6	985.1±332.06	947.2 (362.06)	140.7	.380
Iron (mg)	9.3±2.99	9.0 (4.14)	51.9	9.5±3.31	9.2 (4.19)	52.7	.911
Zinc (mg)	8.8±3.56	8.0 (3.31)	110.2	8.6±3.28	7.9 (3.86)	107.0	.378

Rec.=Recommendation, DRI= Dietary reference intake; IQR= Interquartile range; SD= Standard deviation

[*] The Harris-Benedict equations revised by Roza and Shizgal in 1984 was used to determine energy requirements (using mean age, body weight, and height). For inactive participants, the physical activity level (PAL) was chosen as 1.4, for moderately active participants, as 1.6, and for active participants, as 1.8.

[†]Wilcoxon signed ranks test (Paired samples t-Test was used only for comparisons of carbohydrate and fat percentage)

There are studies in the literature that evaluate the effects of hormonal changes in the menstrual cycle phases on energy and nutrient intake and present different results (Chung et al., 2010; Hızlı Güldemir et al., 2020; Ihalainen et al., 2021; Kammoun et al., 2017; McNeil & Doucet, 2012). In a study, the effect of different periods of the menstrual cycle on food intake was evaluated in 58 women with regular menstrual cycles between the ages of 18-45 years, it was found that energy, carbohydrate, protein and dietary fat intake was significantly increased in the ovulatory and luteal phase (Kammoun et al., 2017). In another study, total energy intake (+160 kcal/day) and protein intake (+6-8 g/day) were found to be significantly higher in the luteal phase and ovulation phase (Chung et al., 2010). Other studies have also reported that energy and nutrient intake consistently increases in the luteal phase of the menstrual cycle (McNeil & Doucet, 2012; Nowak et al., 2020). However, while some studies suggest that hormonal fluctuations during the phases of the menstrual cycle may influence food and nutrient intake, others report no significant effect (Hızlı Güldemir et al., 2020; Ihalainen et al., 2021). Energy and nutrient intake did not significantly differ between the phases in our study. Only for sedentary participants, energy intake in the luteal phase is approximately 200 kcal higher than in the follicular phase. The progesterone level slowing down stomach emptying (Tutar et al., 2023) or providing early satiety (Coquoz et al., 2022) may be the cause of the lack of a significant difference in energy and nutrient intake levels between the phases. However, it was found that the mean score of the "Disinhibition" sub-scale is noticeably higher in the luteal phase (p = .004). If the Disinhibition subscale of the Mindful Eating Scale is high, it generally means that the individual is more prone to overeating or impulsive eating in response to external cues, emotions, or stress, rather than eating in response to true physical hunger. There is a positive correlation between impulsivity and uncontrolled eating, and this situation can be associated with weight gain and obesity (Garcia-Garcia et al., 2022).

The menstrual cycle may also affect food preferences. Most of women experience changes in their eating habits during the menstrual cycle, especially an increase in the intake of sugary and salty foods (Gorczyca et al., 2016). According to the results a prospective cohort study (The BioCycle Study), in contrast to other phases, the late luteal phase was shown to have a much higher appetite and desire for chocolate, sugary and salty foods (Gorczyca et al., 2016). Similarly, in another study evaluating food preferences between phases, it was shown that low fat/high protein and high fat/high complex carbohydrate foods were more strongly desired in the late luteal phase, according to a non-significant trend (McVay et al., 2012). The fact that simple sugars stimulate serotonin synthesis and lessen the negative symptoms of the menstrual cycle may be the explanation of the rise in carbohydrate intake during the luteal phase (Murakami et al., 2008). Therefore, experiencing positive mood after consuming sugary foods may create an expectation against the intake of sugary foods (Lazarevich et al., 2016). Additionally, an increase in impulsivity and irritability symptoms may be observed during the luteal phase. An increase in these symptoms may also increase the desire for sugary foods (Yen et al., 2018). Although no significant results were found between phases in terms of desire for various food groups in our study, desire for high-fat foods and sugary foods tended to increase more than other food groups in the luteal phase. Also, a positive relationship was found between BMI and sugary food preference in the luteal phase (r=0.404; p = .020). In a study evaluating the relationship between food craving behavior and body mass index and body composition in reproductive age females it was found that participants will exhibit greater intensity of the food craving behavior as their body mass index and body fat increase (Chaudhari & Huerta-Franco, 2017). Stressful-event scenarios can promote activation of brain motivation-reward regions as well as food craving in obese individuals (Jastreboff et al., 2013). In a vicious cycle, consuming craving foods can also create addiction and lead to obesity. Like addictive substances, highly processed foods (high concentrations of refined carbohydrates and fat) can trigger reward-related neuronal systems. More significantly, highly processed foods are linked to the behavioral markers of addiction, which include a loss of control over intake and intense food cravings (Gearhardt & Hebebrand, 2021).

In addition to the effect of the menstrual cycle on food intake and eating habits, it also influences REE. Based on a meta-analysis study findings, an increase in REE in the luteal phase was reported (p < .001) (Benton et al., 2020). Similarly, in our study, mean oxygen consumption, mean ventilation rate and REE were noticeably higher in the luteal phase (p < .05). The reason for the increase in REE that occurs in the luteal phase is explained by the increase in progesterone level. Progesterone acts as a metabolic stimulant by directly affecting the thermoregulatory center in the hypothalamus (Davidsen et al., 2007).

Conclusion and Recommendations

In conclusion, the study major findings indicate that REE was significantly higher in the luteal phase, likely due to the increase in progesterone, which stimulates metabolic processes. However, there were no significant differences in body weight, body composition, nutrient intake, or food preferences between the two phases. Despite this, food cravings, particularly for high-fat and sugary foods, showed a tendency to increase during the luteal phase. Additionally, the Disinhibition subscale of the Mindful Eating Scale was significantly higher in the luteal phase, suggesting that women may be more prone to impulsive eating behaviors during this phase. Given the increased disinhibition observed during the luteal phase, it is recommended that women engage in mindful eating practices, particularly during this phase of the menstrual cycle. Techniques such as eating slowly, paying attention to hunger cues, and reducing emotional eating may help mitigate impulsive eating behaviors and food cravings.

Overall, the results of this study contribute to a better understanding of how hormonal fluctuations during the menstrual cycle may influence food intake, food preferences, and eating behavior. It highlights the complex interaction between hormonal changes, mindful eating, and food cravings, which could have important implications for managing eating habits and weight. However, one of the limitations of this study is that smoking was not included as an exclusion criterion. Additionally, the limited sample size reduces the generalizability of the results which may restrict the applicability of the findings to a broader population. Future studies should be conducted to explore the relationship between menstrual cycle phases, mindful eating, and food preferences in larger and more diverse populations. It would be valuable to investigate how different dietary patterns, or psychological factors may mediate the effects of hormonal fluctuations on eating behavior.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Gazi University (Date: November 08, 2022, Decision Number: 2022 – 1161).
Informed Consent: Written consent was obtained from all the participants.
Peer-review: Externally peer-reviewed.
Author Contributions: Concept-B.A., Y.A.; Design-B.A., Y.A.; Supervision-B.A., Y.A.; Data Collection and/or Processing- B.A., E.B.A., M.K., V.Ş.T.; Analysis and/or Interpretation- B.A., E.B.A., M.K., V.Ş.T.; Literature Search- B.A., E.B.A., M.K., V.Ş.T.; Writing Manuscript- B.A., E.B.A., M.K., V.Ş.T.; Critical Review- B.A., Y.A.
Conflict of Interest: The authors have no conflicts of interest to declare.
Financial Disclosure: This work was supported by Tübitak 2209-A-Research Project Support Program for undergraduate Students (Application number 1919B012207210).

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