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Original article

Chronotype is associated with REEs in obese children and adolescents

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Summary. The aim of the present study was to evaluate the association between chronotype and resting energy expenditure (REE) in obese children&adolescents. Obese children&adolescents (57 males,46 females) between 7 and 17 years were recruited. REE measurements of subjects were made with indirect-calorimetry (COSMED, FitMatePro, Rome, Italy). The chronotype was assessed with Turkish validated Children's ChronoType Questionnaire (CCTQ). According to this; morningness/eveningness scale (M/E) score was calculated and classified as ≤23=morningness, 24-32=intermediate and ≥33=eveningness form. Body compositions were analyzed and physical activity levels (PALs) were determined by record.Chronotypes of the participants were determined that 17.5% of them were morningness form, 36.9% were intermediate form and 45.6% were eveningness form. There was no statistical difference in chronotypes according to genders, ages and pubertal status ($p>0.05$). It was found out that participants in eveningness chronotype have lower REE values (1294.6±321.81 kcal/d) than morningness (1849.8±483.21 kcal/d) and intermediate (1617.9±331.10 kcal/d) chronotypes ($p<0.05$). It was noted that participants with eveningness chronotype had lower energy expenditure for physical activity (morningness:2746.5±1037.05 kcal/d, intermediate:2266.8±723.66kcal/d and eveningness:1871.4±752.75 kcal/d) as well as total energy expenditure ($p<0.05$). However, there was no statistically significant difference in PALs according to chronotypes($p<0.05$). There was not a statistically significant difference between BMI-z scores, waist to height ratios and other anthropometric measurements ($p>0.05$). It was determined that the REEs and energy expenditures for physical activity which were the main contributors to total energy expenditures of the individuals who were in the eveningness forms were the lowest. Changes in REEs according to chronotypes of obese children&adolescents, especially in eveningness chronotypes may be a novel contributor for obesity&its outcomes.

Keywords: Chronotype, childhood obesity, adolescents, resting energy expenditure, indirect calorimeter

Introduction

Obesity is one of the most important health problems in developed and developing countries in recent years (1). The prevalence of obesity is increasing not only in adults but also in children and adolescents. While the prevalence of childhood obesity was 4.2% worldwide in 1990, it increased to 6.7% in 2010 and this rate is estimated to be 9.1% in 2020 (2). The increasing prevalence of obesity in childhood causes many serious obesity-related comorbidities at early ages which constitutes a major burden on the health system (3,4).Therefore, determining the factors contributing to the development of obesity is of great importance in terms of public health (5).

Energy balance plays an important role in the development of obesity. Positive energy balance due to excessive energy intake and/or changes in total energy expenditure (TEE) causes obesity (6). TEE is comprised of multiple components such as resting energy expenditure (REE), thermic effect of foods and physical activity (7). Basal metabolic rate (BMR), which constitutes 60-70% of daily energy expenditure, is the largest component of TEE (6).Therefore, every factor that affects the resting energy expenditure can affect body weight significantly (8).

Sleep and circadian rhythms are the key components in the regulation of energy metabolism (9). Circadian rhythm refers to changes in the physiological and biological processes of organisms in about one (10). Studies have shown that sleep duration, quality and circadian system play an important role in metabolic regulation and make individuals prone to obesity and metabolic diseases (11-14). The sleep-wake cycle depends on the interaction of circadian and homeostatic processes. The timing of sleep-wake rhythms may vary from person to person (15). Circadian preferences (chronotypes) of individuals are usually classified in three types including morningness, intermediate and eveningness(16). It is reported that normal circadian rhythms, regulated by the biological clock gene, are important for health and that deteriorations in the circadian system cause changes in metabolic hormone secretion and eating behaviours(14,16).

Inconsistency between social and environmental factors (social jet lag) usually causes circadian deviations (14). Some studies report that evening chronotype is correlated with obesity and obesity indicators and late circadian preferences associate with increased body mass indexes and unhealthy eating habits of individuals and decrease their physical activity levels, sleep durations and quality (14,17,18).

It is reported that short sleep duration and poor sleep quality trigger childhood obesity occurrence; however, sleep time preferences of children and adolescents may also be an important risk factor (19,20). Although it is emphasized that biological and behavioural processes are the mechanisms to explain this correlation, chronotypes of children and adolescents and obesity occurrence and the explanatory mechanisms in such occurrence are still unclear in the literature.

The aim of the present study was to evaluate theassociationbetweenchronotype and REE in obese children & adolescents.

Materials and Methods

Samples

A total of 103 (57 males and 46 females) obese child and adolescent volunteers aged between 7 and 17 years were recruited in the study. The inclusion criteria was obesity (body mass index [BMI] for age z-score≥2) defined according to the World Health Organization (WHO) growth references for 5 to 19 years (21). The participants who have any chronic disease and use any drug and substance (alcohol and cigarettes) were not included in this study. Ethical approval was obtained from the Gazi University Ethic Committee (Number 77082166-604.01.02-11769). Clear explanations were provided for the parents with regard to the purpose of the study, after which written informed consent was obtained from parents in accordance with the Declaration of Helsinki.

Evaluation of General Characteristics

A face-to-face questionnaire form was applied to record several sociodemographic characteristics, sleep durations and habits (for school days and free days) of participants.

Tanner stage of each participant was determined by a paediatrician on the basis of breast stage and pubic hair development in females and genitalia development in males. Tanner stages of the children ranged from 1 to 5 (22,23).

Evaluation of Chronotypes

Children's Chronotype Questionnaire (CCTQ) including 27 items in Turkish was filled out by the participants. This questionnaire was developed as an adaptation of the Munich Chronotype Questionnaire (MCTQ) (24) and the Morningness/Eveningness Scale for Children (MESC) (25). The Turkish version of CCTQ was found to be valid and reliable in Turkish children by Dursun et al. (26), and Cronbach's alpha of Turkish CCTQ was 0.653. This questionnaire consists of 16 items on sleep/wake parameters for the school says and free days, a 10 item M/E scale and a single-item chronotype (CT) (26). The CT score was a single item measure which parents reported their child's chronotype (27).

In this study, morningness/eveningness scale

(M/E) score was calculated to classify chronotypes. The questions between 17 and 26 were used to calculate the score. Answers of these questions were scored from 1 to 5. However, scores of some items (questions 17, 18, 24 and 25) are reversed. Total M/E score was calculated by adding the answers of 10 questions. It provides a range of 10 to 48 points. The total score was classified as follows: ≤23= morningness, 24–32= intermediate and ≥33= eveningness form.

Evaluation of Physical Activity Level

Daily physical activity record form was used to determine physical activity level (PAL) and TEE of individuals. Physical activity of individuals was recorded at 15 minutes intervals. Records were taken simultaneously with questionnaires and all measurements.

Physical activity record was a procedure suitable to estimate energy expenditure in population studies (28).The form gave information regarding activity type, level and duration. Activity duration was multiplied with physical activity ratio (PAR), and results were added together in order to get total PAR. And then, total PAR values were multiplied with the values after dividing REE to a total number of minutes per day (1440 minutes) to get TEE. In addition, TEE was divided into measured REE values for the determination of PAL (29).

Anthropometric Measurements and Body Composition Analysis

Anthropometric measurements and body composition analysis were performed by trained dietitians in the early morning with at least 8 h. Body weight measurement and body composition analysis (fat mass, percentage of fat, fat-free mass, skeletal muscle mass) were made by using the InBody 720 (1–1000 kHz; InBody Co., Ltd. Korea). InBody is one the of bioelectrical impedance analyzers (BIA) with multiple frequencies. It is reported that the InBody analyzers produce a small error, which suggests these methods can be used as a surrogate when dual-energy X-ray absorptiometry (DXA) is not available (30).

Height was measured (cm) with feet close together and the head in Frankfort plane with a portable stadiometer with 0.1-cm. Waist circumference was measured with the subject standing, midway between the last rib and the upper edge of the iliac crest, and hip circumference was measured at the greater gluteal curvature. Both measurements were taken with a non-elastic tape, to the closest 0.1cm. Waist to height ratios of participants was calculated after the measurements.

Resting Energy Expenditure Measurements (REE)

REE measurements were made by using indirect calorimetry (COSMED, FitMatePro, Rome, Italy). Measurements were made between 8.00 am and 10.00 am in the morning after at least 8 h of fasting. The individuals were asked to follow their regular diet and not to do heavy exercises one day before REE measurement. A sterile mask that completely covers the mouth and nose was used to determine average oxygen consumption (VO_2; mL/min). Additionally, this measurement also gave information regarding the average ventilation (Ve, L/min), the average respiratory frequency (Rf, L/min), the average oxygen concentration in the exhaled air (FeO_2, %). Subjects were measured in a supine position in a quiet, thermo-neutral (22–24^{0}C) environment while resting in an immobile state.

Statistical Analysis

All statistical analyses were performed using SPSS (The Statistical Package for Social Sciences) Version 20.0 (SPSS Inc., Chicago, IL, USA). Counts, percentage (%), and mean ± standard deviation ($\bar{x}$ ±SD) values were given for measures variables. For the evaluation of general chronotype frequencies according to genders, age groups and pubertal status, the chi-squared (χ^2) test was used. Suitability of the data to the normal distribution was analyzed using visual (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk tests). One Way Anova and Kruskall-Wallis Variance Analysis tests were used for the comparison of physical activity values and general characteristics according to chronotypes and REE and anthropometric measurements. Dunn-Bonferroni post hoc tests were carried out on each pair of chronotype groups. $p<0.05$ was determined as the level of significance for all of the analyses.

Results

Table 1 shows the distribution of chronotypes according to some characteristics of participants. The chronotype evaluation showed that 17.5% of participants were in morningness form, 36.9% in intermediate form and 45.6 in eveningness form. There was not a statistically significant difference among females' and males' morningness form (19.6% vs. 15.8%, respectively), intermediate form (37.0% vs. 36.8%, respectively) and eveningness form (43.5% vs. 47.4%, respectively ($p>0.05$). No statistically significant difference was found among ages 7–10 years and 11–17 years morningness form (17.3% vs. 17.6%, respectively), intermediate form (36.5% vs. 37.3%, respectively), and eveningness form (46.2% vs. 45.1%, respectively ($p>0.05$). According to the evaluation of the chronotypes of participants based on their pubertal status, no statistical differences were also found in pubertal status ($p>0.05$) (Table 1).

Table 2 shows sleep characteristics and anthropometric measurements according to the chronotypes of the participants. The participants in the morningness, intermediate, and eveningness forms had 21.6±1.02, 27.6±2.80, and 38.5±3.71 M/E scores, respectively ($p<0.05$).

The average sleep durations (h/d) of the participants for school days in morningness, intermediate, and evening forms were 9.2±1.09, 9.2±1.00, and 7.9±1.29, respectively. For free days, sleep durations (h/d) in the morningness, intermediate, and evening forms were 9.7±0.77, 9.7±0.83, and 9.1±0.88, respectively. The difference in sleep durations for school and free days according to chronotypes was statistically significant ($p<0.05$) (Table 2).

According to the evaluation of anthropometric measurements and body compositions of participants on the basis of their chronotypes, BMI-z-scores of participants in morningness, intermediate and eveningness forms were found to be 3.3±0.87, 3.1±0.90 and 3.0±0.76, respectively ($p>0.05$) and body fat mass (kg) of participants were 25.0±10.17 kg, 21.9±8.26 kg and 20.3±7.39 kg, respectively ($p>0.05$) (Table 2). Fat-free mass (kg) of individuals in three forms were found to be 47.3±13.94 kg, 44.4±10.34 and 42.9±8.86 kg, respectively ($p>0.05$) According to the evaluations, waist circumferences of participants in morningness form (98.5±13.70 cm) were higher than that of participants in an intermediate form (93.1±10.22 cm) and eveningness form (93.2±9.38 cm); however, the difference was not statistically significant ($p>0.05$). Also, there was not a statistically significant difference between waist-height ratios according to chronotypes ($p>0.05$) (Table 2).

REE measurements of the participants showed that average REE values of females were 1465.5±305.57

Table 1. Evaluation of chronotypes according to some characteristics of participants

	Chronotypes						
	Morningness		Intermediate		Eveningness		
	n	%	n	%	n	%	p-value
Gender							
Male (n=46)	9	15.8	21	36.8	27	47.4	p>0.05
Female (n=57)	9	19.6	17	37.0	20	43.5	
Age							
7- 10 years (n=52)	9	17.3	19	36.5	24	46.2	p>0.05
11-17 years (n=51)	9	17.6	19	37.3	23	45.1	
Pubertal status							
Tanner stage 1 (n=36)	7	19.4	10	27.8	19	52.8	p>0.05
Tanner stage 2 (n=17)	2	11.8	8	47.1	7	41.2	
Tanner stage 3 (n=17)	2	11.8	8	47.1	7	41.2	
Tanner stage 4 (n=16)	3	18.8	7	43.8	6	37.5	
Tanner stage 5 (n=17)	4	23.5	5	29.4	8	47.1	
Total	18	17.5	38	36.9	47	45.6	

kcal/d, while that of males were 1547.6±484.00 kcal/d (data not shown in the tables).

REE measurements according to chronotypes are shown in Table 3. REE measurements of participants in morningness, intermediate and eveningness forms were 1849.8±483.21 kcal/d, 1617.9±331.10 kcal/d and 1294.6±321.81 kcal/d, respectively. The difference among REE values (kcal/d) according to chronotypes was statistically significant ($p<0.05$). VO_2 values (mL/min) of participants in morningness, intermediate and eveningness forms were found to be 263.1±71.49, 231.8±48.21 and 188.4±46.99, respectively ($p<0.05$). Moreover, Ve (L/min) values of participants in morningness, intermediate and eveningness forms were 8.7±2.92, 7.2±2.00 and 5.9±1.73, respectively ($p<0.05$). There was not a statistically significant difference between Rf (L/min) and FeO_2 (%) values of participants according to chronotypes ($p>0.05$) (Table 3).

Table 2. Sleep characteristics and anthropometric measurements of participants according to their chronotypes

		Chronotypes			
		Morningness (n =18)	Intermediate (n =38)	Eveningness (n =47)	
Variables	**Total (n=103)**	**x̄ ± SD**	**x̄ ± SD**	**x̄ ± SD**	**p-value**
Age (years)	10.6±2.19	10.8±2.64	10.7±2.14	10.6±2.09	p>0.05
M/E score	31.5±7.39	21.6±1.02[a]	27.6±2.80[b]	38.5±3.71[c]	p<0.05*
Sleep duration (h)					
School days	8.6±1.32	9.2±1.09[a]	9.2±1.00[b]	7.9±1.29[c]	p<0.05*
Free days	9.4±0.88	9.7±0.77[a]	9.7±0.83[b]	9.1±0.88[c]	p<0.05*
Anthropometric measurements					
BMI (z score)**	3.1±0.83	3.3±0.87	3.1±0.90	3.0±0.76	p>0.05
Fat Mass (kg)	21.7±8.33	25.0±10.17	21.9±8.26	20.3±7.39	p>0.05
Fat Percentage (%)	31.7±6.14	33.8±7.66	31.5±6.26	31.0±5.31	p>0.05
Fat-Free Mass (kg)	44.2±10.45	47.3±13.94	44.4±10.34	42.9±8.86	p>0.05
Skeletal Muscle Mass (kg)	41.2±9.09	44.4±11.86	40.7±8.31	40.3±8.40	p>0.05
Waist Circumference (cm)	94.1±10.63	98.5±13.70	93.1±10.22	93.2±9.38	p>0.05
Waist/height ratio	0.6±0.05	0.6±0.06	0.6±0.05	0.6±0.04	p>0.05

* Differences between chronotype groups were statistically significant ($p < 0.05$).**BMI: body mass index, h:hours
Different letters indicated statistically significant differences between chronotype groups for multiple comparisons by Dunn-Bonferroni post hoc tests.

Table 3. REE measurements of participants according to their chronotypes

	Total (n = 103)	Chronotypes			
		Morningness (n =18)	Intermediate (n =38)	Eveningness (n =47)	
REE Measurements**	**x̄ ± SD**	**x̄ ± SD**	**x̄ ± SD**	**x̄ ± SD**	**p-value**
Measured REE (kcal/d)	1510.9±414.11	1849.8±483.21	1617.9±331.10	1294.6±321.81	p<0.05*
VO_2 (mL/min)	217.5±59.37	263.1±71.49[a]	231.8±48.21[a]	188.4±46.99[b]	p<0.05*
Ve (L/min)	6.9±2.30	8.7±2.92[a]	7.2±2.00[a]	5.9±1.73[b]	p<0.05*
Rf (L/min)	19.8±3.65	19.3±3.15	19.6±3.50	20.1±3.97	p>0.05
FeO_2 (%)	16.7±0.73	16.9±0.79[a]	16.6±0.63[b]	16.7±0.78[b]	p>0.05

* Differences between chronotype groups were statistically significant ($p<0.05$).**Average oxygen consumption (VO_2), the average ventilation (Ve), the average respiratory frequency (Rf), the average oxygen concentration in the exhaled air (FeO_2)
[a,b]Different letters indicated statistically significant differences between chronotype groups for multiple comparisons by Dunn-Bonferroni post hoc tests.

Table 4 shows major components of daily total energy expenditure; REE, energy expenditures for physical activity and PAL values of participants. Energy expenditures for physical activity of the participants with morningness, intermediate and eveningness chronotypes were 2746.5±1037.05 kcal/d, 2266.8±723.66kcal/d and 1871.4±752.75 kcal/d, respectively (p<0.05). However, PAL values of the participants in morningness, intermediate and eveningness forms were found to be 2.6±0.41, 2.4±0.40 and 2.4±0.42, respectively and the difference was not statistically significant. TEEs of participants in morningness, intermediate and eveningness forms were 4454.8±1315.3 kcal/d, 3817.3±938.01 kcal/d and 3170.3±1001.37 kcal/d, respectively (p<0.05) (Table 4).

Discussion

This study was planned and conducted to evaluate the association between chronotype and energy expenditure in obese children and adolescents**.** To the best of our knowledge, this study was the first to examine these effects in groups of obese children and adolescents.

One of the most important findings of this study is that eveningness chronotype is more frequently observed in obese children and adolescents than other chronotypes (Table 1). A large number of studies exist on the correlation between sleep pattern and obesity risk (19,20,31,32). Accumulated literature showed a modest inverse or U-shaped association between sleep duration and risk of childhood obesity (31,32). Beyond sleep duration, sleep time patterns may contribute to obesity risk. The chronotype with sleep timing patterns is referred to as "morningness/eveningness" preference, which reflects an individual's standing on a continuum between two extremes (33). Today, the sleep patterns of young adults, adolescents, and children contain less sleep duration due to environmental, psychosocial, and biological factors in the evenings and at nights (34,35). Therefore, biological circadian rhythms generally show a tendency to late sleep and late wake-up times, in other words, "late chronotype" (34,35). However, it is well known that the eveningness form in young ages adversely affects general health conditions, physical and mental health, and academic success (36). Moreover, pieces of evidence show that nowadays early-bird or night-owl chronotypes are related to increased obesity risk independently (20). Studies have shown that the evening chronotype is correlated with higher BMI and more unhealthy nutritional behaviours in adolescents (14,37). However, the number of studies examining this correlation in children is quite limited (20). The present study proved that the eveningness form is more common in obese children and adolescents and provided an insight into the gap in the literature.

The results showed that obese children and adolescents in the eveningness form were sleepless for both school and free days than those in morningness and intermediate forms (Table 2). Sleep time and duration are generally independent of each other. However, when separated according to working and free days, sleep durations are usually dependent on chronotypes and independent from gender (38).

Table 4. Evaluation of major components of daily energy expenditures and PAL values of the participants according to their chronotypes

		Chronotypes			
	Total (n = 103)	**Morningness (n =18)**	**Intermediate (n =38)**	**Eveningness (n =47)**	
Energy Expenditure Parameters**	**x̄ ± SD**	**x̄ ± SD**	**x̄ ± SD**	**x̄ ± SD**	**p-value**
Measured REE (kcal/d)	1510.9±414.11	1849.8±483.21	1617.9±331.10	1294.6±321.81	p<0.05*
Energy expenditure for physical activity (kcal/d)	2157.8±849.29	2746.5±1037.05[a]	2266.8±723.66[a]	1871.4±752.75[b]	p<0.05*
TEE (kcal/d)	3616.4±1131.79	4454.8±1315.3[a]	3817.3±938.01[a]	3170.3±1001.37[b]	p<0.05*
PAL value	2.4±0.41	2.6±0.41	2.4±0.40	2.4±0.42	p>0.05

* Differences between chronotype groups were statistically significant (p<0.05). **PAL: Physical Activity Level, TEE: Total Energy Expenditure. [a,b] Different letters indicated statistically significant differences between chronotype groups for multiple comparisons by Dunn-Bonferroni post hoc tests.

The chronotypes of obese children and adolescents did not show any difference between genders (Table 1). Several studies have been conducted on different age groups and have proven the correlation between chronotypes and genders (39,40). A study showed gender differences in chronotypes, and the men presented a more pronounced eveningness preference in university students (39). Other study showed that menopause is especially a strong predictor of the morningness form rather than age. Another study demonstrated that women are more morning-oriented than men until 30 years, gender-based chronotypes show the important difference in the range of 30–45 years, and the ontogeny of chronotype is different in men and women after 45 years (40). The reason why this study could not determine the chronotype differences between genders may be the fact that the study consisted of children and adolescents.

The study could not find any difference among anthropometric measurements according to chronotypes (Table 2). It is reported that the eveningness chronotype is correlated with high BMI and more unhealthy dietary behaviours in adolescents, and the number of studies finding this correlation in children is inadequate (34). In a cross-sectional study conducted with young adolescents (11–13 years) in the United Kingdom, a later chronotype was found to be correlated with the risk of increased BMI, poorer dietary behaviours, and short sleep duration is an independent risk factor for BMI rather than sleep quality (14). Other study reported that identifying the relationship between social jet lag and BMI, as well as chronotype, and health-related behaviours in adolescents is a chronobiological approach to preventing obesity (41). Another study showed that social jet lag is correlated with BMI z-scores and waist-to-height ratio in adolescents of 14–17 years, and night sleep duration is not correlated with waist-to-height ratios and BMI z-scores in a school period when social jet lag is adjusted. Moreover, a study found that morningness/eveningness forms do not moderate sleep duration and BMI z-scores (41). Futher study reported that evening preference is correlated with increased BMI in adults with type 2 diabetes, and late breakfast time mediates the correlation between morningness-eveningness preference and BMI (42). In a study conducted on adolescents, adjustment of bedtimes regulates choices/preferences of breakfast, which is one of the most important meals in the prevention of obesity (43). The participants consisting of obese individuals (BMI for age z-score≥2) may be the reason why no correlation could be found between chronotypes and anthropometric measurements in the present study. Especially in obese individuals with short sleep duration, the eveningness chronotype is correlated with increased BMI, resting heart rate, portion size and changes in dietary behaviours, more frequent sleep apnea, and increased stress hormones (5). Within this scope, it is considered that prevention of eveningness chronotype form in obese individuals including our study group may be an important step in reducing obesity-related complications.

The most prominent finding of this study is that obese children and adolescents have different REEs according to their chronotypes; those in the eveningness form have the lowest REE values (Table 3). In the literature, the correlation between sleep and REE has not been sufficiently characterized especially in children and adolescents (31). Studies have generally been conducted on individuals in different age groups and with sleep disorders such as obstructive sleep apnea syndrome (OSAS) and sleep-disordered breathing and focused on sleep parameters such as sleep duration and quality (31,44,45). A study evaluated the correlation between sleep and REE in obese adults and found that poor sleep quality causes increase in the REE level by scaling up serum cortisol and norepinephrine levels (31). Moreover, a study determined that adults who are in the eveningness form and sleep less than 6.5 h a day have more 24 h urinary epinephrine and morning plasma adrenocorticotropic hormone (ACTH) levels (5).

Abnormal sleep/wake patterns may change the circulation levels of some nutrients such as glucose, fatty acids, and triglyceride and some hormones such as insulin, glucocorticoid, and adipokines. These changes may affect obesity prognosis by causing metabolic changes primarily in adipocytes (46). This study showed that there are REE differences/changes among participants sleeping for almost 9 h a day (adequate) as one of the factors affecting obesity prognosis in childhood/adolescence.

Pubertal development was associated with a shift toward later chronotypes (47). REE was also significantly greater in the pubertal group than among those in the prepubertal group (48,49). In contrast to the literature, no differences were found between chronotype forms regarding pubertal status (Table 1). Thus, the findings of lower REE in evening types could not be arisen due to confounding by pubertal status in the present study.

Evaluating the physical activities of participants is one of the most important factors related to TEE. Interestingly, a difference between physical activity levels was not found. However, the study found that the participants with an eveningness chronotype had lower energy expenditure for physical activities and TEEs than other chronotypes (Table 4). Studies in the literature demonstrate that adolescents with a later chronotype are less physically active than those with an earlier chronotype (41, 50). Similarly, the participants with an eveningness chronotype have more unhealthy habits and physical inactivity levels for adults (51,52). In this study, the lack of significant difference between physical activity levels of morningness and eveningness chronotypes may be caused by the fact that all participants took part in the study in the same period (school time) and/or have the same school works. In addition, self-reported physical activity records were used to evaluate the physical activity levels of the participants. Further studies should use methods that do not include personal statements.

This study showed that the REEs of obese children and adolescents were changed according to chronotypes for both genders.The REEs and energy expenditures for physical activities, which were the main contributors of TEEs of the individuals who were in the eveningness forms, were the lowest. Besides, sleep durations were the lowest for eveningness chronotypes. The mechanisms through which poor sleep patterns or chronotypes affect REE and/or energy expenditure parameters or their effect on obesity risk and prognosis in children and adolescents are controversial. After a clear observation of REE, physical activity and TEE decrease in obese children and adolescents in this study, which suggests that this may be one of the obesity mechanisms. However, it is necessary to conduct prospective studies to thoroughly evaluate how obesity prognosis is affected. Additionally, this study emphasizes the necessity of considering chronotypes, an indicator of biological rhythm, in the calculation of energy requirements to design nutritional programs and special diets for obese children and adolescents.

This study has strengths and limitations. Measurement of REE by indirect calorimetry provided an individual objective evaluation. However, the evaluations based on personal statements may have caused bias or inconsistent results like all studies. Moreover, this study was not designed to be performed on obese and non-obese participants, and it was aimed to evaluate the effect of chronotype in obese participants only. In this context, it may also be useful to examine the effect of chronotypes on REE in non-obese individuals in future studies. Dietary intake and 24 h fuel (nutrients) use can be also be considered in future studies.

Conflict of Interest

No potential conflict of interest relevant to this article was reported by the authors

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