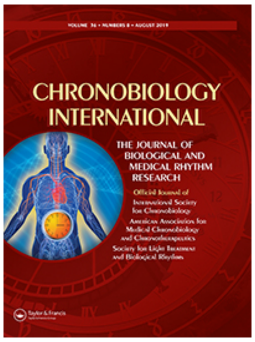

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The relationship between chronotype and obesity in children and adolescent with attention deficit hyperactivity disorder

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ABSTRACT
Children and adolescents with Attention Deficit Hyperactivity Disorder (ADHD) have a high prevalence of obesity, but the relationship between these two problems is not clear. Chronotype preferences may be one of the possible mechanisms underlying the link between ADHD and obesity. This is the first study to investigate whether chronotype preferences are a mechanism linking ADHD symptoms to obesity in children and adolescents. This cross-sectional study included 110 drug-naive children and adolescents aged 7–17 years with ADHD. The Kiddie Schedule for Affective Disorders and Schizophrenia-Present and Lifetime Version (K-SADS-PL) was used to diagnose ADHD or to exclude psychiatric comorbidity. The Conners' Parents Rating Scale-Revised Short Version (CPRS-RS) and Children's Chronotype Questionnaire (CCQ) were used to assess the severity of ADHD symptoms and chronotype preferences. Body mass index (BMI) was calculated and classified according to national age- and gender-specific reference values. The participants were divided into three groups as normal weight (<85%, n = 38), overweight (85%-95%, n = 30) and obesity (>95%, n = 42) according to their BMI percentile. There were statistically significant differences between the three groups in terms of chronotype preference (p = .000). Morningness preference was 86.84% in the normal BMI group and 26.19% in the obese BMI group. Eveningness preference was 7.89% in the normal BMI group and 61.90% in the obese BMI group. There was a correlation between the BMI percentile scores and the morningness/eveningness scale (M/E) scores. Moreover, there was a correlation between the BMI percentile scores and the oppositional and ADHD index scores. According to logistic regression analysis, the odds ratio of having evening type for obesity was 5.66 and the odds ratio of having morning type for normal weight was 13.03. Independently from ADHD symptoms, eveningness was directly related to obesity and morningness was directly related to normal weight. Prospective studies should be performed to better understand the relationship between ADHD, overweight/obesity and chronotype.

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chronotype; obesity; attention deficit hyperactivity disorder; child/adolescent

Introduction

Attention Deficit Hyperactivity Disorder (ADHD)

ADHD is one of the most common neurodevelopmental disorders in childhood. Worldwide, it ranges from 5.3% to 7.1% in school-age children. It is characterized by developmentally inappropriate levels of inattention, hyperactivity, and impulsivity (Polanczyk et al. 2007). 65% of childhood-onset cases continues into adulthood (Faraone et al. 2006). Due to its characteristic symptoms and related conditions/disorders, ADHD creates a difficult situation for the society in terms of psychological dysfunction, social and financial costs, vocational outcomes, and familial stress (Doshi et al. 2012). ADHD shows prominent heterogeneity in clinical, etiological and pathophysiological aspects similar to all complicated medical and psychiatric disorders. Although the comorbidity between ADHD and psychiatric disorders was widely investigated, its relationship with somatic problems was less pronounced (Biederman 2005). In recent years, however, there has been strong evidence demonstrating that there is a relationship between neuropsychiatric disorders and medical problems. Especially, the relationship between ADHD and obesity has been focused. The idea of this potential linkage is of great importance for public health because of the rising risk of obesity and serious diseases associated with obesity (including diabetes, cardiovascular disease and cancer) (Ng et al. 2014).

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Obesity

Obesity is a major growing health problem in children and adolescents. It has serious and risky consequences for morbidity and mortality such as sleep apnea, diabetes mellitus, hyperlipidemia, hypertension, and cancer. In addition to medical problems, obesity causes psychosocial problems such as stigmatization and psychiatric disorders (Daniels et al. 2005). Evidence also suggests that childhood obesity can predict adulthood obesity (Must 2003). The Global Burden of Disease Study 2017 (GBD 2017), coordinated by the Institute for Health Metrics and Evaluation (IHME), has recently estimated that obesity includes approximately 110 million children and adolescents (Collaborators 2017). Obesity is a complex multifactorial chronic disease affected by both genetic and environmental factors. Previous research focused on the environmental risks associated with dietary intake and lifestyle (e.g., physical inactivity). However, coexisting psychological symptoms and disorders including ADHD may play an important role in obesity (Cortese et al. 2015). Recent research has revealed a link between ADHD and obesity. Several studies have demonsrated that childhood and adulthood obesity is associated with childhood ADHD (Cortese et al. 2013). Similarly, a recent study has shown that children with ADHD had higher BMI scores than children without ADHD and that stimulant medications reduced early childhood BMI rise; however, this reduction was not protective for obesity in the longer term (Schwartz et al. 2014). Fuemmeler et al. reported that both inattention and hyperactive–impulsive symptoms were associated with the prevalence of obesity in individuals with ADHD (Fuemmeler et al. 2011).

Chronotype

Humans show cyclical rhythmicity in a variety of cognitive, psychological, physiological, behavioral, and hormonal processes. This cyclic structure called circadian rhythm is affected by exogenous and endogenous factors. It also changes many processes such as mood, cognition, sleep-wake cycles, hormone levels, and temperature. Chronotype can be defined as a trait determining individual circadian preference in rhythm relative to external light/dark cycles (Adan et al. 2012; Dursun et al. 2015; Nielsen 2010; Selvi et al. 2007; Wirz-Justice 2003). Chronotypes can generally be grouped into three types as morning, intermediate, and evening types. These types vary according to physical and mental activities, usual meal times, sleep times, waking times, performance, mood, alertness, and appetite. Individuals with morningness go to sleep earlier at night, wake up earlier, and have a relatively stable sleep rhythm than individuals with eveningness. Individuals with morningness prefer starting their daily physical and mental activities earlier and are more productive in the early hours of day. Individuals with eveningness show opposite characteristics in all of the specified fields. Intermediate types exhibit both morningness/eveningness characteristics (Selvi et al. 2017). Study investigating the link between chronotypes and personality traits have reported that eveningness-type individuals become more outward-looking, have lower levels of avoidance behaviours, take more risks, tend to be more impulsive, and have high-sensation seeking personalities in contrast to morningness- and intermediate-type individuals (Díaz-Morales 2007).

Chronotype and ADHD

One of the strongest and most consistent data reported in the studies showing the relationship between ADHD and chronotype preference is that there was a correlation between eveningness and ADHD symptoms (Vogel et al. 2015). There is a bidirectional relationship between evening types and ADHD. In addition to ADHD, disruptive and impulsive behaviors are more common in eveningness-type individuals (Imeraj et al. 2012). Many recent studies have demonsrated that there are associations between eveningness and irregular sleep-wake rhythm, worse sleep quality, sleep problems (such as difficulty going to sleep), delayed sleep onset, daytime sleepiness, tiredness in children and adolescents with ADHD (Durmuş et al. 2017; Van der Heijden et al. 2005). In addition, several studies on eating behaviors and circadian preferences reported that individuals with eveningness had worse control over feeding than individuals with morningness. This evidence suggests that not falling asleep and staying up late at night can lead to excessive intake of foods (Schmidt and Randler 2010; Selvi et al. 2017). Sleep problems and hyperactivity/impulsivity appear to mediate the relationship between chronotype preference and feeding. Chronotype preferences (especially evening type) may be a component linking ADHD symptoms to obesity/overweight. In rhythm disturbances (especially evening type), this relationship indicates that sleep disorders and inappropriate eating patterns may lead to obesity in children and adolescents with ADHD in the long term (Arble et al. 2010; McClung 2013; O'reardon et al. 2004).

Chronotype and obesity

The mechanisms of the relationship between obesity and chronotype are not completely understood in children and adolescents, but the current data highlight that sleep deprivation/restriction, levels of physical activity, and meal timing/habits in relation to chronotype may explain this connection (Arora and Taheri 2015; Schaal et al. 2010). Some studies have shown that eveningness is significantly linked to obesity when compared to morningness (Culnan et al. 2013; Lucassen et al. 2013; Yu et al. 2015). In a broad sample of children, several authors have demonstrated that sleep restriction is significantly associated with increased central adiposity determined by waist circumference (Chaput and Tremblay 2007). Similarly, other authors have showed that eveningness is associated with higher body mass index (BMI) z-scores and unhealthy eating patterns (Arora and Taheri 2015; Lucassen et al. 2013). Eveningness has been associated with poor dietary control, larger portion, high total calorie/cholesterol intake, late-night eating, and a tendency to skip/omit breakfast in relation to unhealthy eating patterns (Mota et al. 2016; Nakade et al. 2009). It has been also revealed that eveningness is significantly associated with lower levels of physical activity and sedentary lifestyles when compared to morningness (Wennman et al. 2015). Interestingly, adult studies have indicated that bariatric surgery is less effective in evening-type patients than in morning-type patients and that evening-type patients lose less weight than morning-type patients after obesity surgery due to both eating habits and physical activity (Ruiz-Lozano et al. 2016).

In the light of these data, it can be said that both circadian system and ADHD can affect sleep–wake cycles, feeding and impulsivite and may cause obesity after a certain period of time. The relationship between chronotype preference, obesity, and ADHD has not been studied in children and adolescents as far as we know. The aim of this study was to investigate the associations between ADHD symptoms, BMI percentiles/obesity, and circadian rhythm differences in children and adolescents with ADHD.

Materials and methods

Subjects and study design

This cross-sectional study included 110 drug-naive children and adolescents aged 7–17 years with ADHD. It was conducted in the Department of Child and Adolescent Psychiatry at Selcuk University in Turkey. It was approved by the Local Ethics Committee of Selcuk University. Children and adolescents with ADHD who agreed to participate were included in the study. Those with comorbid psychiatric disorders (e,g., neurodevelopmental disorders, psychosis, depression, generalized anxiety disorder, substance abuse), genetic or neurological disorders (e.g., epilepsy), endocrinological or allergic diseases, and chronic systemic diseases were excluded from the study. While 4 parents rejected to participate in the study, 39 children were excluded from the study based on the exclusion/inclusion criteria. All participants were evaluated for psychiatric disorders by the Kiddie Schedule for Affective Disorders and Schizophrenia-Present and Lifetime Version (K-SADS-PL). The Sociodemographic Data Collection Form, Conners' Parents Rating Scale-Revised Short Version (CPRS-RS) and Children's Chronotype Questionnaire (CCQ) were administered to them. Body mass index (BMI) was objectively calculated for each participant by dividing weight in kilograms (kg) by height in square meters (m^2) and classified according to national age- and gender-specific reference values. Considering scientific standards, obesity was defined as ≥95th percentile BMI while overweight was defined as ≥ 85th to ≤ 94th percentile.

Kiddie schedule for affective disorders and schizophrenia-present and lifetime version (K-SADS-PL)

It was used to screen for psychopathology in the participants. It is a semi-structured interview used for children and adolescents aged between 6 and 18 years and was prepared according to DSM-III and DSM-IV diagnostic criteria (Kaufman et al. 1997). It contains subheadings such as affective disorders, psychotic disorders, anxiety disorders, externalizing disorders, alcohol/substance abuse, and eating and tic disorders. It was translated and adapted into Turkish in 2004 by Gokler et al. who conducted the validity and reliability study of the Turkish version of the scale (Gökler et al. 2004). In this scale, psychopathologies are examined by combining the data obtained from children/adolescents and their parents by child and adolescent psychiatrists. If there is any conflict or inconsistency between different sources, the physician's decision is based on clinical evaluation. It assesses both current and past psychopathology.

Children's chronotype questionnaire (CCQ)

It was developed to investigate sleep problems/habits of children by Owens et al and consists of 33 items (Owens et al. 2000). It is the commonly used assessment questionnaire to define circadian rhythm differences. It is a parent-report, 27-item mixed-format questionnaire resulting in multiple measures of chronotype in children: the midsleep point on free days (MSF), a morningness/eveningness scale (M/E) score, and a five-point chronotype (CT) score. It consists of 16 items on sleep/wake parameters (e.g., bedtime, lightsoff time, sleep latency, wake-up time, get-up time, fully alert time, regular naps) for scheduled days and free days, 10 Likert-type questions (range, 10–48) and a single item on chronotypes. Three different measures of children's chronotypes are as follows: morningness type, intermediate type and eveningness type, which are classified using an M/E scale score of ≤23, 24–32, and ≥33. Dursun et al. conducted reliability and validity studies of the Turkish form (Dursun et al. 2015). Turkish CCQ provided internal consistency with a Cronbach's alpha of 0.653. After the factor analysis was performed, it was decided that the scale would be included in evaluations as a whole (single factor).

Conners' parents rating scale-revised short version (CPRS-RS)

It is the most useful and popular rating scale for ADHD domains. Conners et al. revised this scale (Conners et al. 1998). It contains 27 items and was translated and adapted for Turkish children by Kaner et al. The Turkish version of the scale was found to be reliable, valid, and appropriate for clinical purpose and research (Kaner et al. 2013). Each item is answered to on a 4-point Likert-type scale by parents (0 = never, 1 = rarely, 2 = often, and 3 = always). There are four subscales including oppositional (6 items), cognitive problem/inattention (6 items), hyperactivity (6 items) and ADHD index (12 items). The Cronbach's alpha coefficient of the scale was determined to be between 0.73 and 0.86. It shows high test–retest reliability (between 0.56 and 0.72).

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows Version 22.0 (SPSS Inc; Chicago, IL, USA). Descriptive statistics were used to describe the demographic and clinical characteristics of the participants. For normally distributed variables, ANOVA and Tukey's post hoc test were used to analyze differences between groups according to chronotype preference. For non-normally distributed variables, the Kruskal-Wallis test was used to analyze differences between groups according to chronotype preference. The relationships between psychological test scores and clinical variables were evaluated using the Pearson and Spearman correlation coefficients. The predictors of BMI percentile score/obesity such as age, gender, ADHD symptom severity, and chronotype preference were determined using logistic regression analysis. A p-value less than 0.05 was considered statistically significant.

Results

The total number of participants in the study was 110. The mean age was 10.30 ± 2.44 years (range, 7–17 years). The study group consisted of 78 boys

Table 1. Sociodemographic features.

Participants	Normal BMI Percetiles	Overweight BMI Percetiles	Obese BMI Percetiles	Statistical Analyses
Male Gender	48 (%75)	8 (%66.6)	22 (%64.7)	**p = .533 x^2 = 1.258**
Age	10.42 ± 2.49	10.50 ± 2.81	10.02 ± 2.24	**p = .769 (Kruskal–Wallis test)**
Educational level of the Father				**p = .712 x^2 = 3.739**
Primary school	13	1	3	
Secondary school	9	1	6	
High school	19	5	13	
University	23	5	12	
Educational level of the Mother				**p = .383 x^2 = 6.372**
Primary school	17	4	4	
Secondary school	12	1	9	
High school	17	2	12	
University	18	5	9	
Parents who live together	57	9	29	**p = .418 x^2 = 1.745**
Current psychiatric symptoms of fathers	4	0	2	**p = .318 x^2 = 1.578**
Current psychiatric symptoms of mothers	9	1	4	**p = .457 x^2 = 1.779**
Level of income (per month)				**p = .191 x^2 = 6.118**
Low	10	6	8	
Middle	25	16	30	
High	3	7	3	

(70.9%) and 32 girls (29.10%). The participants were divided into three groups as normal weight (<85%), overweight (85–95%) and obesity (>95%) according to their BMI percentile. There were no statistically significant differences between the three groups in terms of the age, gender, parental educational level, and socioeconomic level. The study group consisted of 61 morning-type patients (55.45%), 13 intermediate-type patients (11.81%) and 36 evening-type patients (32.72%). There were no statistically significant differences between these three groups in terms of age and gender (Table 1).

There were no statistically significant differences between the three groups in terms of the CPRS-RS subscale scores (cognitive problems/inattention, oppositional, hyperactivity, and ADHD index) (Table 2). There were statistically significant differences between the three groups in terms of chronotype preference (*p* = .000) (Table 2). Morningness preference was 86.84% in the normal BMI group and 26.19% in the obese BMI group. Eveningness preference was 7.89% in the normal BMI group and 61.90% in the obese BMI group. There were no statistically significant differences between the three groups in terms of the CCQ-MSF score.

The Spearman correlation coefficient was used to analyze the relationships between the BMI percentile scores and the CPRS-RS subscale scores, the M/E and MSF scores of the CCQ. There was a correlation between the BMI percentile scores and the morningness/eveningness scale (M/E) scores. Moreover, there was a correlation between the BMI percentile scores and the oppositional and

Table 2. CPRS-RS and CCQ according to BMI percentile groups.

Participants	Normal BMI Percetiles	Overweight BMI Percetiles	Obese BMI Percetiles	Statistical Analyses
CCO scores				**p = .000 x^2 = 44.627**
Morningness type	33 (%86.84)	17 (%56.6)	11 (%26.19)	
Intermediate type	2 (%5.26)	6 (%20.0)	5 (%11.90)	
Eviningness type	3 (%7.89)	7 (%23.4)	26 (%61.90)	
MSF	9,17 ± 0.79	9,14 ± 0.74	8,95 ± 0.82	**p = .413 (Kruskal–Wallis test)**
CPRS-RS				**(Kruskal–Wallis test)**
Cognitive problems/inattention	13,53 ± 3.09	14,41 ± 3.02	13,23 ± 4.17	***p* = .667**
Oppositional	9,03 ± 4.22	8,66 ± 4.11	10,76 ± 3.88	**p = .682**
Hyperactivity/Impulsivity	9,15 ± 4.65	9,00 ± 5.51	9,94 ± 4.55	**p = .148**
ADHD Index	25,12 ± 5.36	26,00 ± 4.59	25,94 ± 6.49	**p = .632**

CPRS-RS; Conners' Parents Rating Scale-Revised Short Version.
CCQ; Children's Chronotype Questionnaire
MSF; Midsleep point on free days

ADHD index scores. There was a correlation between the CCQ-MSF times and the oppositional and ADHD index scores. The results of Spearman correlation are presented in Table 3.

Risk factors for obesity (>95th percentile) were evaluated using logistic regression analysis (enter model). According to this analysis, the odds ratio of having evening type for obesity was 5.66 (OR 5.66, Cl 1.91–16.81) and the odds ratio of having morning type for normal weight was 13.03 (OR 13.03, Cl 1.46–116.14) (Table 4).

Table 4. Logistic regression analysis enter model for obesity.

	B	S.E.	Wald	Sig.	Exp(B)	Confidence Interval %95
Age	−161	117	1,897	168	851	677–1,071
Gender	229	597	147	701	1,257	390–4.054
Morningness type	2,567	1,116	5,291	**021**	13,031	1,462–116.148
Eviningness type	1,734	555	9,771	**002**	5,666	1,910–16.811
ADHD Index	−019	045	174	677	982	899–1.071

Discussion

In our study, the participants were divided into three groups according to their BMI percentile and evaluated in terms of BMI percentile and chronotype, and the associations between factors affecting BMI percentile and ADHD symptoms were examined. To our knowledge, this is the first study to investigate the relationship between chronotype preferences and BMI percentiles in children and adolescents with ADHD, which is an important predictor of obesity. The main finding of the present study was that there was a definite link between evening type and obesity. Morningness preference was 86.84% in the normal BMI group and 26.19% in the obese BMI group. Eveningness preference was 7.89% in the normal BMI group and 61.90% in the obese BMI group. In addition to these data, the odds ratio of having evening type for obesity was 5.66 and the odds ratio of having morning type for normal weight was 13.03. These are very powerful data that show the importance of chronotype preference.

ADHD has a high level of heritability indicating a significant genetic component (Matthews et al. 2014). Interestingly, some authors have suggested that sleep/wake behaviour can contribute to the core symptoms of ADHD such as inattention, hyperactivity, impulsivity, and cognitive/behavioral symptoms (Babkoff et al. 1991; Coogan and McGowan 2017). The strongest and most consistent result reported in several studies on ADHD is that there is an association between later chronotype (evening preference) and ADHD symptoms (Baird et al. 2012; Gruber et al. 2012). In our study, the rate of eveningness preference in children and adolescent with ADHD was 32.72%. Studies investigating the link between ADHD and chronotype have demonsrated that increased levels of ADHD symptoms, poorer sustained attention on a continuous performance test, excessive daytime sleepiness/inattention, and unstable timing of days are associated with evening preference in individuals with ADHD (Kooij and Bijlenga 2014; Rybak et al. 2007; Vogel et al. 2015).

In our study, there were no significant differences in ADHD symptoms between the three groups, but there were significant differences in chronotype preferences between the three groups. It may demonsrate that chronotype preference has an independent effect on BMI percentile. Our results may support the argument that evening

Table 3. Spearman product–moment correlation coefficients.

	1	2	3	4	5	6	7
1. O	1.000						
2. C/I	.254**						
3. H/I	.480**	.374**					
4. ADHDI	.346**	.752**	.587**				
5. M/E	.212*	.115	.001	.147			
6. MSF	−.207*	−.157	−.122	-,281**	−.363**		
7. PERC	.247**	.136	.172	.210*	.528**	−.139	1.000

Correlation is significant at the 0.01 level (2-tailed).** Correlation is significant at the 0.05 level (2-tailed).*
MSF; Midsleep point on free days. M/E; Morningness/eveningness scale score. PERC; Percentile Score. ADHDI; ADHD Index Score. O; Oppositional Score. C/I; Cognitive problem/Inattention Score. H/I; Hyperactivity/Impulsivity Score.

preference is a mechanism linking ADHD to obesity. We believe that the fact that the odds ratio of having morning type for normal weight was 13.03 is associated with this condition. Similar to our results, Vogel et al. demonstrated that both inattentive and hyperactive-impulsive symptoms were not directly related to obesity (Vogel et al. 2015). ADHD and circadian rhythm may share a common genetic etiology; however, we believe that their effects on obesity are independent of each other. The circadian rhythm is encoded and regulated at the genetic level by a number of CLOCK genes. CLOCK gene products are controlled by the formation of a series of interlocking transcriptional feedback loops (Zhang et al. 2014). Some genetic studies have shown that there is an association between circadian CLOCK gene polymorphisms and ADHD. Kissling et al., Xu et al. and Jeong et al. have reported that some single nucleotide polymorphisms (SNPs) in CLOCK are associated with ADHD symptoms (Jeong et al. 2014; Kissling et al. 2008; Xu et al. 2010). It has been indicated that individuals with eveningness are characterized as being more outward-looking, high risk-takers, high sensation seekers, independent and having lower levels of avoidance behaviours and perseverance similar to individuals with ADHD (Adan et al. 2010; Ponzi et al. 2014). It has been reported that individuals with eveningness have worse control over feeding, are more likely to skip breakfast and exhibit excessive food consumption (especially at night) (Fleig and Randler 2009; Schmidt and Randler 2010). The nature of both ADHD and evening preference seems to increase the risk of obesity. This may explain that 61.90% of obese individuals with ADHD in our study had eveningness preference.

In our study, the Spearman correlation analysis revealed a significant correlation between the BMI percentile scores and the oppositional and ADHD index scores. In studies investigating the link between ADHD and obesity, the three pathways were hypothesized: (1) obesity/overweight or health conditions associated with obesity/overweight such as sleep-disordered breathing and excessive daytime sleepiness may cause ADHD or increase ADHD symptoms, (2) Common biological dysfunction leads to both ADHD and obesity, and (3) ADHD contributes to obesity (Cortese and Vincenzi 2012). There are data showing that abnormal eating behaviors cause ADHD symptoms. Patients with bulimia nervosa or other abnormal eating behaviors may present with impulsive and repeated intervals of their activities to get food. It has been indicated that abnormal activities and intervals lead to ADHD symptoms, such as inattention, impulsivity, disorganization, and restlessness (Cortese et al. 2007). The other hypothesis, explaining the relationship between obesity and ADHD, can be explained by "hypoarousal theory". According to this theory, sleep-disordered breathing and excessive daytime sleepiness are more common in individuals with obese and therefore obese people can demand more sleep. They may use motor hyperactivity and impulsivity as a strategy to stay awake and alert (Weinberg and Brumback 1990). In relation to this theory, meta-analyses have shown that excessive daytime sleepiness and sleep-disordered breathing are common in patients with ADHD versus controls (Cortese et al. 2009). The association between obesity and excessive daytime sleepiness has been shown in many studies. It is also seen to be independent of sleep-disordered breathing or other sleep disturbances. Vgontzas et al. showed that the main cause of excessive daytime sleepiness in obese individuals was circadian rhythm abnormalities, not sleep-disordered breathing or other sleep disorders (Vgontzas et al. 2006). Many studies have demonstrated that individuals with eveningness represent increasing levels of excessive daytime sleepiness and more irregular sleep-wake habits (Adan et al. 2006; Ong et al. 2007). Therefore, it is inevitable that the risk of obesity increases significantly in children and adolescents with ADHD having evening preference. The other potential link between ADHD and obesity is that two conditions are different expressions of common underlying biological mechanisms. "Reward deficiency syndrome" is thought to underlie the etiology of both ADHD and obesity. Substance use, risk-taking, and inappropriate eating are behaviors related to insufficient dopamine-related natural reinforcement (Comings and Blum 2000; Heiligenstein and Keeling 1995). It has been shown that risk-taking behaviors are frequently seen in patients with circadian rhythm abnormalities (especially evening type) and are considered to underlie the etiology of both ADHD and obesity. The third hypothesis on the link between ADHD and obesity is that behavioral and cognitive deficits of ADHD may show an important effect on inappropriate eating behaviors, which in turn lead to obesity. Davis et al. found that ADHD impulsive behaviors such as deficient inhibitory control and delay aversion were positively correlated with binge-eating and emotion-induced eating (Davis et al. 2006; Lourenço et al. 2008). In contrast to our results, Davis et al. demonsrated that ADHD-related inattention and executive function deficits may cause obesity by disrupting a regular eating pattern (Davis et al. 2006).

Several limitations of the study need to be considered. Firstly, the assessment of chronotype preference was only gathered from subjective parent/self-report forms rather than objective measures (such as actigraphy). Other limitation is that the participants were obtained from outpatient clinics. This sample might not reflect the general population due to biases associated with treatment-seeking samples. Another limitation is that it is cross-sectional rather than longitudinal. Longitudinal studies can clearly demonstrate the relationship between ADHD, circadian preference and obesity.

In summary, we demonstrated that evening preference was directly related to obesity and morning preference was directly related to normal weight independently from ADHD symptoms in children and adolescents with ADHD. Our study also found that hyperactivity/impulsivity and ADHD index which are important for a global view on the severity of ADHD were related to BMI percentile. These findings might explain why at least a subgroup of child and adolescent obese patients might not do well with standard obesity treatment that does not consider sleep-wake cycles and ADHD pathology. We hope that future well-designed prospective studies can better explain the relationship between ADHD, obesity and chronotype.

Conflict of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

References

Adan A, Archer SN, Hidalgo MP, Di Milia L, Natale V, Randler C. 2012. Circadian typology: a comprehensive review. Chronobiol Int. 29:1153–1175.

Adan A, Fabbri M, Natale V, Prat G. 2006. Sleep Beliefs Scale (SBS) and circadian typology. J Sleep Res. 15:125–132.

Adan A, Lachica J, Caci H, Natale V. 2010. Circadian typology and temperament and character personality dimensions. Chronobiol Int. 27:181–193.

Arble DM, Ramsey KM, Bass J, Turek FW. 2010. Circadian disruption and metabolic disease: findings from animal models. Best Pract Res Clin Endocrinol Metab. 24:785–800.

Arora T, Taheri S. 2015. Associations among late chronotype, body mass index and dietary behaviors in young adolescents. Int J Obes. 39:39.

Babkoff H, Caspy T, Hishikawa Y, Mikulincer M. 1991. Subjective sleepiness ratings: the effects of sleep deprivation, circadian rhythmicity and cognitive performance. Sleep. 14:534–539.

Baird A, Coogan A, Siddiqui A, Donev R, Thome J. 2012. Adult attention-deficit hyperactivity disorder is associated with alterations in circadian rhythms at the behavioural, endocrine and molecular levels. Mol Psychiatry. 17:988.

Biederman J. 2005. Attention-deficit/hyperactivity disorder: a selective overview. Biol Psychiatry. 57:1215–1220.

Chaput JP, Tremblay A. 2007. Does short sleep duration favor abdominal adiposity in children? Int J Pediat Obesity. 2:188–191.

Collaborators GO. 2017. Health effects of overweight and obesity in 195 countries over 25 years. N Engl J Med. 377:13–27.

Comings DE, Blum K. 2000. Reward deficiency syndrome: genetic aspects of behavioral disorders. In HBM. Uylings, GG. van Eden, JPC. de Bruin, MGP. Feenstra, CMA. Pennartz (Eds.,), Progress in brain research. Elsevier. 126:3–499.

Conners CK, Sitarenios G, Parker JD, Epstein JN. 1998. The revised Conners' Parent Rating Scale (CPRS-R): factor structure, reliability, and criterion validity. J Abnorm Child Psychol. 26:257–268.

Coogan AN, McGowan NM. 2017. A systematic review of circadian function, chronotype and chronotherapy in attention deficit hyperactivity disorder. ADHD Atten Defic Hyperact Disord. 9:129–147.

Cortese S, Faraone SV, Konofal E, Lecendreux M. 2009. Sleep in children with attention-deficit/hyperactivity disorder: meta-analysis of subjective and objective studies. J Am Acad Child Adolesc Psychiatry. 48:894–908.

Cortese S, Isnard P, Frelut M, Michel G, Quantin L, Guedeney A, Falissard B, Acquaviva E, Dalla Bernardina B, Mouren M. 2007. Association between symptoms of attention-deficit/hyperactivity disorder and bulimic behaviors in a clinical sample of severely obese adolescents. Int J Obes. 31:340.

Cortese S, Moreira-Maia CR, St. Fleur D, Morcillo-Peñalver C, Rohde LA, Faraone SV. 2015. Association

between ADHD and obesity: a systematic review and meta-analysis. Am J Psychiatry. 173:34–43.
Cortese S, Olazagasti MAR, Klein RG, Castellanos FX, Proal E, Mannuzza S. 2013. Obesity in men with childhood ADHD: a 33-year controlled, prospective, follow-up study. Pediatrics.Peds. 131:e1731–e1738.
Cortese S, Vincenzi B. 2012. Obesity and ADHD: clinical and neurobiological implications. Curr Top Behav Neurosci. 9:199–218.
Culnan E, Kloss JD, Grandner M. 2013. A prospective study of weight gain associated with chronotype among college freshmen. Chronobiol Int. 30:682–690.
Daniels SR, Arnett DK, Eckel RH, Gidding SS, Hayman LL, Kumanyika S, Robinson TN, Scott BJ, St. Jeor S, Williams CL. 2005. Overweight in children and adolescents: pathophysiology, consequences, prevention, and treatment. Circulation. 111:1999–2012.
Davis C, Levitan RD, Smith M, Tweed S, Curtis C. 2006. Associations among overeating, overweight, and attention deficit/hyperactivity disorder: a structural equation modelling approach. Eat Behav. 7:266–274.
Díaz-Morales JF. 2007. Morning and evening-types: exploring their personality styles. Pers Individ Dif. 43:769–778.
Doshi JA, Hodgkins P, Kahle J, Sikirica V, Cangelosi MJ, Setyawan J, Erder MH, Neumann PJ. 2012. Economic impact of childhood and adult attention-deficit/hyperactivity disorder in the United States. J Am Acad Child Adolesc Psychiatry. 51(990–1002):e1002.
Durmuş FB, Arman AR, Ayaz AB. 2017. Chronotype and its relationship with sleep disorders in children with attention deficit hyperactivity disorder. Chronobiol Int. 34:886–894.
Dursun OB, Ogutlu H, Esin IS. 2015. Turkish validation and adaptation of children's chronotype questionnaire (CCTQ). Eurasian J Med. 47:56.
Faraone SV, Biederman J, Mick E. 2006. The age-dependent decline of attention deficit hyperactivity disorder: a meta-analysis of follow-up studies. Psychol Med. 36:159–165.
Fleig D, Randler C. 2009. Association between chronotype and diet in adolescents based on food logs. Eat Behav. 10:115–118.
Fuemmeler BF, Østbye T, Yang C, McClernon FJ, Kollins SH. 2011. Association between attention-deficit/hyperactivity disorder symptoms and obesity and hypertension in early adulthood: a population-based study. Int J Obes. 35:852.
Gökler B, Ünal F, Pehlivantürk B, Kültür EÇ, Akdemir D, Taner Y. 2004. Reliability and validity of schedule for affective disorders and schizophrenia for school age children-present and lifetime version-Turkish Version (K-SADS-PL-T). Turk J Child Adolesc Ment Health. 11:109–116.
Gruber R, Fontil L, Bergmame L, Wiebe ST, Amsel R, Frenette S, Carrier J. 2012. Contributions of circadian tendencies and behavioral problems to sleep onset problems of children with ADHD. BMC Psychiatry. 12:212.
Heiligenstein E, Keeling RP. 1995. Presentation of unrecognized attention deficit hyperactivity disorder in college students. J Am Coll Health. 43:226–228.
Imeraj L, Sonuga-Barke E, Antrop I, Roeyers H, Wiersema R, Bal S, Deboutte D. 2012. Altered circadian profiles in attention-deficit/hyperactivity disorder: an integrative review and theoretical framework for future studies. Neurosci Biobehav Rev. 36:1897–1919.
Jeong SH, Yu J-C, Lee CH, Choi K-S, Choi J-E, Kim SH, Joo E-J. 2014. Human CLOCK gene-associated attention deficit hyperactivity disorder-related features in healthy adults: quantitative association study using Wender Utah Rating Scale. Eur Arch Psychiatry Clin Neurosci. 264:71–81.
Kaner S, Buyukozturk S, Iseri E. 2013. Conners parent rating scale-revised short: turkish standardization study/ Conners anababa dereceleme olcegi-yenilenmis kisa: turkiye stardardizasyon calismasi. Arch Neuropsychiatry. 50:100–110.
Kaufman J, Birmaher B, Brent D, Rao U, Flynn C, Moreci P, Williamson D, Ryan N. 1997. Schedule for affective disorders and schizophrenia for school-age children-present and lifetime version (K-SADS-PL): initial reliability and validity data. J Am Acad Child Adolesc Psychiatry. 36:980–988.
Kissling C, Retz W, Wiemann S, Coogan AN, Clement RM, Hünnerkopf R, Conner AC, Freitag CM, Rösler M, Thome J. 2008. A polymorphism at the 3⊠-untranslated region of the CLOCK gene is associated with adult attention-deficit hyperactivity disorder. Am J Med Genet Part B. 147:333–338.
Kooij J, Bijlenga D. 2014. High prevalence of self-reported photophobia in adult ADHD. Front Neurol. 5:256.
Lourenço BH, Arthur T, Rodrigues MD, Guazzelli I, Frazzatto E, Deram S, Nicolau CY, Halpern A, Villares SM. 2008. Binge eating symptoms, diet composition and metabolic characteristics of obese children and adolescents. Appetite. 50:223–230.
Lucassen EA, Zhao X, Rother KI, Mattingly MS, Courville AB, de Jonge L, Csako G, Cizza G, Group SES. 2013. Evening chronotype is associated with changes in eating behavior, more sleep apnea, and increased stress hormones in short sleeping obese individuals. PLoS One. 8:e56519.
Matthews M, Nigg JT, Fair DA. 2014. Attention deficit hyperactivity disorder. Curr Top Behav Neurosci. 16:235–266.
McClung CA. 2013. How might circadian rhythms control mood? Let me count the ways. Biol Psychiatry. 74:242–249.
Mota MC, Waterhouse J, De-Souza DA, Rossato LT, Silva CM, Araújo MBJ, Tufik S, de Mello MT, Crispim CA. 2016. Association between chronotype, food intake and physical activity in medical residents. Chronobiol Int. 33:730–739.
Must A. 2003. Does overweight in childhood have an impact on adult health? Nutr Rev. 61:139.
Nakade M, Takeuchi H, Kurotani M, Harada T. 2009. Effects of meal habits and alcohol/cigarette consumption on morningness-eveningness preference and sleep habits by Japanese female students aged 18–29. J Physiol Anthropol. 28:83–90.

Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, Mullany EC, Biryukov S, Abbafati C, Abera SF. 2014. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. The Lancet. 384:766–781.

Nielsen T. 2010. Nightmares associated with the eveningness chronotype. J Biol Rhythms. 25:53–62.

O'reardon JP, Ringel BL, Dinges DF, Allison KC, Rogers NL, Martino NS, Stunkard AJ. 2004. Circadian eating and sleeping patterns in the night eating syndrome. Obes Res. 12:1789–1796.

Ong JC, Huang JS, Kuo TF, Manber R. 2007. Characteristics of insomniacs with self-reported morning and evening chronotypes. J Clin Sleep Med. 3:289–294.

Owens JA, Spirito A, McGuinn M. 2000. The Children's Sleep Habits Questionnaire (CSHQ): psychometric properties of a survey instrument for school-aged children. Sleep-New York-. 23:1043–1052.

Polanczyk G, De Lima MS, Horta BL, Biederman J, Rohde LA. 2007. The worldwide prevalence of ADHD: a systematic review and metaregression analysis. Am J Psychiatry. 164:942–948.

Ponzi D, Wilson MC, Maestripieri D. 2014. Eveningness is associated with higher risk-taking, independent of sex and personality. Psychol Rep. 115:932–947.

Ruiz-Lozano T, Vidal J, De Hollanda A, Canteras M, Garaulet M, Izquierdo-Pulido M. 2016. Evening chronotype associates with obesity in severely obese subjects: interaction with CLOCK 3111T/C. Int J Obes. 40:1550.

Rybak YE, McNeely HE, Mackenzie BE, Jain UR, Levitan RD. 2007. Seasonality and circadian preference in adult attention-deficit/hyperactivity disorder: clinical and neuropsychological correlates. Compr Psychiatry. 48:562–571.

Schaal S, Peter M, Randler C. 2010. Morningness-eveningness and physical activity in adolescents. Int J Sport Exercise Psychol. 8:147–159.

Schmidt S, Randler C. 2010. Morningness-eveningness and eating disorders in a sample of adolescent girls. J Individ Differ. 31:38–45.

Schwartz BS, Bailey-Davis L, Bandeen-Roche K, Pollak J, Hirsch AG, Nau C, Liu AY, Glass TA. 2014. Attention deficit disorder, stimulant use, and childhood body mass index trajectory. Pediatrics.Peds.133(4):668–676. doi: 10.1542/peds.2013-3427.

Selvi Y, Gulec M, Agargun MY, Besiroglu L. 2007. Mood changes after sleep deprivation in morningness–eveningness chronotypes in healthy individuals. J Sleep Res. 16:241–244.

Selvi Y, Kandeger A, Boysan M, Akbaba N, Sayin AA, Tekinarslan E, Koc BO, Uygur OF, Sar V. 2017. The effects of individual biological rhythm differences on sleep quality, daytime sleepiness, and dissociative experiences. Psychiatry Res. 256:243–248.

Van der Heijden KB, Smits MG, Someren EJV, Boudewijn Gunning W. 2005. Idiopathic chronic sleep onset insomnia in attention-deficit/hyperactivity disorder: a circadian rhythm sleep disorder. Chronobiol Int. 22:559–570.

Vgontzas AN, Bixler EO, Chrousos GP. 2006. Obesity-related sleepiness and fatigue: the role of the stress system and cytokines. Ann N Y Acad Sci. 1083:329–344.

Vogel SW, Bijlenga D, Tanke M, Bron TI, van der Heijden KB, Swaab H, Beekman AT, Kooij JS. 2015. Circadian rhythm disruption as a link between Attention-Deficit/Hyperactivity Disorder and obesity? J Psychosom Res. 79:443–450.

Weinberg WA, Brumback RA. 1990. Primary disorder of vigilance: a novel explanation of inattentiveness, daydreaming, boredom, restlessness, and sleepiness. J Pediatr. 116:720–725.

Wennman H, Kronholm E, Partonen T, Peltonen M, Vasankari T, Borodulin K. 2015. Evening typology and morning tiredness associates with low leisure time physical activity and high sitting. Chronobiol Int. 32:1090–1100.

Wirz-Justice A. 2003. Chronobiology and mood disorders. Dialogues Clin Neurosci. 5:315.

Xu X, Breen G, Chen C-K, Huang Y-S, Wu -Y-Y, Asherson P. 2010. Association study between a polymorphism at the 3′-untranslated region of CLOCK gene and attention deficit hyperactivity disorder. Behav Brain Funct. 6:48.

Yu JH, Yun C-H, Ahn JH, Suh S, Cho HJ, Lee SK, Yoo HJ, Seo JA, Kim SG, Choi KM. 2015. Evening chronotype is associated with metabolic disorders and body composition in middle-aged adults. J Clin Endocrinol Metab. 100:1494–1502.

Zhang R, Lahens NF, Ballance HI, Hughes ME, Hogenesch JB (2014). A circadian gene expression atlas in mammals: implications for biology and medicine. *Proceedings of the National Academy of Sciences (PNAS).* 111 (45):16219–16224. doi:10.1073/pnas.1408886111