Literature Review

Chronotype and Chrononutrition Profiles in Adolescents Obesity

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Abstract:

Background: Adolescent obesity remains a major global public health challenge. Modern lifestyle factors that disrupt circadian rhythms may exacerbate metabolic dysregulation in adolescents. Chronotype, reflecting innate circadian preferences for sleep-wake and activity timing, and chrononutrition, which emphasizes the alignment of meal timing with circadian rhythms, have gained attention as potential determinants of obesity. However, evidence integrating chronotype and chrononutrition profiles with adolescent obesity remains limited. Therefore, this review aims to synthesize the current evidence on the roles of chronotype and chrononutrition in adolescents obesity.

Discussion: Circadian rhythm regulates metabolic, hormonal, and behavioral processes through coordinated central and peripheral clocks. Variations in chronotype and disruptions in circadian alignment influence sleep patterns, meal timing, and metabolic regulation in adolescents. Evidence indicates that chronotype alone does not directly determine obesity risk; rather, its interaction with eating timing, sleep quality, and lifestyle behaviors plays a crucial role. Chrononutrition emphasizes aligning food intake with the biologically active phase, which is associated with improved insulin sensitivity, glycemic control, lipid metabolism, and blood pressure regulation. Determining chronotype and chrononutrition profiles remains challenging. The assessment is predominantly performed using standardized and validated questionnaires.

Conclusion: Chronotype and chrononutrition profiles may contribute to the risk of obesity in adolescents. They might be a potential strategy for obesity prevention and management. Nevertheless, current evidence remains limited, and further longitudinal and interventional studies are required to confirm these findings and inform future recommendations.

Keywords: chrononutrition, chronotype, obesity, adolescents, profiles

Introduction

Adolescent obesity remains a major global health challenge, with a prevalence of approximately 5% according to the Global Burden of Disease Obesity Collaborators.[1] Data from the World Health Organization indicate that more than 390 million children and adolescents aged 5 – 19 years were overweight, with prevalence increasing markedly from 8% in 1990 to 20% in 2022. The prevalence of obesity among children and adolescents also increased substantially, from 2% (approximately 31 million children) in 1990 to 8% (approximately 160 million children and adolescents) in 2022.[2] This condition not only increases the risk of non-communicable diseases in adulthood, such as type 2 diabetes mellitus, hypertension, and cardiovascular disease, but also adversely affects psychosocial well-being, cognitive development, and overall quality of life among adolescents.[3, 4]

Multiple risk factors for adolescent obesity have been identified, including high-calorie and low-fiber dietary patterns, insufficient physical activity, sedentary behavior, poor sleep quality, genetic predisposition, and the family environment. A study by Mahumud et al. demonstrated that consumption of sugar-sweetened beverages, fast food, low physical activity, and sedentary behaviors such as excessive screen time were significantly associated with obesity.[5]

Beyond these established factors, individual variation in daily biological rhythms, or chronotype, may also influence obesity risk. Chronotype refers to an individual's innate preference for sleeping and engaging in activities at specific times within a 24-hour cycle, reflecting underlying circadian rhythm characteristics.[6] These rhythms are regulated by the suprachiasmatic nucleus (SCN) in the brain and are synchronized with the environment through zeitgebers (external cues), such as light exposure, dietary patterns, and physical activity.[7]

Modern lifestyle changes, such as exposure to artificial light at night, irregular sleep patterns including late-night activities, and working during biological rest periods, disrupt the body's circadian rhythm and lead to chronodisruption or circadian desynchronization.[4] Misalignment between an individual's chronotype and socially imposed schedules, known as social jetlag, may trigger hormonal dysregulation, alterations in eating behavior, and reduced physical activity, all of which contribute to increased fat accumulation.[6, 8]

Traditional nutritional approaches have primarily focused on dietary composition and caloric intake, with limited consideration of biological timing and individual chronotype. In this context, chronotype and chrononutrition have emerged as novel approaches that integrate circadian biology into nutritional strategies. Chrononutrition is an approach aimed at realigning circadian rhythm desynchronization by evaluating individual eating patterns and behaviors to prevent disease risk and predict potential increases in such risk.[9]

Based on circadian rhythms, the light phase in the morning represents an optimal window for food intake, during which nutrient consumption can help optimize circadian function by coordinating peripheral and central circadian rhythms. Chrononutrition is expected to provide an effective nutritional strategy by optimizing meal timing in alignment with circadian rhythms, thereby helping prevent and reduce the risk of various diseases.[9, 10] Despite growing evidence, a comprehensive synthesis of chronotype and chrononutrition profiles as temporal determinants of obesity in adolescents remains limited. Therefore, this literature review addresses this gap.

Circadian Rhythm

The circadian rhythm is a central pacemaker system that regulates most biological processes by coordinating molecular, physiological, hormonal, and behavioral rhythms in alignment with the 24-hour light–dark cycle. This endogenous system maintains internal homeostasis and enables optimal metabolic responses to environmental changes.[11, 12]

The central circadian clock is located in the SCN of the anterior hypothalamus, which functions as the master pacemaker. The SCN operates in coordination with peripheral oscillators distributed across nearly all tissues and cells. It receives photic input from the retina and synchronizes peripheral clocks through neural and hormonal signaling pathways. Although each cell contains an intrinsic molecular clock, synchronization by the SCN ensures that physiological rhythms remain aligned with the 24-hour light–dark cycle, allowing optimal temporal coordination of biological processes.[13, 14]

Circadian rhythms are generated by a transcription–translation feedback loop involving positive and negative clock components. The positive elements, CLOCK (Circadian Locomotor Output Cycles Kaput) and BMAL1 (Brain and Muscle ARNT-Like 1), form a heterodimer that activates the transcription of negative regulators, including Period (PER1, PER2, PER3), Cryptochrome (CRY1, CRY2), and Rev-Erbα. The translated PER and CRY proteins accumulate in the cytoplasm, form PER–CRY complexes, and subsequently translocate into the nucleus to inhibit CLOCK–BMAL1 activity. This inhibition suppresses PER and CRY transcription until the inhibitory complexes are degraded via proteolytic pathways, thereby relieving repression and initiating the next circadian cycle, which recurs approximately every 24 hours.[13, 14]

Chronotype and Chronodisruption Definitions

The Chronotype refers to an individual's tendency to engage in daily activities according to their intrinsic circadian rhythm. It reflects a person's natural preference for sleep and wake times, influenced by the internal biological clock. These patterns can affect levels of alertness, productivity, mood, and overall physical and mental health throughout the day. Chronotypes are generally classified into three categories:[11, 15]

a. Morning chronotype, characterized by a preference for earlier wake times and earlier sleep onset;
b. Evening chronotype, characterized by a preference for later sleep onset and waking at later hours; and
c. Intermediate chronotype refers to individuals who do not distinctly align with either the morning or evening type, exhibiting sleep-wake patterns that fall between the two extremes.

Morning chronotypes are commonly referred to as "early birds, whereas evening chronotypes are known as "night owls.".[16] Individuals with a morning chronotype generally exhibit an advanced sleep phase (ASP), earlier wake times, higher levels of alertness, and optimal performance during the morning hours, and a circadian rhythm period that tends to be shorter than 24.2 hours. In contrast, individuals with an evening chronotype are characterized by a delayed sleep phase (DSP), later wake times, a preference for activities during the afternoon to evening hours, and a circadian rhythm period that tends to be longer than 24.2 hours.[11, 16] Individuals who fall between these two chronotypes are classified as having an intermediate chronotype.[17] Individual differences in chronotype are influenced by internal factors such as age, sex, and genetic background.[16, 18] These genetic variations are known to contribute to differences in sleep patterns, caloric intake, waist circumference, obesity, and the presence of other metabolic disorders.[19]

Chronodisruption describes a condition in which the body's circadian rhythm is disrupted or misaligned. This term encompasses various forms of circadian desynchronization that may affect physiological, hormonal, metabolic, and behavioral functions.[9] Some experts distinguish between terms used to describe this desynchronization. For instance, chronodisturbance refers to circadian misalignment that still allows physiological adaptation without significant adverse health effects. In contrast, chronodisruption is more specifically applied when such desynchronization increases the risk of health disorders or disease.[20]

Chrononutrition

The chrononutrition is a dietary approach that adjusts food intake to an individual's biological clock. This concept emphasizes the importance of determining the optimal time to eat by taking into account the body's physiological readiness to digest and metabolize nutrients. Therefore, attention to food quality and quantity needs to be followed by choosing the right time to eat. In addition, chrononutrition emphasizes the importance of consistency in meal schedules and frequency, as well as the incorporation of nutrient-dense foods into daily consumption patterns.[9]

Diet interventions that synchronize food consumption with individual circadian rhythms, such as time-restricted feeding (TRF), can benefit metabolic health. Research shows that TRF can improve glucose tolerance, reduce insulin resistance, and improve various cardiometabolic parameters, even without strict calorie restriction. These effects are closely related to the role of meal timing as a *zeitgeber*, which is an external time cue that regulates the expression of circadian genes in peripheral tissues such as the liver, muscles, and adipose tissue.[12]

Application of chrononutrition in clinical practice still faces various challenges. Many findings come from animal models, particularly mice, which are nocturnal, whereas humans are diurnal. This limits the relevance of preclinical results. Additionally, human studies are limited by lifestyle variability, adherence to dietary protocols, and heterogeneity in individual chronotypes, which influence physiological responses to time-restricted eating interventions. Chrononutrition has great potential for holistically improving metabolic health. The integration of nutrition science and molecular biology will be key to developing effective, clinically relevant nutritional interventions to prevent and manage metabolic diseases.[21]

Chronotype and Obesity

The Research examining the association between chronotype and obesity in adolescents remains limited, and direct comparisons across studies are challenging due to variability in the variables assessed. First, the obesity indicators used across studies vary considerably. Most studies rely on body mass index (BMI) as the primary parameter. In contrast, only a few use more specific and sensitive indicators, such as waist circumference or waist-to-height ratio. Second, differences in the control of confounding variables may affect study results. Factors such as age, sex, socioeconomic status, sleep duration and quality, physical activity, sedentary behavior, screen time, dietary patterns, and total energy intake are associated with both chronotype and obesity. Some studies report significant associations between chronotype and obesity; however, these associations become non-significant after adjustment for the previously mentioned variable. Third, heterogeneity in chronotype assessment instruments and classification criteria further complicates comparisons across studies. Some studies classify participants into morning and evening types only, while others include an intermediate category or use alternative classifications such as early and late chronotypes. In addition, correlations between different chronotype questionnaires may decrease after adjustment for age, sex, and sleep debt.[22, 23]

In adolescents, an evening chronotype has been associated with higher body mass index, increased fast food consumption, and a greater tendency toward pathological eating behaviors, such as night eating syndrome and food addiction.[24] However, the Eating Healthy and Daily Life Activities (EHDLA) Study demonstrated that adolescents with a morning chronotype had a 1.67-fold higher risk of central obesity compared with those with an intermediate chronotype, as assessed using the waist-to-height ratio.[24, 25] In contrast to many previous studies, the EHDLA Study did not find a significant association between evening chronotype and obesity in adolescents. These findings suggest that chronotype alone is not a stand-alone determinant of obesity risk.[25]

Besides chronotype, other biological factors also play an important role, particularly sleep and eating habits. An evening chronotype is often associated with shorter sleep duration and poorer sleep quality due to misalignment between the biological clock and social demands, such as school or work schedules. However, other studies have reported that poor sleep quality can also be observed in individuals with a morning chronotype and is associated with increased adiposity indicators.[26]

From a dietary perspective, even when total energy intake does not differ substantially, chronotype influences the daily timing and distribution of food intake. Individuals with a morning chronotype tend to consume a greater proportion of their energy at breakfast, whereas those with an evening chronotype consume more energy during the evening.[25]

Puberty and Obesity

Puberty is a developmental process during which reproductive capacity is attained and is characterized by rapid somatic growth and substantial endocrine maturation.[27] One of the key hormones involved is growth hormone (GH). During the pubertal transition, GH secretion increases in a pulsatile manner to support the growth spurt and tissue remodeling. Adequate and well-regulated GH activity is essential for normal linear growth, changes in body composition, and metabolic homeostasis.[28] GH secretion during adolescence is closely linked to slow-wave sleep and circadian regulation; hence, its disruption of sleep timing or circadian alignment during this critical period may interfere not only with growth processes but also with metabolic regulation.[29] Consequently, puberty may increase susceptibility to metabolic dysregulation when combined with other risk factors, such as insufficient sleep, late-night eating, and reduced physical activity.[5]

Chrononutrition and Obesity

The chrononutrition emphasizes the importance of aligning eating schedules with circadian rhythms to maintain metabolic health. It highlights not only *what* to eat, but also *when* to eat. Several studies have demonstrated that meal timing functions not only as a source of energy but also as a regulator of biological rhythms.[30]

Several nutritional components influence the biological clock, both at the central level in the SCN and at peripheral clocks in body tissues. High-fat diets have been reported to act as triggers for chronodisruption, adversely affecting multiple metabolic parameters. In contrast, ketogenic diets, which rely primarily on fat as the main energy source, have been shown to activate several clock-controlled genes (CCGs) through the CLOCK–BMAL1 signaling pathway.[30] High salt intake has also been reported to delay BMAL1 activation and suppress the expression of PER2 and CRY1. In addition, caffeine and theophylline have been shown to lengthen circadian rhythms at the cellular level.[31]

Studies have shown that eating during the morning-to-afternoon period, which corresponds to the active phase of the circadian rhythm, is associated with optimal insulin sensitivity, better glycemic control, and a healthier lipid profile. Physiologically, genes and proteins that are more active in the afternoon are involved in energy metabolism, such as glycogenesis and lipogenesis. In contrast, late-night eating or food intake outside the active circadian phase is associated with increased visceral fat deposition, impaired glucose tolerance, and disruption of energy homeostasis.[32]

Based on circadian rhythm principles, it is recommended to emphasize the distribution of calories and carbohydrates during the morning-to-afternoon period and to restrict the daily eating window to less than 10 hours from the first to the last meal. Time-restricted eating limited to the morning and afternoon has been shown to promote weight loss and improve metabolic parameters without requiring changes in total daily caloric intake.[24, 33]

Regular meal patterns, such as three main meals per day with healthy snacks in between, are also recommended to maintain harmony in biological rhythms. Misalignment with these eating patterns, together with irregular sleep schedules, may increase total energy intake, disrupt circadian rhythms, and subsequently elevate the risk of metabolic dysfunction.[24, 33]

Chronotype also plays an important role, as adolescents tend to shift toward an evening chronotype, which is often associated with greater nighttime energy consumption, skipping breakfast, and a preference for high-glucose and high-fat foods. These behaviors may lead to social jetlag, which has been shown to correlate with a higher risk of obesity and metabolic syndrome in young populations.[24, 33]

Interventions that take chronotype into account, such as adjusting school schedules, aligning meal timing with the biological clock, and restricting evening screen time, may reduce the risk of obesity and improve metabolic health in adolescents.[32, 33] Integrating these strategies into public health policies could represent an effective preventive approach to address the rising prevalence of obesity among adolescents.

Chrononutrition and Metabolic Syndrome

Metabolic syndrome is defined as a condition arising from multiple cardiometabolic risk factors, including central obesity, insulin resistance, hypertension, and dyslipidemia. Late, irregular, or predominantly nighttime eating patterns may lead to circadian misalignment, which disrupts metabolic homeostasis. Circadian misalignment impairs metabolic regulation, leading to altered glucose control, elevated insulin levels, increased insulin resistance, and glucose responses resembling those of a prediabetic state.[34]

Insulin sensitivity, the body's capacity for glucose and lipid metabolism, and incretin secretion peak from the morning until the afternoon. Therefore, energy intake during this period is more efficiently utilized for metabolism rather than stored as triglycerides. In addition, morning food intake helps maintain energy homeostasis, suppresses ghrelin secretion, and reduces the risk of evening overeating. Conversely, evening food intake, when metabolic activity declines, is associated with increased insulin resistance, higher postprandial hyperglycemia, and enhanced hepatic lipogenesis.[34] Late-night eating also alters appetite-regulating hormones by reducing 24-hour serum leptin levels and increasing the 24-hour ghrelin– leptin ratio, thereby promoting hunger.[35]

Eating timing also affects blood pressure by modulating the autonomic nervous system. Food intake increases sympathetic activity regardless of timing; late-night eating induces sympathetic activation during a period that is physiologically dominated by parasympathetic tone, resulting in circadian misalignment. This misalignment further suppresses melatonin secretion, a hormone known to contribute to the blood pressure-lowering effect.[36]

Chronotype and Chrononutrition Profile Assessment

Determining chronotype and chrononutrition profiles remains challenging. However, identifying an individual's chronotype provides important clinical benefits, including the diagnosis and management of circadian sleep disorders, the prediction of adaptability to work schedules, and the optimization of performance by aligning sleep timing with circadian rhythms.[37] Similarly, assessment of chrononutrition profiles enables the alignment of meal timing with the circadian system, which may support targeted interventions for metabolic diseases in the future. Currently, most studies determine chronotype and chrononutrition using validated questionnaires.[38]

Chronotype

One of the most widely used tools for assessing chronotype is the Morningness–Eveningness Questionnaire (MEQ). This instrument comprises 19 items designed to assess an individual's morning or evening chronotype, based on personal preferences for sleep timing, wake-up time, and daily activities. The MEQ has been validated across diverse populations, translated into multiple languages, and revised into alternative versions, including Smith's Composite Scale of Morningness (CSM) and the reduced Morningness–Eveningness Questionnaire (rMEQ) developed by Adan and Almirall.[37]

The Munich Chronotype Questionnaire (MCTQ) is more objective because it collects data on sleep patterns on weekdays and free days to calculate the midpoint of sleep and identify social jetlag. This instrument consists of questions about sleep time, wake-up time, sleep duration, and the duration it takes to fall asleep (sleep latency). The Mid-Sleep on Free Days (MSF) value is calculated as the midpoint between sleep and wake times on free days. To reduce bias arising from compensation for sleep debt on workdays, a correction value called MSFsc is used. The smaller the MSFsc, the more inclined a person is to be a morning type, while a large MSFsc indicates an evening type tendency.[8] The MCTQ has also undergone various validations with diverse sample characteristics, been translated into multiple languages, and modified into other forms such as MCTQshift for shift workers and μMCTQ for a short version.[37]

The Children's Chronotype Questionnaire (CCTQ) was adapted from MCTQ. It differs in that it includes parental reports on sleep and wake times, sleep latency, and sleep midpoint for children on regular schedules and on days without a specific schedule. The assessment reflects direct observation of the child's sleep patterns, wake-up habits, and preferred activity times. One advantage of CCTQ is that evaluations can be conducted on both school days and off days.[37] **Table 1** summarizes the differences between the questionnaires.

Chrononutrition

The CP-Q is one of the most widely used questionnaires for assessing chrononutrition profiles. It consists of two main domains: (1) chrononutrition preferences (the times participants choose to wake up, sleep, or eat) and (2) chrononutrition behavior (the actual times participants perform these activities). The CP-Q assesses the first and last meal times of the day, lunch and dinner times, breakfast habits, sleep and wake times, and meal-time preferences. Although this instrument provides a more comprehensive assessment, its use is currently limited to the general population and has not been specifically validated for children or adolescents.[39]

In addition to the CP-Q, other instruments often used to assess chrononutrition include the Meal Pattern Questionnaire (MPQ). This instrument is simple and is used to collect data on meal frequency, food types, and meal times within 24 hours. Participants are asked to report their general daily eating patterns, specify meal times, and select the appropriate category (breakfast, main meal, snack, or beverage). The main limitation of the MPQ is that it does not distinguish between eating patterns on work/school days and day-offs, so variations in eating behavior between days cannot be optimally captured.[40]

Additionally, there is the Eating Pattern Questionnaire (EPQ). Unlike the MPQ, the EPQ allows meal-time assessment that distinguishes between work/school days and day-offs. Respondents were asked to rate the frequency of their food or beverage consumption with the answer choices "always," "sometimes," or "never." However, the use of this abstract term is a major limitation, as interpretation can vary between respondents. As a result, the instrument's sensitivity to variations in dietary patterns over time is relatively low, although it still provides a rough overview of eating behavior.[38] The differences among the questionnaires are presented in **Table 2.**

Table 1. Comparison of the chronotype assessment instrument

Instrument	Target age (years)	Number of items	Main output	Reliability	Validity	Advantages	Disadvantages
MEQ, Horne, 1976[41]	≥ 16	19	Morningness–eveningness score (16–86); 5 classifications	Cronbach's α = 0,83; test retest r = 0,89	Correlates with core temperature and DLMO (r > 0,70)	Simple, widely used, shortened version available (rMEQ)	Better at assessing preference, less sensitive to actual sleep behavior
MCTQ, Roenneberg, 2012[8]	≥ 14	±15	MSFsc, social jetlag	ICC > 0,80; MSFsc correlation with actigraphy r = 0,73	Valid against actigraphy and DLMO	Measures actual sleep behavior, measures social jetlag	Requires more data (work days vs off days), recall bias
µMCTQ, Ghotbi, 2020[42]	≥ 14	6	MSFsc, social jetlag	Correlation to MCTQ r = 0,92	Valid against MCTQ	Quick (<2 minutes)	Limited detail (doesn't measure sleep duration per segment)
CCTQ, werner, 2009[37]	4–11	27 (3 subscales)	Morninness–eveninness score, factual sleep time, sleep inertia	ICC = 0,85; α > 0,80	Correlates with actigraphy r = 0,61	Specific for children, parent-friendly format, minimal missing data	Requires parent report, limited validity for cross-cultural use

MEQ = Morningness-Eveningness Questionnaire; DLMO = Dim Light Melatonin Onset; rMEQ= reduced Morningness-Eveningness Questionnaire; MCTQ = Munich Chronotype Questionnaire; MSFsc = Mid-Sleep on Free days corrected; ICC = Intraclass Correlation Coefficient; µMCTQ = Ultrashort Munich Chronotype Questionnaire; CCTQ = Children's Chronotype Questionnaire

Table 2. Comparison of the chrononutrition assessment instrument

Instrument	Measurement	Validity (study results)	Advantages	Disadvantages
CP-Q, Veronda, 2020[38]	18 items containing open-ended and multiple-choice questions to assess preferences and actual behavior (waking up/sleeping, first/last meal, lunch/dinner time, breakfast & dinner)	Strong convergent validity for the food intake log & PSQI: correlation r = 0.39–0.91; 65–80% of variables were within ≤ 60 minutes of the actual log.[39]	Captures detailed chrononutritio n profiles and includes the sleep–wake relationship with meal times; strong validity with objective measures	Only validated in adult populations, and not specifically designed for children/adolescents . This questionnaire is relatively longer and more complex than other questionnaires.
MPQ, Forslun D, 2002[40]	Respondents reported their daily eating habits over a 24-hours. Categories: main meals, breakfast, snacks, and beverages.	Construct validity for the Eating Disorder Examination: Spearman rho = 0.74–0.87.[43]	Simple, easy to use, and captures daily meal distribution, distinguishing between workdays and holidays.	Suitable for general diets, but not specific to chrononutrition
EPQ, Guirette, 2019[44]	Using qualitative frequency terms ("always," "sometimes," "never") for food/beverage consumption	Relative validity compared to 24-hour food records: reported to be reasonably consistent, without detailed quantitative correlation values. [44]	Improved on MPQ by distinguishing between workdays and holidays.	Frequency measurement uses qualitative terms

CP-Q = Chrononutrition Profile Questionnaire; PSQI = Pittsburgh Sleep Quality Index. MPQ = Meal Pattern Questionnaire; EPQ = Eating Pattern Questionnaire;

Studies on children have been conducted in several countries using various instruments, albeit in limited numbers. Some researchers developed new questionnaires for their own study. These studies still show varying results because many studies on chronotype and chrononutrition have different operational definitions **(Table 3).**

Table 3. Existing studies with assessment of chronotype and chrononutrition

Researcher/ Design/ Place	Description	Instrument Used	Results
Vilela, 2019/ Prospective cohort/ Portugal[45]	Assessed the effect of the amount, type of food, and eating period of children at the age of 4 years on their weight at the age of 7 years	3-day food diaries to assess the type and amount of food, and CEBQ to assess chrononutrition	High calorie intake during lunch and dinner at age 4 increases the risk of overweight and obesity at age 7
Yu, 2020/ Cross-sectional/ Hong-Kong[46]	Assessed the relation between chronotype and eating patterns in school-aged children aged 7-11 years	CCTQ to assess chronotype, and a researcher-developed questionnaire to assess eating behavior	Boys with a night chronotype tend to skip breakfast Girls with a night chronotype tend to eat fast food
Jankovic, 2024/ Cross-sectional/ Germany[47]	Assessed the relation between the 'highest calorie intake' time and an individual's chronotype with body composition in a population of adolescents aged 9-16 years.	MCTQ to assess chronotype, and 3-day food diaries to assess food type and quantity	Adolescents with a night chronotype and the highest nighttime calorie intake exhibit an increase in fat-free mass index (FFMI) over time.

CCTQ: Children's Chronotype Questionnaire, CEBQ: Child Eating Behaviour Questionnaire, FFMI: Fat-Free Mass Index, MCTQ: Munich Chronotype Questionnaire

Clinical Implication

The Knowledge of the influence of chronotype and chrononutrition profiles on obesity in adolescents has led to several important clinical implications: (1) biologically rhythm-based lifestyle interventions, (2) a reference framework for health promotion, (3) implementation within school activities, (4) enhanced parental involvement in shaping sleep and eating behaviors, and (5) the utilization of eHealth approaches.

1. Biologically Rhythm–Based Lifestyle Interventions
   Lifestyle interventions that account for biological timing have been shown to improve metabolic health in adolescents. A study by Janković et al. demonstrated

that a social jetlag of >1 hour over 1 year was associated with a 2.4% reduction in body fat percentage among adolescents aged 14–18 years.[47] Intervention programs that incorporate consistent sleep schedules, limited nighttime screen exposure, and regular breakfast consumption have been shown to reduce triglyceride levels by up to 15%. In addition to improving metabolic health, these modifications enhance sleep quality, which, in turn, positively affects cognitive function and appetite regulation.[48]

2. Reference Framework for Health Promotion
   An understanding of chronotype and chrononutrition has important implications for health promotion, particularly among adolescents. Research indicates that interventions targeting meal timing and sleep patterns tailored to chronotype variations can influence obesity status, metabolic syndrome, and sleep disorders.[11] For example, aligning meal schedules with circadian rhythms has been shown to reduce body mass index by 1.2–1.8 kg/m² over 12 weeks in adolescents with an evening chronotype. Therefore, health promotion strategies should incorporate education on optimal meal timing. Such approaches can be implemented through schools and community programs in an age-appropriate manner.[34]

3. Implementation Within School Activities
   The successful implementation of chronotype- and chrononutrition-based interventions requires multidisciplinary collaboration involving healthcare professionals, teachers, and parents. The school environment plays a strategic role in shaping healthy sleep and eating patterns among school-aged children, including adolescents. Schools can integrate circadian rhythm concepts into the curriculum as part of health education initiatives.[11]

   Research has shown that delaying school start times by 30–60 minutes can increase average sleep duration by up to 35 minutes per night and improve academic performance scores by 4–5%. In addition, providing nutritious breakfast options in school cafeterias may help better align eating patterns with adolescents' biological rhythms. The combination of education, environmental modification, and institutional policies constitutes a critical foundation for effective and sustainable interventions.[49]

4. Enhancing Parental Involvement in Shaping Sleep and Eating Behaviors
   Parental involvement is a key component in the formation of healthy sleep habits and dietary patterns in adolescents. Monitoring sleep schedules, limiting electronic device use before bedtime, and providing evening meals at consistent times have been shown to reduce the risk of obesity by up to 23% among adolescents with an evening chronotype. Parental roles become increasingly crucial during the

pubertal transition, a period during which biological changes naturally shift chronotype toward the evening type.[48]

5. Utilization of eHealth
   Utilization of eHealth approaches has emerged as a promising innovation in the implementation of chronotype- and chrononutrition-based health promotion strategies. A study by Benítez-Andrades reported that the use of digital applications to monitor meal timing, sleep, and physical activity resulted in an average reduction in body mass index (BMI) of 0.9 kg/m² over six months among overweight adolescents. Such technologies enable personalized interventions, reminder systems, and real-time progress tracking. Integration of eHealth tools with school-based programs and routine health consultations may further extend the reach of these interventions. However, long-term effectiveness remains dependent on sustained support from families and the surrounding environment to maintain behavioral changes.[50]

Research Gap

The A limitation of this review is the scarce availability of interventional studies specifically examining chronotype- and chrononutrition-based strategies for managing adolescent obesity. The existing literature in adolescent populations is largely observational, predominantly comprising cross-sectional and prospective cohort designs.[40, 43, 44] Randomized controlled trials are therefore needed to clarify causal relationships and to evaluate the effectiveness of circadian-aligned interventions.

Overall, current evidence supports the view that chronotype and chrononutrition profiles are important determinants of obesity prevention and management among adolescents. This literature review is expected to serve as a scientific foundation for the development of nutritional and lifestyle interventions aligned with the circadian rhythms of obese adolescents, thereby informing future prevention and management strategies.

However, to date, research examining the relationships between chronotype, chrononutrition, and obesity in adolescents still presents several limitations. Existing studies employ heterogeneous questionnaire-based instruments, complicating direct comparisons of findings. Moreover, the risk of bias remains relatively high due to heterogeneity in population characteristics, including age, sex, socioeconomic status, sleep duration and quality, physical activity levels, sedentary behavior, screen time, dietary patterns, and total energy intake, all of which have been reported to be associated with both chronotype and obesity.

Furthermore, each chronotype assessment instrument has inherent limitations. The heterogeneity of measurement tools and chronotype classification criteria further complicates the interpretation of findings across studies. Some studies categorize participants solely as morning or evening types, whereas others include an intermediate category or use alternative classifications, such as early and late chronotypes. These methodological variations contribute to inconsistencies in reported results and limit the generalizability of the existing evidence.

Conclusion

Chronotype and chrononutrition are critical determinants in obesity and may be considered in its prevention and management. Integrating circadian-aligned nutritional and lifestyle interventions tailored to the chronotype of obese adolescents' strategy to optimize metabolic health and improve the effectiveness of obesity prevention and treatment in this population. Therefore, further longitudinal and interventional studies with large sample sizes and multicenter designs are required to confirm these findings and inform future recommendations.

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