

Circadian Rhythm and Obesity

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Abstract. Obesity with significant implications for public health has become a global epidemic. Recently, there is growing evidence indicating that the disturbance of circadian rhythms have a pivotal role in the onset of obesity. Insufficient sleep, a common consequence of modern lifestyle, further disrupts circadian rhythms and always leads to higher body mass index (BMI) and metabolic disturbances. Circadian misalignment affects various aspects of metabolism, including appetite regulation, glucose metabolism, and lipid metabolism. Disturbances in the timing of food intake, such as late-night eating or irregular meal patterns, can disrupt the synchronisation between the circadian clock of suprachiasmatic nucleus and peripheral clock, resulting in impaired metabolic function and increased adiposity. Circadian clocks oversee expressions of crucial genes associated with the energy balance and lipid metabolism at the molecular level. Genetic studies have identified specific clock genes that are related to metabolic disorders and overweight. Perturbation of genes is regulated by the body's internal clock, including those responsible for adipogenesis and insulin signaling, acts as a major player in the progression of obesity. Understanding the relationship between circadian rhythms and obesity has important implications for preventive and therapeutic strategies. Implementing interventions that restore circadian alignment, such as timed light exposure, sleep optimization, and following regular meal timing, may help mitigate the risk of obesity and its associated metabolic complications. This article reviews the current literature on the influence of circadian rhythm on obesity and explores its underlying mechanisms.

Keywords: Circadian rhythm; Obesity; therapy.

1. Introduction

With the swift advancement of the global economy, rising living standards and ageing societies, the incidence of obesity-related chronic diseases caused by over-nutrition, especially type II diabetes, is on the rise and is becoming one of the major health hazards of the population. Clinical studies have found that disturbing the body's biological clock can result in metabolic syndrome, especially type II diabetes, but the causative mechanisms are not yet understood [1].

Obesity is defined as being significantly overweight with an overabundant layer of fat, a condition arising from the over-accumulation of body fat, particularly triglycerides. Excess accumulated body fat caused by too much dietary intake or changes in the body's meticulous metabolism causes an increase in extra body weight and a pathological and physiological change or subtle change in the body. Data from WHO show that since 1975, the global prevalence of obesity has nearly tripled, with the number of individuals affected steadily rising. During the year 2016, the global count of adults aged 18 and above who were overweight surpassed 1.9 billion, with an additional 650 million categorized as obese. In the year 2019, 38 million children under 5 years old were overweight or obsessed. A significant portion of the global population resides in countries where the mortality rate associated with overweight and obesity surpasses that of underweight individuals. Obesity gives rise to numerous health conditions, and it is argued that it serves as the root cause of various diseases. Consequently, the most urgent way for people to reduce the incidence of obesity is to conduct in-depth research on the root causes of obesity and related molecular mechanisms, and to explore effective treatment methods.

In recent years, the link between obesity and circadian rhythms has been gradually explored, and this area of the circadian clock is currently receiving great attention. A study conducted by Brigham Young University in the United States, found out that Circadian rhythm disorders such as insomnia can lead to physical obesity. Obesity arises from an unusual buildup of white adipose tissue and is

typically attributed to factors such as excessive nutrient intake, inadequate dietary choices, physical inactivity, and persistent insulin resistance. Nonetheless, numerous studies have demonstrated that disturbances in circadian rhythms, whether due to genetic factors or environmental aspects (such as exposure to nocturnal light, sleep disruptions, social jet lag, and late-night snacking), profoundly impact lipid metabolism in individuals and expedite the progression of obesity.

For instance, mice which are clock mutated and with a knockout (K.O.) of the *Bmal1* gene display impaired glucose tolerance, decreased insulin secretion, heightened susceptibility to high-fat diets, develop hypertensive characteristics, and ultimately experience weight gain. Furthermore, in the *Bmal1* knockout (K.O.) model, there was observed targeted impairment in peripheral tissues including skeletal muscle, β -cells, liver and other tissues, resulting in disrupted glucose metabolism and perturbations in systemic glucose dynamic homeostasis. *Drosophila* with mutations in their circadian cycle demonstrated moderate alterations in lipid metabolism, manifested by noticeable changes in diacylglycerol and acylcarnitine levels, along with heightened sensitivity to periods of food deprivation or starvation. Conversely, the *Bmal1*, *Cry1*, *Cry2*, and *PER2* genes expressions in obese individuals were found to be significantly upregulated in the presence of white light (daytime) and significantly downregulated during dark hours (nighttime). This observation suggests that disturbed lipid metabolism not only impacts the expression of biological clock genes but also influences the downstream pathways associated with these genes. Additional evidence supporting the interaction between the biological clock and lipid metabolism comes from studies showing that disruptions in the circadian rhythm induced by environmental factors can bring about the progression of obesity. For instance, artificial light seen by the eye in the nighttime can cause circadian rhythm disruption, which will disrupt lipid and many other hormones metabolism disorder.

This review is going to dig deeper into the relationship between circadian rhythms and obesity, providing an additional perspective on obesity prevention.

2. Circadian Rhythm, Obesity and their Connection

2.1. Circadian Rhythm and its Molecular Mechanisms

All life must depend on and adapt to its environment in order to survive. The Earth's rotation causes environmental factors such as light, temperature and humidity to have a 24-hour cycle, and this cyclical change in environmental factors has an important impact on the physiology and behaviors of organisms on Earth [2].

The biological clock has an autonomous cycle of approximately 24 hours, hence the name *perihelion*. In addition to the circadian biorhythms of the near 24-hour period, there are also different types of biorhythms such as supra-diurnal rhythms, which are shorter than the 24-hour period, and sub-diurnal rhythms, which are longer than the 24-hour period, including lunar, tidal and annual rhythms. The term biological clock is used here to refer to the recent biological clock unless otherwise specified.

The regulation of circadian rhythms is governed by a biological clock system comprising a collection of genes and mechanisms that contribute to the synthesis and translation of proteins. These include: *CRY* (Cryptochrome), *PER* (Period), *BMAL1* (Brain and Muscle ARNT-like protein 1), *CLOCK* (Circadian Locomotor Output Cycle Kaput) and others [3].

CLOCK and *BMAL1* proteins form a complex that functions as transcription factors, binding to the targeting gene-specific promoter region [4]. Through this binding, they modulate the expression of these target genes, either activating or repressing their transcription. *PER* and *CRY* are other fusion proteins. They can inhibit the regulation of target genes by *CLOCK/BMAL1*, creating a self-loop feedback regulation. The expression of *PER* and *CRY* in the biological clock system shows "peaks and valleys", which are influenced by factors such as daylight cycle, temperature, food intake and exercise.

This biological clock system is essential for regulating metabolic procedures and behavioral activities throughout the body. For example, in terms of diet, the circadian rhythm regulates insulin

secretion, which controls blood glucose levels, and the peristalsis and acidity of the gastrointestinal tract, which affects appetite and energy intake. If the body's biological clock system is disturbed or irregular, it can lead to metabolic disorders and disease. For example, studies have found that night shift workers and people who spend long hours indoors have a disturbed biological clock system, which makes them susceptible to obesity, metabolic syndrome and cardiovascular diseases. Therefore, how to maintain a reasonable circadian rhythm is very important in preventing obesity and related diseases.

2.2. Definition of obesity and the causes of obesity

Excessive fat build-up that impacts health is referred to as overweight and obesity. The most common index tool used in our lives to classify adults as overweight and obese is the Body Mass Index (BMI), whose definition is the square of height in meters dividing weight in kilograms (kg/m^2).

To assess obesity severity based on BMI, international standards typically rely on the BMI thresholds established by the World Health Organization. The World Health Organization provides the following definitions for overweight and obesity in adults: overweight is characterized by a BMI in the range of 25.0 to 29.9, while obesity is determined by a BMI of 30.0 or greater.

Metabolic diseases caused by overnutrition are an increasing threat to human health. Metabolic processes are tightly regulated, and imbalances in food consumption and energy expenditure can resulting in the accumulation of nutrients and metabolites, making the incidence of metabolic diseases, cardiovascular diseases, tumors and a number of other diseases rises dramatically. Several factors contribute to obesity, including genetics, environmental influences, alterations in energy metabolism and hormonal regulation, an augmentation in both the quantity and dimensions of adipocytes, psychological and psychiatric factors, lifestyle and dietary choices, medication-induced and gastrointestinal disorders.

The biological clock serves as an intrinsic mechanism for adapting to the environment and works critically in the regulation of metabolism. The levels of many hormones that regulate important metabolic pathways are modulated by the circadian clock, such as insulin, glucagon, lipocalin and leptin. They transmit information from the central nervous system to peripheral tissues and organs responsible for metabolism, which is essential for the regulation of metabolic homeostasis. Many important metabolic pathways with significant circadian rhythms, such as blood glucose and amino acid metabolism, are also regulated by the biological clock.

The impact of circadian rhythms on obesity is complex, but it can influence weight control and act importantly in the occurrence and the development of obesity. Researches noted that irregular work schedules and poor lifestyle habits (e.g., staying up late at night, eating at night, etc.) can interfere with the intrinsic biological clock and circadian rhythms, leading to metabolic disturbances and imbalances in energy regulation, which can increase body weight. Regular sleep patterns and dietary habits, on the other hand, can help maintain stable circadian rhythms and optimize metabolic and energy regulation, helping to lower risks of obesity and metabolic diseases.

Following sections will explain the effects of circadian rhythm disorders on obesity, including at the hormonal level.

2.3. Circadian Rhythm Disorders usually lead to Obesity

There is a circadian rhythm to the secretion of any hormone. Stability of hormone circadian rhythms determines whether people are healthy or not. If a person's circadian rhythm is disturbed, their hormone production will also be disturbed, resulting in the body not being able to cope properly with the changes and causing various health problems, such as obesity.

The trough of leptin occurs between 8:00 and 12:00 and the peak occurs between 24:00 and 3:00, which is familiar with the results of Sinha and so on, the first researchers to elucidate the gene, molecular structure and physiological role of leptin [5]. In analyzing the connection between circadian rhythm variations of glucocorticoids and circadian rhythm variations of leptin, researchers found no significant correlation when body fat was excluded ($P_1 = 0.287$; $P_2 = 0.4107$) [6]. Therefore,

it can be hypothesized that cortisol levels do not alter the circadian rhythm changes of leptin. However, the magnitude of leptin circadian rhythm variation differed between normal and obese individuals, and their leptin circadian rhythm variation was inversely correlated with BMI. This means that the more obese people are, the more obtuse the leptin circadian rhythm is.

3. Key Roles of Circadian Rhythm in Obesity

3.1. Regulation of sleep patterns

Disturbance in sleep patterns and insufficient sleep has a connection with increasing risk of obesity. The circadian clock influences sleep-wake cycles, and irregular sleep patterns can disrupt the normal regulation of appetite-controlling hormones, such as leptin and ghrelin, leading to increased food intake and weight gain.

Sufficient and high-quality sleep is essential for maintaining a healthy circadian rhythm and supporting weight management. Inadequate sleep and poor sleep quality disrupt the balance of hunger and satiety hormones, increase cravings for high-calorie foods, and decrease energy expenditure during wakefulness. Establishing a regular sleep routine, optimizing your sleep environment to promote better rest, and incorporating relaxation techniques are good ways to enhance the duration and quality of your sleep, helping to achieve a sleep duration of 7-9 hours per night.

3.2. Appetite and food intake regulation

Circadian rhythm influences the timing of food intake. The body has evolved to eat during the active phase (daytime for humans), when metabolism and energy expenditure are higher. Disruptions in the circadian clock, such as late-night eating or shift work, can lead to altered appetite regulation, increased calorie consumption, and imbalance between energy input and consumption that can cause an increase in weight.

The circadian clock also influences timing of meals, and irregular eating patterns, such as frequent snacking or eating meals at unusual times, can disrupt the body's metabolic processes. Irregular meal timing may enact impaired glucose tolerance, increased insulin levels and difficulties in nutrient utilization, potentially promoting weight gain and obesity [7]. It is recommended to maintain regular meal times and avoid late-night eating to support a well-functioning circadian clock.

3.3. Hormonal regulation

The circadian rhythm has an important part in controlling of hormone levels involved in energy balance, including leptin, ghrelin, insulin, and cortisol. Leptin, known as the satiety hormone, signals fullness to the brain and helps regulate food intake. Ghrelin, the hunger hormone, stimulates appetite. Disruptions in the circadian rhythm can lead to imbalances in these hormones, resulting in increased hunger, overeating, and weight gain. Consistent sleep patterns and regular meal times help maintain hormonal balance.

Melatonin, a hormone secreted through the pineal gland at night, serves to regulate the sleep-wake cycle. It also affects metabolism and energy expenditure. Exposure to light at night, particularly blue light emitted by electronic devices, has the potential to suppress melatonin production, disrupt sleep patterns, and potentially lead to metabolic imbalances and weight gain. It is advisable to limit exposure to bright lights and electronic screens before bedtime to promote healthy melatonin release.

3.4. Metabolic regulation

Circadian rhythm affects various metabolic processes, including glucose and lipid metabolism. Research has demonstrated that disturbances in the body's internal circadian rhythms will result in metabolic disturbances, including compromised glucose tolerance and heightened insulin resistance, which can lead to obesity and type 2 diabetes.

Adipose tissue (fat cells) has its circadian clock, which regulates the timing of adipocyte differentiation, lipolysis (breakdown of fat), and adipokine secretion. Disruptions in this circadian control of adipose tissue function can contribute to abnormal fat storage and altered secretion of adipokines, leading to obesity-related metabolic disorders.

3.5. Influence on physical activity

Circadian rhythm can influence physical performance and exercise capacity. Research suggests that exercising in synchrony with the body's internal clock may lead to greater gains in terms of endurance, strength, and fat burning. It is beneficial to align exercise routines with the active phase of the circadian rhythm, typically during the daytime, to maximize the benefits of physical activity for weight management.

On the other hand, circadian rhythm can affect the timing and intensity of physical activity. Perturbations in circadian timing, such as jet lag or shift work, may disrupt regular exercise routines and lead to decreased physical activity levels, which can contribute to weight gain and obesity.

4. The contact mechanism

4.1. Melatonin

An endogenous indoleamine hormone called melatonin can be found in almost every organism, from simple photosynthetic bacteria to humans [8]. It plays a role in a number of physiological functions. Melatonin is produced rhythmically by the pineal gland of vertebrates [9], controlled by the parasympathetic suprachiasmatic nucleus of the hypothalamus and has profound physiological effects through the G-protein-coupled membrane receptors, melatonin receptors 1 (MT1) and 2 (MT2) [10].

Bartness et al. in 1984 [11] found that short photoperiodic treatment of hamsters following pinealectomy caused an increase in body weight, suggesting that the pineal gland, melatonin, and body weight are related. Later, a growing body of data showed that exogenous melatonin treatment decreased the body mass of animals [12]. Melatonin has been shown to reduce associated features such as weight gain and visceral fat deposition, particularly in mammals fed high-fat or high-sugar diets.

Studies have indicated that melatonin can alleviate hyperglycemia in animals through the enhancement of insulin sensitivity [13], the stimulation of pancreatic β -cell regeneration [14], and the facilitation of hepatic glycogen synthesis [15]. Melatonin, nevertheless, increases the risk of hyperglycemia in some human investigations, inversely proportional to the diminished effect in animal studies. Because MT2 is significantly overexpressed throughout human pancreatic islets and carries the common rs10830963 mutant gene, it is well known that melatonin affects glucose homeostasis [16].

The impact of melatonin signaling in glucose metabolic processes of the peripheral tissue has been emphasized, such as the liver, skeletal muscle, and pancreas [17]. This is because melatonin receptors are expressed in numerous tissues. What is indispensable to the process of insulin-induced PI3K-AKT activity is melatonin. Melatonin stimulated glycogen production in hepatocyte cells through the G_i protein, which is a component of IRS1-PI3K- PKC-AKT-GSK-3 pathway. Melatonin regulates gluconeogenesis in the liver of rats by upregulating SIRT1 expression and phosphorylating STAT3. In mouse skeletal muscle, melatonin promotes glucose absorption by activating the IRS1-PI3K-PKC pathway. In order to counteract insulin resistance in rats, it stimulates cAMP- CREB-PGC-1 pathway. Melatonin receptors in the pancreas regulate various activities of insulin by binding to numerous parallel signaling pathways. Melatonin inhibits insulin secretion by signaling through MT1 coupled to G_i proteins to depress the cAMP-PKA-CREB pathway or via MT2 coupled to G_i proteins to depress the cGMP pathway. Melatonin enhances insulin secretion by regulating cellular inositol triphosphate and Ca^{2+} levels through the specific coupling of MT1 to G_q proteins. Melatonin stimulates IGF-1 pathway through MT1, effectively controlling islet to grow and differentiate. In

addition, melatonin suppresses insulin gene expression via MT2 and subsequently Ras-related Raf-1 and ERK signaling pathways [17].

4.2. Insulin

Circadian rhythms can impact obesity by affecting insulin, an essential hormone responsible for keeping blood sugar levels fluctuate within a reasonable range and facilitating the accumulation of excess glucose as body fat.

4.2.1 Insulin production and sensitivity

Insulin secretion by the pancreas is regulated by a circadian rhythm, which adjusts according to fluctuations in blood sugar levels. Insulin levels naturally peak in the morning and gradually decrease throughout the day. Disruptions in the circadian rhythm, such as irregular sleep patterns or shift work, can lead to impaired insulin production and reduced insulin sensitivity, which may cause elevated blood sugar levels and a higher likelihood of weight gain and obesity.

4.2.2 Glucose metabolism

Circadian rhythms also influence the body's ability to effectively metabolize glucose. Research has shown that individuals with disrupted circadian rhythms have impaired glucose tolerance and decreased glucose uptake in cells, leading to elevated blood sugar levels. Persistently higher than normal blood glucose levels may causes insulin resistance, which reduces the sensitivity of the body's cells to the impact of insulin, and majorly contribute to obesity and even type 2 diabetes.

4.2.3 Appetite regulation

Insulin additionally works importantly in the regulation of appetite. When insulin levels rise after having a meal, it signals the brain that the body has received sufficient energy, reducing appetite and promoting feelings of fullness. However, disruptions in the circadian rhythm can disrupt the normal release of insulin and its effects on appetite regulation. Studies have shown that circadian misalignment, such as late-night eating and irregular meal times, can result in dysregulated insulin secretion, increased hunger, and a higher likelihood of overeating and weight gain.

4.2.4 Fat storage and metabolism

Insulin also operates in storing surplus glucose as fat in human body's adipose tissue. If there is a continuous elevation in insulin levels, such as in cases of insulin resistance or chronic disturbance to the body's internal clock, it is more probable for the body to store extra calories as fat instead of using them for energy. Consequently, this will result in an augmented buildup of fat and contribute to obesity.

4.3. Glucocorticoids

Glucocorticoids, a class of steroid hormones that regulate metabolism, inflammation, and stress response, as well as other factors, have the potential to impact obesity. Here's how circadian rhythms impact obesity through glucocorticoids.

4.3.1 Cortisol secretion

Cortisol, the main glucocorticoid hormone in the body, is a diurnal molecule. Cortisol usually reaches its peak early in the morning and slowly declines during the day. The circadian rhythm, specifically the central clock located in the hypothalamus and the peripheral clocks present in various tissues, is responsible for this diurnal variation. Disruptions in the circadian rhythm, such as irregular sleep patterns, can lead to dysregulation in cortisol secretion. Chronically elevated cortisol levels, especially at night, have been linked to increasing appetite, cravings for unhealthy foods (particularly high in sugar and fat), and the deposition of abdominal fat.

4.3.2 Energy metabolism

Glucocorticoids, including cortisol, have modulatory effects on energy metabolism. They promote gluconeogenesis (the production of glucose from non-carbohydrate sources) and inhibit glucose uptake in muscle cells, which may create increased blood glucose levels and insulin resistance, contributing to obesity. Glucocorticoids can also promote the breakdown of muscle protein, leading to muscle wasting and metabolic rate decreasing, making people much easier to gain weight and much harder to lose weight.

4.3.3 Lipid metabolism

Glucocorticoids influence lipid metabolism and can contribute to the accumulation of visceral fat, which is associated with increased health risks. They stimulate the breakdown of adipose tissue, releasing fatty acids into circulation. High levels of cortisol lead to growing fat storage in the human body, especially in the abdominal region. Visceral fat is metabolically active and produces various inflammatory molecules that can further contribute to obesity-related complications, such as insulin resistance and chronic inflammation.

4.3.4 Appetite regulation

Glucocorticoids have been implicated in the regulation of appetite. Elevated cortisol levels can influence the activity of brain regions involved in appetite control, resulting in heightened feelings of hunger and desires, specifically for calorie-dense and unhealthy food choices. This can contribute to overeating and weight gain, ultimately leading to obesity.

4.4. Leptin

Leptin, derived from the obesity gene and released by white adipocytes, exerts its influence on the central nervous system, overseeing energy metabolism and maintaining a relatively constant level of body fat in both humans and animals. The secretion of leptin has a certain circadian rhythm that gets low in the daytime and high at night. Here's how circadian rhythms affect obesity through leptin.

4.4.1 Leptin secretion

Leptin exhibits a diurnal rhythm, with its levels reaching the peak in the nighttime and becoming lowest in the early morning. This rhythmic pattern is impacted by our circadian rhythm, particularly the hypothalamic central clock. Disruptions in the circadian rhythm, such as irregular sleep patterns or shift work, can disrupt the normal secretion pattern of leptin. Chronically disturbed sleep or night-shift work has been associated with the human body's lower leptin levels and a mess of leptin rhythm at the same time. Reduced leptin signaling can lead to increased appetite and reduced satiety, potentially contributing to overeating and weight gain.

4.4.2 Appetite regulation

Leptin serves as a vital component in the regulation of appetite and the balance of energy. Its primary function involves targeting the hypothalamus, particularly the arcuate nucleus, to inhibit appetite and stimulate energy expenditure. When leptin levels are low or leptin signaling is disrupted, it can lead to a state of leptin resistance, where the brain becomes less responsive to the satiety signals sent by leptin. Leptin resistance can result in increased appetite, reduced energy expenditure, and difficulty in maintaining a healthy weight.

4.4.3 Metabolic rate

Leptin additionally impacts energy expenditure and metabolic rate. In situations where leptin levels are diminished or there is impaired leptin signaling, it can result in a decreased metabolic rate, which makes weight gain more likely and weight loss more challenging. Consequently, it may promote the onset and advancement of obesity.

4.4.4 Fat storage and distribution

In states of leptin deficiency or resistance, there can be an imbalance in fat accumulation, particularly an increase in visceral adipose tissue, which is associated with increased health risks. Disrupted circadian rhythms can contribute to leptin dysregulation, leading to altered fat storage patterns and an increased propensity for obesity.

5. Treatment of Obesity Targeting Circadian Rhythms

Focusing on circadian rhythms can have a substantial impact on the treatment and control of obesity. Here are some strategies that focus on aligning circadian rhythms to promote weight loss and improve metabolic health.

5.1. Sleep optimization

Adequate and quality sleep is crucial for regulating circadian rhythms and promoting overall health. Lack of sleep or poor sleep quality can disrupt the normal secretion of hormones involved in appetite regulation, including leptin. Therefore, improving sleep habits is essential. Strive for a consistent duration of 7-9 hours of uninterrupted sleep every night and adopting proper sleep hygiene practices, for example, maintain a regular sleep and get-up schedule, create a sleep-conducive environment, refrain from stimulants like caffeine and electronic devices before bedtime. These measures are able to help you assist in optimizing circadian rhythms and promoting effective weight management.

5.2. Light exposure

Exposure to natural light during the day, especially in the morning, helps synchronize the internal circadian clock. Engaging in at least 30 minutes of outdoor activity in the morning can aid in synchronizing the timing of different physiological processes, including metabolism. Natural light exposure can also help improve mood and energy levels, which can positively impact overall well-being and encourage physical activity.

5.3. Meal timing

Chrono-nutrition, which focuses on the timing and distribution of meals, can be an effective strategy for weight management. Following a regular eating pattern and aligning meal times with the body's internal clock can optimize metabolism and improve weight loss outcomes. It is generally recommended to obtain most of your calories during the day and avoid late-night eating. This practice helps maintain stable circadian rhythms and reduce the likelihood of weight gain.

5.4. Time-restricted eating (TRE)

TRE involves limiting the daily feeding window and fasting for the rest of the day. This approach can help synchronize circadian rhythms and improve metabolic health. Popular variations of TRE include the 16:8 method (adhering to a fasting period of 16 hours and confining caloric intake within an 8-hour time frame is recommended) or the 14:10 method. TRE has shown promising effects on weight loss, insulin sensitivity, and other metabolic parameters.

5.5. Physical activity

Regular exercise has numerous benefits for weight management and overall health. You can effectively regulate circadian rhythms and promote weight loss endeavors by going out and doing more physical activities. Exercise during the daytime helps promote alertness and energy expenditure, while avoiding intense exercise close to bedtime is important for maintaining a healthy sleep-wake cycle.

6. Conclusion

Disruptions in the circadian rhythm have been proved to be associated with a range of unhealthy situations, such as obesity. The disruption of circadian rhythm seems to play a part in the further exacerbation of obesity by affecting several metabolic processes. It is crucial to emphasize that any weight management strategy should be customized and adjusted according to the individual's unique requirements and preferences. When experiencing obesity that cannot be improved on your own, seek advice and assistance from a healthcare professional or registered dietitian who can help develop a comprehensive treatment plan and provide valuable guidance and support to optimize circadian rhythms. By targeting circadian rhythms through strategies like sleep optimization, light exposure, meal timing, time-restricted eating, and regular physical activity, individuals can improve their metabolic health, enhance leptin signaling, and ultimately support sustainable weight loss and obesity management. Future research should focus on elucidating the precise mechanisms linking circadian rhythm disruption to obesity and exploring targeted interventions to restore circadian alignment as a potential strategy for obesity prevention and management. More subsequent research should elucidate the exact mechanisms involved and develop specific interventions that utilize circadian regulation to combat obesity and its associated health risks.

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