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Exploring the Impact of Chrono-Nutrition on Metabolism and Weight Management: A Comprehensive Review

Mandira Chatterjee[1], Tanima Paul Das[2]

[1]M.Sc student, Kalyani University
Email: *mandira2601[at]gmail.com*

[2]Assistant Professor, Department of Food and Nutrition, Prasanta Chandra Mahalonobis Mahavidyalaya,111/3, B.T.Road, Kolkata 700108
Email: *tanima.fnta[at]gmail.com*

Abstract: ***Chrono-nutrition researches how the time of meals influences human health, using the suprachiasmatic nucleus (SCN), the brain's internal clock. This clock regulates how often you eat, your metabolism, and other body processes. The body's circadian rhythm control how food is processed, how much energy is used, and how health indicators like hormones and glucose are used. However, our love for excellent food can interfere with natural cycles and change how we eat. The effects of different meal times, such as eating in the morning vs the evening and eating within a set time limit, on metabolism and weight are studied by researchers. This reveals connection between the internal clock, meal timing, and metabolism, furthering our understanding of the potential health benefits of chrono-nutrition. The function of chrono-nutrition on metabolism and weight control is examined in this review.***

Keywords: Chrono-nutrition, circadian rhythm, metabolism, hormones, weight control

1. Introduction

Circadian rhythm, which revolve around the 24-hour day/night cycle, are controlled centrally and within peripheral tissues (1). They oversee a multitude of biological and behavioral processes. The circadian clock is sensitive to the energy and nutrients we consume, underlining its crucial role in regulating our metabolism (2).

This intricate connection between the circadian clock system and metabolism means that disturbances in one can affect the other. In today's fast-paced world, factors like shift work, stress, and disrupted sleep often lead to circadian misalignment, increasing the risk of metabolic disorders (3,4). Eating habits affect your body's internal clock. Irregular meals can disrupt this clock, causing health issues. Stick to a regular eating schedule for better health (5).Chrono-nutrition is all about understanding the timing of when we eat and its impact on our metabolism and weight (2, 4). Our body's internal clock, called the circadian rhythm, plays a vital role in this. It regulates various bodily functions, and when we eat is just as important as what we eat for our metabolic efficiency and weight control (1) .Our body's metabolism changes during the day. In the morning and early afternoon, our metabolism is faster, so it's a good time for big, energy-packed meals. But as evening comes, our metabolism slows down. This means we should go for lighter, less calorie-heavy meals at night (6). Our body releases certain substances like insulin and melatonin. These substances affect how we handle calories and store fat. When we eat in sync with these releases, it can help our body use nutrients better, which might help us control our weight. This is the idea behind chrono-nutrition (7). Research in this field has produced intriguing findings. Some studies suggest that chrono-nutrition may contribute to reduced risk factors for obesity, type 2 diabetes, and other metabolic disorders (4). It's essential to recognize that individual factors, such as genetics and lifestyle, can influence the effectiveness of this approach. As the understanding of chrono-nutrition continues to evolve, it represents a promising avenue for enhancing our knowledge of how meal timing impacts metabolism and weight management, with the potential to revolutionize dietary guidelines and practices (2,3).

2. Literature Survey

Circadian Rhythm

Circadian rhythm is an intricate biological clock that operates in almost all living organisms, including humans. It's synchronized with the 24-hour day-night cycle. This internal clock regulates various physiological processes, such as body temperature, hormone secretion, and sleep-wake patterns (8). It plays a crucial role in ensuring that these functions occur at the right time, allowing your body to adapt and function optimally in harmony with the external environment. Disruptions in your circadian rhythm can lead to sleep problems, mood disturbances, and other health issues (8,9). The circadian rhythm is an intricate biological system that influences the timing of various physiological processes. At its core are specific genes, known as clock genes, which control the production of proteins within our body's cells (10). These clock genes operate as molecular timekeepers, orchestrating the body's activities over a 24-hour cycle (8). The master clock, which oversees this entire system, resides in the suprachiasmatic nucleus (SCN) in the brain. The SCN is highly responsive to external cues, particularly light. When exposed to light, especially in the morning, it signals the body to wake up and become alert, helping align our internal clock with the natural day-night cycle (11). The circadian rhythm also exerts control over hormonal regulation. For instance, it governs the release of melatonin, a hormone responsible for promoting sleepiness.

In the evening, when it gets dark, the SCN signals the pineal gland to produce melatonin, preparing our body for sleep (11, 12). Our body temperature follows a circadian pattern, with its lowest point typically occurring in the early morning and its highest point in the late afternoon. This temperature fluctuation influences your alertness and sleep-wake cycle (13, 14) .Metabolic processes are also under the circadian rhythm's sway. For instance, insulin, which manages blood sugar levels, is more effective during the daytime, making meals consumed earlier in the day better for blood sugar control (15). The circadian rhythm plays a pivotal role in regulating your sleep-wake cycle, causing you to wake up in the morning and feel tired at night (13, 15). External cues, such as exposure to natural light, mealtimes, and physical activity, play a crucial role in synchronizing and reinforcing the circadian rhythm. For instance, early morning exposure to bright light can help reset our internal clock and maintain a consistent 24-hour cycle (16).

The circadian rhythm is a complex biological system that governs the timing of various physiological processes, including sleep, hormone regulation, body temperature, and metabolic functions. It is influenced by both internal factors, such as clock genes, and external cues, like light exposure and meal timing. Disruptions to this rhythm can have profound effects on our health and well-being (14, 15, 16).

Chronotype

The internal timekeeping system, known as the circadian rhythm, follows a 24-hour cycle and plays a critical role in regulating an individual's level of alertness. It's like an internal clock that synchronizes with the external day-night cycle (17). During the day, this circadian rhythm acts as a powerful signal, essentially telling the body that it's time to be awake, active, and alert. It orchestrates a complex set of physiological and behavioral changes to ensure that an individual is at their most alert and energetic during the daylight hours. As the day progresses and evening approaches, the circadian rhythm continues to exert its influence, reaching its zenith as the day transitions into evening (18). This peak in circadian activity is responsible for the period of maximum alertness and wakefulness during the day, often referred to as the "wake maintenance zone."In simple terms, the circadian rhythm is like an internal clock that fine-tunes our alertness, with its influence intensifying as the day unfolds, reaching its peak in the evening (17, 18).

Inside the human body, there's a system that functions as a sleep regulator, much like a financial ledger. This system constantly keeps track of the hours an individual remains awake and the body's ongoing need for sleep. This tracking system is often referred to as "sleep debt."

The concept of sleep debt can be compared to a running tally of sleep owed to the body. As a person stays awake, this sleep debt steadily accrues. The more hours a person remains awake, the greater the sleep debt becomes. This accumulating sleep debt triggers a growing inclination to sleep and a progressive sense of drowsiness. It's similar to a gentle reminder from the body that it's time to rest and replenish the sleep "account."(18, 19).

Chrono Nutrition Influences Human Health

Animal and human studies show that when we eat during the day can affect our body's metabolic rhythms, which are crucial for our health. Our food intake has a significant impact on our internal circadian clocks, which are like tiny molecular oscillators found in nearly every cell and tissue in our body (20). These clocks help coordinate various metabolic processes.When we eat at irregular times, it can throw off our circadian system. This disruption, caused by mistimed eating, can lead to problems with how our body regulates energy and metabolism(20,21). Ultimately, it increases the risks of heart and metabolic issues, such as obesity, type 2 diabetes, and cardiovascular disease (21).

The exact reasons behind this likely involve multiple signals in our body, various hormones related to energy regulation, and changes in how our body handles fat. Some of these hormones, like cortisol, insulin, and leptin, follow a daily rhythm. Their levels peak at specific times during the day, making it better for our body to process nutrients earlier in the day. One particularly important hormone is Adiponectin (22). It's produced by our fat cells and has many health benefits, including helping with diabetes, inflammation, and heart health. When Adiponectin levels are low, it's linked to obesity and related health problems. But losing weight or eating less can increase Adiponectin levels, making our bodies more sensitive to insulin and improving overall health (21,22).

Irregular eating patterns mean eating at different times throughout the day without a consistent schedule. Research shows that many adults have eating habits like this, andthey don't stick to the usual breakfast, lunch, and dinner routine.One common irregular eating habit is skipping breakfast. Having breakfast regularly is linked to better nutrition and lower sugar intake for the rest of the day. Studies have suggested that skipping breakfast is associated with a higher risk of heart disease, type 2 diabetes, obesity, and even cardiovascular-related mortality (23).

The autonomic nervous system (ANS) plays a important role in regulating the body's response to stress. Sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS) are the two branches of ANS. These two branches work in a coordinated manner to manage stress and maintain equilibrium in the body (22).

Sympathetic Nervous System (SNS):

- **Fight or Flight Response**: Stress activates SNS, then it initiates the "fight or flight" response. This involves the release of stress hormones like adrenaline and nor adrenaline.
- **Increased Alertness:** The SNS increases heart rate, dilates airways, and redirects blood flow to the muscles, preparing the body for quick action.
- **Mobilizing Energy:** It mobilizes energy stores to provide the body with the necessary resources to respond to a stressful situation (22, 23).

Parasympathetic Nervous System (PNS):

- **Rest and Digest:** The PNS, often referred to as the "rest and digest" system, works in opposition to the SNS. It promotes relaxation, conserves energy, and supports recovery.

- **Counterbalancing Stress:** When the stressor subsides, the PNS takes over to counteract the effects of the SNS. It slows the heart rate, constricts airways, and redirects blood flow to the digestive and reproductive systems.
- **Recovery and Healing:** The PNS facilitates recovery by promoting functions like digestion, tissue repair, and energy storage (25).

The SNS and PNS maintain a balance in the body's response to stress. They ensure that the body is prepared to react to stressors when needed but also able to return to a state of rest and recovery once the threat has passed. Chronic or excessive activation of the SNS, often due to ongoing stress, can lead to health issues, so it's crucial to manage and reduce stress to maintain a healthy balance in the autonomic nervous system. Techniques like relaxation, meditation, and deep breathing can help activate the PNS and reduce the impact of chronic stress on the body (23, 24, 25).

Circadian Rhythm Controls Hormones

Circadian rhythm indeed plays a vital role in regulating hormone production and release within the body. These internal rhythms help orchestrate the timing of various hormonal processes, influencing a wide range of physiological functions Cortisol, often referred to as the "stress hormone," exhibits a well-defined circadian pattern in its release. This means that the body's production of cortisol follows a specific daily schedule (26).

In the early morning, particularly upon waking, cortisol levels tend to reach their highest point. This morning surge in cortisol is a natural response designed to prepare the body for the demands of the day. It helps increase alertness, provides the energy needed for daily activities, and As the day progresses, cortisol levels gradually decline. By evening, they are typically at their lowest point (27). This diurnal variation in cortisol is crucial for maintaining a healthy response to stress and for regulating energy metabolism. It ensures that cortisol is available when needed for dealing with challenging situations, and it also allows the body to wind down and prepare for rest during the night(28) .Chronic stress or irregular sleep patterns can disrupt this natural cortisol rhythm, potentially leading to health issues. High and prolonged cortisol levels, as seen in chronic stress, can have negative effects on various body systems, including the immune, cardiovascular, and metabolic systems. Therefore, maintaining a healthy circadian cortisol rhythm is essential for overall well-being (29).

Melatonin, often referred to as the "sleep hormone," is a crucial component of the body's sleep-wake regulation. It's synthesized in the pineal gland, a small endocrine gland located deep within the brain.Melatonin production is profoundly influenced by the circadian rhythm, a natural internal clock that governs various physiological processes over a 24-hour cycle (28). The circadian rhythm is closely tied to the light-dark cycle, meaning it responds to changes in natural light. Melatonin acts as a biological timekeeper, helping to synchronize various bodily functions with the day-night cycle. When it starts to get dark in the evening, the pineal gland begins to produce melatonin. This rise in melatonin levels serves as a signal to the body that nighttime is approaching. Exposure to light, especially blue and white light, can suppress melatonin production. This is why it's recommended to reduce exposure to electronic screens before bedtime, as the artificial light can interfere with the body's natural melatonin release (28, 29).

Insulin: Circadian rhythm can affect the body's sensitivity to insulin and the release of this hormone by the pancreas. Disruption of circadian rhythm, often seen in shift work or irregular sleep patterns, can lead to insulin resistance and an increased risk of metabolic disorders like type 2 diabetes (30).

Appetite-Regulating Hormones: circadian rhythm impact hormones related to appetite and metabolism, including ghrelin (which stimulates hunger) and leptin (which signals satiety). Disruption of these rhythms can contribute to weight-related issues (31).

*Adiponectin:*This hormone, associated with metabolic health, follows a circadian pattern. Its levels are typically higher during the day and lower at night (30, 31).

Circadian rhythm helps align the timing of these hormonal processes with the body's daily activities and environmental cues, such as light and darkness. Maintaining a regular sleep-wake schedule and exposure to natural light can help support healthy circadian rhythm and, in turn, optimize hormonal regulation for overall well-being. Disruption of circadian rhythm, as seen in conditions like shift work sleep disorder, can lead to imbalances in hormone production and contribute to health issues (28, 30, 31).

Influence of Suprachiasmatic Nucleus (SCN on circadian rhythim

The suprachiasmatic nucleus (SCN) is a small paired structure in the hypothalamus region of the brain. It acts as the body's central biological clock, governing the body's circadian rhythm. Circadian rhythm are approximately 24-hour cycles that control various physiological and behavioral processes (32).The SCN's main functions include regulating the body's internal clock and aligning it with the external environment, primarily the natural light-dark cycle (33) . It receives information about light and darkness from the eyes, allowing it to adjust circadian rhythm based on external light cues. This synchronization helps ensure that processes like the sleep-wake cycle, body temperature, hormone secretion, and other daily activities occur at the appropriate times (32, 33). The SCN also influences the pineal gland's secretion of melatonin, a hormone that plays a significant role in regulating sleep and wakefulness. It inhibits melatonin production during the day to promote wakefulness and stimulates melatonin release at night to facilitate sleep (34). In addition to regulating the sleep-wake cycle, the SCN also affects other processes like hunger, alertness, and hormone release. It plays a critical role in coordinating these processes throughout the day to maintain overall health and well-being.The SCN's proper functioning is essential for maintaining circadian rhythm and overall health. Disruptions to its function can lead to sleep disorders, mood disturbances, and various health problems (35).

The SCN is responsible for generating and maintaining the body's internal circadian rhythm. These rhythms include the sleep-wake cycle, body temperature, hormone secretion, and other daily processes. The SCN helps align these internal rhythms with the external environment, primarily the light-dark cycle (33, 35).

The SCN receives direct input from the eyes via the optic nerve. Specialized photoreceptor cells in the retina send information about light and darkness to the SCN. This allows the SCN to adjust the body's circadian rhythm based on external light cues, ensuring that our internal clock stays synchronized with the natural day-night cycle (36).

The SCN influences the pineal gland's secretion of melatonin, a hormone that plays a key role in regulating sleep and wakefulness. During the night, the SCN inhibits melatonin production, helping to keep individuals awake. In the morning, when exposed to light, the SCN signals the pineal gland to decrease melatonin secretion, promoting wakefulness (33, 34, 35, 36).

Circadian Rhythm Disruption

Narcolepsy

Circadian rhythm disruption can be a significant issue for individuals with narcolepsy. Narcolepsy is a neurological disorder characterized by excessive daytime sleepiness, sudden loss of muscle tone (catalepsy), sleep paralysis, and hallucinations. These symptoms can be exacerbated when the circadian rhythm, which regulate the sleep-wake cycle, are disrupted (37)

People with narcolepsy often struggle with maintaining a regular sleep schedule because they may experience excessive daytime sleepiness and unexpected sleep attacks. This can disrupt their natural circadian rhythm, making it challenging to maintain a consistent sleep-wake pattern (38).

Narcolepsy can lead to fragmented sleep at night, with frequent awakenings and disturbances. This can further disrupt the normal progression of sleep cycles and interfere with the alignment of the circadian rhythm (39).

The circadian rhythm is primarily governed by the body's internal clock, which is influenced by external cues like light and darkness. Disruption in these cues, such as staying awake during the night or sleeping during the day due to narcoleptic symptoms, can lead to a misalignment between the internal clock and the external environment (37,39) .This misalignment can worsen narcolepsy symptoms and lead to sleep disturbances.Managing circadian rhythm disruption in narcolepsy may involve strategies like light therapy, maintaining a consistent sleep schedule, and adjusting medication regimens under the guidance of a healthcare provider. Behavioral and lifestyle modifications can also help individuals with narcolepsy to better align their sleep patterns with their circadian rhythm, ultimately improving their quality of life and symptom management (40).

Some medications used to treat narcolepsy, such as stimulants or wake-promoting agents, can affect the circadian rhythm and potentially lead to further disruption. Proper management of these medications is important to minimize their impact on the sleep-wake cycle (37,40).

Importance for teenagers in maintaining body weight

Hormonal Balance: Excess body fat can disrupt hormonal balance, potentially leading to irregular menstrual cycles in females and hormonal imbalances in males. Maintaining a healthy weight can help regulate these hormonal changes (41).

Decreased Risk of Eating Disorders: Striving for a healthy weight while focusing on balanced nutrition can reduce the risk of developing eating disorders like anorexia or bulimia (42).

Improved Sports Performance: For teenagers involved in sports or physical activities, maintaining a healthy weight can enhance performance, agility, and endurance (43).

Lower Risk of Joint Problems: Carrying excess weight can strain the joints, leading to issues like knee pain and osteoarthritis later in life. Maintaining a healthy weight can reduce the risk of joint problems (44).

Better Quality of Life: Being at a healthy weight allows teenagers to enjoy a better quality of life, with more energy, fewer physical limitations, and improved overall well-being (45).

Lower Risk of Sleep Problems: Excess weight can contribute to sleep disturbances such as sleep. Maintaining a healthy weight can lead to better sleep quality and overall rest (46).

Reduced Risk of Psychological Stress: Maintaining a healthy weight can reduce stress related to body image concerns and weight-related bullying or discrimination (45).

Positive Role Modeling: Teenagers who maintain a healthy weight can serve as positive role models for their peers and siblings, promoting healthy lifestyle choices among their social circles (40,43).

Support for Academic Goals: Good nutrition and regular physical activity can enhance concentration, memory, and cognitive abilities, which can benefit academic performance (47).

Longevity: Maintaining a healthy weight can contribute to a longer and healthier life, reducing the risk of premature mortality associated with weight-related health issues.

Better Immune Function: A balanced diet and a healthy weight can support a strong immune system, reducing the risk of illnesses and infections (48).

3. Conclusion

Chrono-nutrition research explores the intricate relationship between our internal biological clock, meal timing, and its impact on metabolism and weight control. The suprachiasmatic nucleus (SCN) plays a pivotal role in regulating when we eat, how our metabolism functions, and various other physiological processes. circadian rhythm

dictate how our bodies process food, utilize energy, and manage key health indicators like hormones and glucose.

Studies investigating the effects of different meal times, such as morning versus evening eating and adherence to set time limits, have shed light on how our eating habits can interfere with our natural circadian rhythm. These studies provide valuable insights into how meal timing can influence our metabolic processes and weight management.

Chrono-nutrition research has the potential to uncover the health benefits associated with aligning our eating patterns with our internal clock, promoting overall well-being. By understanding how chrono-nutrition affects metabolism and weight control, we can make more informed choices about when and what we eat, potentially leading to improved health outcomes and enhanced quality of life. Further research in this field will likely continue to expand our understanding of the complex interplay between meal timing, our biological clock, and overall health.

4. Future Scope

Chrononutrition can help in the framework of nutritional requirements specific to age, gender, race, biological status, metabolic status thus preventing risks of metabolic disorders and tailored lifestyle management.

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Author Profile

Ms. Mandira Chatterjee has completed her graduation in Food and Nutrition (Honours) from PCM Mahavidyalaya, 111/3, B. T. Road, Kolkata 700108 affiliated to WBSU and currently pursuing M.Sc in Food and Nutrition from Kalyani University , West Bengal.

Dr. Tanima Paul Das has completed her PhD from University of Calcutta and engaged as Assistant Professor in the Department of Food and Nutrition, PCM Mahavidyalaya, 111/3, B.T.Road, Kolkata 700108 affiliated to WBSU for more than a decade.