Practical Applications of The Circadian Rhythm

Erin Ford

Abstract

The Circadian Rhythm is a cycle within the body that controls multiple biological processes such as the sleep-wake cycle, body temperature, hormone releasing, and digestive system. The circadian rhythm is widely theorized and understood to be developed because of the daily cycle of light and dark. This can be attributed to sunlight serving as the primary source of food for photosynthetic organisms, causing a cycle within the organism that causes food to be processed during the hours of daylight and a period of fasting during the night. Recent research has suggested that disruptions in this rhythm can lead to various issues within the body. However, there have been advancements in the applications of the circadian rhythm in the areas of the immune system and infection; exercise and sleep; digestion and food-processing; and cancer and treatments. This paper explores the fundamental mechanisms of the circadian rhythm and the impact on human health in various areas, advocating for practical applications of this profound biological cycle.

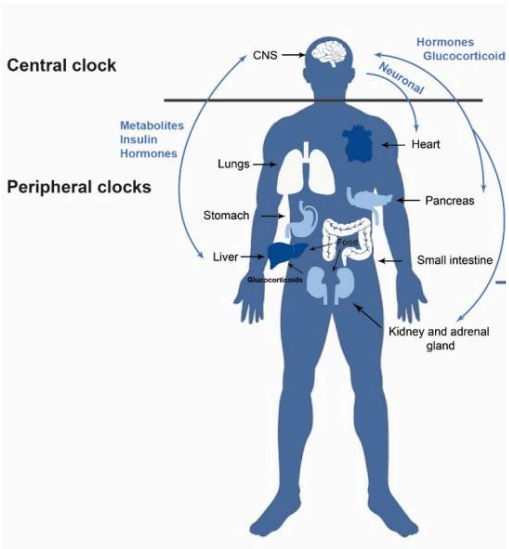
Introduction to the Circadian Rhythm and Its Importance

The circadian rhythm can be defined as the internal clock that controls feelings of awakeness and sleepiness in response to the 24 hour cycles of light and dark from the environment. The importance of the circadian rhythm cannot be understated, as the proper functioning of this cycle is crucial for everything from memory consolidation, eating habits, and digestion to body healing, temperature, and hormone release (Reddy, 2023). These processes ensure that your body is able to function normally.

An example emphasizing the importance of the circadian rhythm is the release of melatonin and cortisol, a process necessary for the proper functioning of the sleep wake cycle and even further, the proper functioning of the brain. Melatonin is a hormone that is released from the pineal gland to induce sleepiness in response to a lack of light while cortisol is a hormone that promotes alertness in response to the presence of light (Reddy, 2023). This occurs because of the suprachiasmatic nucleus (SCN) of the hypothalamus, the region of your brain that controls homeostasis. In the presence of light, the retinal cells within the eyes will perceive this light and transmit this information via the optic nerve. The optic nerve then activates the SCN, producing a signaling molecule called GABA (gamma-amino-butyric acid), inhibiting the release of melatonin. In essence, the light perceived by the optic nerve causes the body to send out signals through the SCN, preventing the release of melatonin so that the feeling of sleepiness goes away during the day. The opposite occurs when there is no longer light: the retinal cells recognize the lack of light and inhibit the SCN, preventing the release of GABA and initiating the production of melatonin and inducing sleepiness (Reddy, 2023).The proper functioning of the circadian rhythm for this process is essential because a lack of/excess melatonin could cause the body to not be able to sleep at night or a feeling of tiredness during the day. Lack of sleep can even affect mood, learning ability, and social cognisance (Sleep Deprivation, 2022).

A lack of properly functioning circadian rhythm can lead to various sleeping disorders, as well as issues related to the absence of zeitgebers—environmental signals like light, temperature, or food that cue the body to adapt its processes accordingly (Chaix, 2016). For example, “While blind individuals do have a pathway in the brain that functions as their body clock, roughly half of blind individuals experience non-24-hour sleep-wake rhythm disorder, during which their sleep cycles get later every night, jumps around, or results in waking up later in the day” (Reddy, 2023).

This process is just one of many that is controlled by the circadian rhythm, stressing its importance. The circadian rhythm is able to function because of the influence of zeitgebers. Because of the many bodily processes influenced by the circadian rhythm, the manipulation of zeitgebers and timing of treatments along with them is being researched as a method of treatment for various illnesses and infections via the immune system. Additionally, lifestyle changes that utilize the timing of the circadian rhythm can lead to better overall health; the circadian rhythm is even being taken into consideration for cancer treatment in a practice called “circadian medicine or chronotherapy” (Dose, 2023). The importance of the circadian rhythm and its ability to be manipulated through zeitgebers has led discoveries about its influence over immune response efficiency.



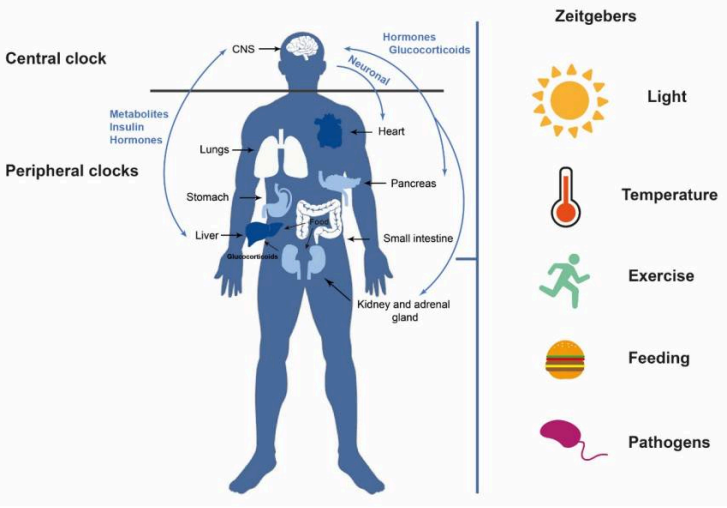


Figure 1. A diagram explaining the processes controlled by the circadian rhythm as well as the factors controlling it. Cycle zoomed in on previous page. Obtained from an overview article by Ana Amiama-Roig and others.

Timing and the Immune System

One of the systems the circadian rhythm can be used to control and improve is the immune system. The circadian rhythm is responsible for the timing of expression of many proteins; some of these are important for the initial response for the immune system. One such protein is REV-ERBα: this protein is a key part of the immune system because it "regulates transcription of inflammatory genes in macrophages" (Ruan, 2021). These macrophages are the lymphocytes that are responsible for removing unfamiliar and potentially harmful entities in the body. Another example is Nuclear receptor RORγt which is "a master regulator for the development of IL-17-producing T helper cells (TH17 cells), an important immune cell type for autoimmunity" (Ruan, 2021). T helper cells are essential for activating other cells within the immune system, such as those required to eliminate infected cells and foreign bodies. Additionally, the circadian rhythm controls the acquisition of lymphocytes. For example, the amount of B and T lymphocytes in circulation oscillates along with the rest and activity cycle, with increased numbers in the rest phase. The more lymphocytes in circulation, the more effective the immune response will be and the faster the recovery. The control the circadian rhythm has over these processes make the manipulation of zeitgebers a viable option for the treatment of infections. For example, light and dark cycles are used to increase T and B cells within a patient because of their peak during the rest phase. The lack of light acts as a zeitgeber to initiate the rest phase, leading to the increase in production of these cells. This leads to an increased immune response from the patient and a better chance of recovery from the infection (Ruan, 2021). By placing the patient in a room with low light and initiating this rest phase of the circadian rhythm, more white blood cells can be produced. This timing along with the circadian rhythm can contribute to the immune system's ability to fight off an infection.

Exercise and the Circadian Rhythm

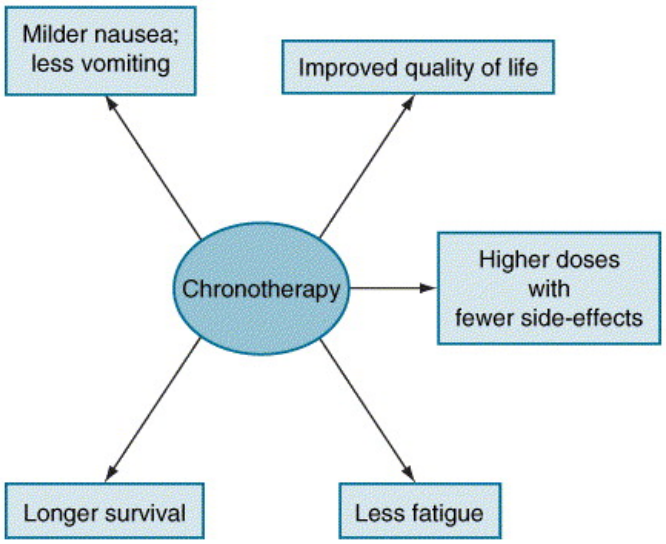
The timing of daily activities such as eating and exercise along with the circadian rhythm can result in more efficient bodily processes such as exercise and digestion. As light and dark cycles are important in the moderation of lymphocytes, the timing of daily activities--like eating or exercising--can improve the effectiveness of various bodily processes. Research has demonstrated that blood pressure, body temperature, hormone levels, and heart rate variability are all controlled by circadian variation (Dose, 2023). With these physiological features being integral to sport performance, timing exercise with the optimal levels of these factors can increase effectiveness of exercise and peak performance during periods of exercise. Conversely, misalignment can be detrimental to effectiveness of sleep cycles: "Night exercise causes a phase delay of the onset of dim-light melatonin" (Wang, 2022). As a result, exercise before bed is not recommended because it can block the production of the hormone that induces the feeling of tiredness and it is advised that physical activity take place slightly earlier in the day. Therefore, a better sleep schedule can be obtained based on the timing of exercise with consideration of the circadian rhythm. This better sleep schedule leads to all of the benefits associated with more sleep, such as improved immune response to possible pathogens (Ruan 2021). This indicates that consideration of the circadian rhythm in the timing of exercise can not only improve the quality of the exercise but also improve other necessary functions such as sleep and digestion.

Effective Digestion and The Circadian Rhythm

Similar to the timing of exercise, the timing of meals with consideration of the circadian rhythm can also result in a healthier lifestyle. For example, "insulin mediates the phase adjustment of the circadian rhythm of the tissues related to food in mice" (Wang, 2022). This process is important for tissue function which, in turn, assists in digestion and absorption of nutrients and aligning the stomach's circadian rhythm with meal times. Hence, the timing of meals with respect to the circadian rhythm can affect the efficiency of meal processing. Recent research supports this idea: in a study describing how the circadian rhythm controls pathways related to metabolic processing, researchers found that these pathways begin to increase when eating is anticipated. This is a temporary effect that declines after a few hours (Chaix. A, 2019). These results indicate that having a scheduled eating time every day can assist in the absorption of nutrients because the body will always be prepared to process food during that time. Furthermore, deviating from this schedule would mean consuming a large amount of nutrients when the body is not prepared to process it, and, as a result, leads to a less efficient digestive process. This supports the argument that "the consumption of a larger portion of caloric intake during the first half of wakeful hours may be preferred for better blood glucose regulation and weight control" (Dose, 2023). Essentially, after a large period of fasting, or sleep, the body has had a long period of time to prepare for the next meal and because of this, the circadian rhythm has ensured that the proper pathways are prepared. Cumulatively, the timing of meals alongside the circadian rhythm results in more efficient digestion and leads to better absorption of the nutrients necessary for other processes within the body.

Chronotherapy and Cancer Treatment

The circadian rhythm's applications are not only exclusive to day to day life but also have significance within the medical field. The timing of the circadian rhythm can be used to increase effectiveness of cancer treatments and the overall quality of life in cancer patients. The time of day when cancer treatments are administered can affect how much of the dose can be tolerated and the side effects experienced by the patient. An example of this was a study done with mice that found "the same dose of an anticancer drug became lethally toxic only when administered at certain times of day, whereas at other times of day, a 10-fold increase in dose was tolerated"(Ancoli-Israel, 2005). These results seem logical when considering the amount of processes that are controlled by the timing of the circadian rhythm. Certain proteins being made at specific times may help the body process the drugs or could cause unpleasant interactions leading to side effects of the drug. If the circadian rhythm dependent proteins that cause unpleasant interactions are made mostly within the first hours of waking, then the majority of this interaction can be avoided by taking the drug treating the cancer later in the day. Other research focusing on cancer patients has shown that the quality of life of the patient increases significantly when chronotherapy is used. Administration of the drug during the morning was compared with administration during the evening and it was found that during the morning hours patients experienced "milder nausea, and less vomiting in those receiving the chemotherapy in the evening" (Ancoli-Israel, 2005). The reduction of these unpleasant side effects leads to the patient feeling better physically, which in turn leads to "better psychosocial adaptation (including better social relations, less feeling of loss of independence, less anxiety, less depression, and less somatic discomfort) than patients receiving traditional therapy" (Ancoli-Israel, 2005). It is then likely that chronotherapy plays a part in the patient having fewer side effects and better quality of life during treatment.



Chronotherapy is an effective treatment method because of the difference between the circadian rhythms followed by cancerous and noncancerous cells. According to Benjamin Dose "Chronotherapy aims to exploit these differences in circadian rhythms by administering treatments at times when cancer cells are most vulnerable, and healthy cells are least vulnerable, thereby reducing toxicity and enhancing efficacy" (Dose, 2023). This strategy ensures that the cancer treatment can be administered at a time when it will be the most effective and when the healthy cells will be least affected which is what causes the minimized side effects. This kind of thinking may extend beyond cancer treatment and to other more common medications with adverse side effects. If other medications can be found to be more effective or have reduced side effects at certain periods of the circadian rhythm, then the same benefits as those from chronotherapy can be obtained.

Conclusion

To summarize, the circadian rhythm is a very powerful process in the human body that has a great deal of control over the different processes in the body; therefore, it is important to consider the circadian rhythm when carrying out certain processes, such as fighting off an infection. For example, more lymphocytes are produced during the rest phase which is initiated by a lack of light. The use of light and dark cycles can then be used to increase the amount of lymphocytes in circulation, which could increase the immune response to an infection. It is also important to consider the circadian rhythm in everyday habits such as when to eat or exercise. Exercising before bed can delay the release of melatonin and can lead to a worse night of sleep. Additionally, eating at the same time everyday can help the body process the caloric intake better because the circadian rhythm causes the proper digestive proteins to be produced at that same time each day. Furthermore, because the circadian rhythms of cancerous and noncancerous cells differ, the timing of cancer treatments to when cancerous cells are most vulnerable and noncancerous cells will be least affected by the treatment. This can lead to a decrease in unpleasant side effects, increase in effectiveness and overall better treatment experience for the patient. These applications emphasize how important the circadian rhythm truly is and further research may reveal even more applications of this complex system leading to new treatments and even more ways to live a healthier lifestyle.

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