CIRCADIAN RHYTHMS AND HORMONAL HOMEOSTASIS IN ANIMALS: A REVIEW

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ABSTRACT

Circadian rhythms modify many physiological and behavioral mechanisms, include cycles of sleep-wake, the release of hormones, and metabolism. with an average period, a duration of 24 hours. Environmental disturbance of the daily rhythms might results in negative effects on animal health consequences in animals, and human involved in shift work. The neural system controls circadian rhythms consisting of a biological clock, input pathways, and output pathways. Within the anterior hypothalamus, a biological clock has arisen from the paired suprachiasmatic nuclei (SCN). Rods, cones, and a population of naturally photosensitive retinal ganglion cells sense light for circadian entrainment. A highly conserved set of genes, collectively called "clock genes," also controls circadian rhythms. Also, the pineal gland of birds has one or more circadian oscillators which play an important part in the overall temporal organization. The most common diseases involve variations in circadian rhythms, and circadian dysfunction is also a causative factor for other chronic diseases. Despite strong development in the past 20 years in discovering circadian mechanisms, much residual to be learned about circadian clocks.

INTRODUCTION

Circadian rhythms are biological rhythms driven by a biological everyday clock that continues even in a constant setting. This biological clock is an approximately 24-hour cycle in the living organism's biochemical, physiological, or behavioral processes, and aimed at optimizing cellular functions and acknowledging the solar day-related environmental challenges (1). It is widespread, in humans, plants, animals specially, poultry, birds, fungi, and even some bacteria (cyanobacteria). These studies are however limited in poultry (2). The circadian avian system is more complicated than the mammalian system. It is consisted of circadian oscillators that reside in the pineal gland, the retina and the suprachiasmatic nucleus. The SCN contains two types: the visual (v-SCN) and the medial (m-SCN). Avian has extra-ocular photoreceptors, so they have independent so controlled pacemakers that are missing in mammalian (3). Therefore, more attention may be required to study chronophysiology in avian species. (4). The pattern of importance of circadian rhythms involves the sleep-wake process and regular fluctuations in hormone development. Circadian rhythms as well contribute to the pathogenesis of diseases like myocardial infarction and reactive airway disease. Even regular rhythms are usually restricted during the natural photoperiod under tropical conditions in broilers (5). Birds are a premium model for investigating the influence of biological clocks in the reproductive system for two purposes: daily ovulation-oviposition rhythms are well defined and simple to locate in adult female birds (6). The morphological features and functional anatomical parts of preovulatory follicles are very well recognized and the follicle size determines the stage of follicular growth.The study aimed to investigate the relationship between the circadian rhythms and some hormonal homeostasis.

Circadian Timing System:

The Circadian timing system is the neural system that is responsible for the generation and regulation of circadian rhythms which is consists of three units:

(1) Biological clock or master clocks or circadian pacemaker.

(2) An input pathway which lets environmental stimuli to reset the clock.

(3) Output pathway that controls the processes physiology and behavioral (7).

Circadian clock cells in animals are organized into multicellular pacemakers and are regulated along with the rhythms. The circadian system involves 'master clocks' like the mammalian suprachiasmatic nucleus (SCN) in the brain and peripheral pacemakers, which can control rhythmic processes in ovary, liver and heart. Mechanisms by which the peripheral oscillators are regulated by the SCN including rhythmic body temperature, food intake, and hormones (8). Avian circadian is regulated via the numerous circadian pacemakers, the medial suprachiasmatic nuclei (mSCN) and the visual suprachiasmatic nuclei (vSCN) which have directly and indirectly photo input from multiple eyepiece and extraocular photoreceptors. At the molecular level, a highly conserved group of genes, collectively termed "clock genes," controls circadian rhythms varying from Drosophila to humans. The Products of these genes dynamically react to create rhythmic patterns of transcription, translation, biochemical, physiological processes, and behavior. Circadian rhythm exerts a profound influence on various physiological responses and ultimately the productivity of animals(9).

Notable examples of circadian rhythms include the sleep-wake cycle, daily rhythms in body temperature, and day-night rhythms in cortisol and melatonin production. Day-night differences in gonadotropin, testosterone, growth hormone and thyrotropin secretion are also present(10).

Circadian rhythm and gonadotropic hormones relationship

The circadian system is essential in vertebrate reproduction because its effects follicle maturation and ovulation(11). The central circadian structure avian comprises of 3 discrete oscillators in a hypothalamic zone, the retinae and the pineal gland, probably similar to the SCN of mammals. (12). The close relation among the circadian timing mechanism and the hypothalamic-pituitary-gonadal axis was confirmed by prior research. In short, a central clock signal is essential to initiate the increase of the LH and consequently for ovulation. A circadian ovarian clock has been well established recently in several species of mammals and non-mammals, and its role in most known cases is linked to the timing of gene expression in mature granulosa cells, including genes related to steroidogenesis, gonadotropin responsiveness and ovulation. (13). Gonadotropins (FSH and LH) possibly can regulate clock gene rhythms, which act to synchronize follicular cell activity (14).

Circadian Rhythm and Homeostasis of Hormone

Numerous hormones have been shown to have regular oscillations, amongst those best described are melatonin, cortisol, gonadal steroids, prolactin, thyroid hormone and growth hormone. A so-called nutritionally-sensitive hormones, which include insulin, ghrelin, leptin and adiponectin, further oscillate circadian and their secretion is controlled, at least to some extent, by environmental stimuli such as feeding times and light-dark cycles (15).

Melatonin

Melatonin a hormone is mainly produced by the pineal gland and function as an important part in a variety of mammalian physiological processes, such as control for brain chemistry associated with visual, reproductive, neuroimmune and neuroendocrine actions. The principal function of this substance is to regulate the biological clock and change the body's rhythm. The synthesis and release of melatonin are enhanced in the dark, at sunset and inhibited by sunlight. Melatonin synthesis peaks at midnight, 24:00 to 03:00 in both nocturnal and diurnal species. Nevertheless, artificial light at night causes levels of plasma melatonin to decline (16). SCN interacts directly with the pineal gland through the sympathetic neurons of the upper cervical ganglion and, however, the rhythmic behavior of the SCN affects the production of melatonin specifically correlated with the duration of the day. Sure, melatonin can be called the main (relayer) conveying light-information about the dark cycle (17).

The above hormone even plays a crucial role during sexual behavior as well as in the implantation of blastocysts in various mammal species, such as goats, hamsters, horses and rodents. Mothers melatonin delivery in mammalian often means that the normal photoperiod experienced by the mother's pregnancy or breastfeeding is transmitted to the embryo through both the placenta or milk (18).

In addition, it participates in estrogen production by suppressing the aromatase enzyme that regulates its rearrangement from its androgenic precursors, changing a whole cycle of blastocyst implantation as well as follicle production. Experiments also have shown that rodents subjected to constant light stimulating or pinealectomized experience a decrease in the amount of melatonin released, causing changes in the estrous cycle prolonging the estrous period. The exogenous administration of melatonin in rats pinealectomized or exposed to continuous light, however, controlled the process (19). In contrast, a decline in follicle-stimulating hormone (FSH) levels was reported following pinealectomy with successive melatonin therapy, resulting in deterioration of follicular action and ovarian hormone output. This endogenous melatonin connections are controlled inside the SCN with its receptors and even the reproductive effects begin to happen and are governed within the hypothalamus (20).

Cortisol

Cortisol is a powerful hormone produced within the adrenal glands. It will regulate several metabolism processes, like lipolysis, proteolysis and glycogenolysis. The quantity and frequency of cortisol are regulated through the circadian clock. The production of cortisol in circulation approaching its peak just before morning awakening. The cortisol slows down across the whole day. During sleep it reaches its lowest rate after midnight(21). Cortisol is one of the best described of all glucocorticoid hormones from a circadian. Cortisol is a significant hormone that controls body metabolic events. This improves the use of endogenous fuel stores for glucose, free fatty acids and amino acids. Consequently , high cortisol levels function as a catabolic hormone that decreases lean body and muscle mass and improves energy usage (22). In humans, cortisol production actually increases throughout the night and exhibits a maximum of release around 07:00–08:00 am in the morning, thus preserving the endocrine balance in waking stress (23).

The liver, kidney and adipose tissue, glucocorticoids and cortisol can modulate clock-controlled gene expression. In a jet lag model with the mouse, glucocorticoids were also recognized as the major modulators for clock resynchronization (18,21,24). Recently it has been stated that clock genes exhibit their usual circadian rhythms in rats following adrenalectomy and rhythm disruption of feeding / fasting, even though the neuronal hepatic inputs were preserved. Such statistics show the importance of fasting / feeding cycles and adrenal hormones for proper synchronization of the hepatic clock with SCN (25).

The SCN always regulates the daily secretion of glucocorticoids from the adrenal cortex, leading to optimal development for the diurnal animals in the early hours of the morning and evening hours nocturnal animals. The adrenocorticotropic hormone (ACTH) that stimulates corticosterone secretion from the adrenal cortex exhibits a consistent style of discharge from the corticotropic pituitary cells. Such a cycle is blocked by light, and through its connections to the paraventricular nucleus it tends to concentrate directly on SCN (26). This careful control is important given the key functions that hormone performs, especially the precursor to aldosterone and for the regulation of hepatic metabolism (27).

Insulin

Insulin is the body's major anabolic hormone it is a peptide hormone formed by islet beta cells in pancreatic. It controls the metabolism of carbohydrates, fat and proteins by facilitating the absorption of glucose from the blood into the muscle cells of the liver, skin and skeleton (20). Consequently, glucose resistance and insulin release vary within a day. Both insulin sensitivity and insulin secretion decrease at night in the metabolism normal course (particularly 3:00 a.m.- and 5:00 a.m.) relative to the morning. This phenomenon of the dawn for a metabolic pathway underscores the effect of the circadian regulation of glucose metabolism. Hormones acting as insulin antagonists (especially growth hormone) show hyper-insulinemic activity in the normal physiological process in the body as a result of reducing insulin production 3:00- 5:00 am, to return to its normal blood sugar levels. In contrast, the effect of the growth hormone released during the night, particularly in diabetic patients, may not be remedied when insulin release is disrupted. This causes in a circadian pathological rhythm, that could induce morning hyperglycemia regardless of eating habits(28).

Ghrelin

Ghrelin is a hormone produced and released mainly via the small quantities of the stomach often released by the brain, small intestine and pancreas. There are several roles in Ghrelin. This is called the 'hunger hormones' since the key action activates appetite, improves food intake and facilitates accumulation of fat. The oxyntic cells in the stomach secrete ghrelin, independently of light, pertaining with their own circadian rhythm prior to actually feeding time. Often in mice ghrelin primarily regulated the clock genes activation in the SCN, thereby improving the food intake (29).

Adiponectin and Leptin

Adiponectin is an adipokine because it secretes from adipose tissue. The production peak appeared from 12:00 -14:00 am. Adiponectin is regarded as an anti-inflammatory and insulin-sensitive drug, its amount is indirectly associated with obesity, and its body weight gain (30,31). the animals showed reduced circadian locomotive function in a mouse model of metabolic syndrome with hypoadiponectinemia but an elevated activity during the light period.

After the hepatic glucose levels rise, the white adipose tissue secreted leptin, and it acts at the hypothalamus appetite core level, transmitting satiety signals, preventing overflow. For humans, leptin levels increase during the night and enhanced expression of genes in the SCN and the light-phase shifting action increased in female mice. Also, leptin showed SCN reset in rats (32,33).

Thyroid-Stimulating Hormone (TSH)

The thyroid-stimulating hormone (TSH) is a glycoprotein hormone generated from thyrotropic cells in the anterior pituitary gland which stimulates the thyroid gland to release thyroxine (T4) and (T3) which induces the metabolism of nearly every body tissue. Hypothalamic thyrotropin-releasing hormone (TRH) controls the production and secretion of TSH (34). Secretion of TSH has a direct daily rhythm and the anterior hypothalamic pituitary thyroid axis (HPT) has been under circadian control in the suprachiasmatic nuclei (SCN) via the central circadian pacemaker. Among humans, circulating TSH levels show a strong regular pattern. Plasma concentrations begin to rise in the late afternoon or early evening before sleep starts, and reach maximal levels during the early part of the night. Following the nighttime peak in TSH, plasma TSH concentration then declines during the rest of the sleep period until reaching low daytime levels (35).

ايقاعات الساعة البايلوجية والاتزان الهورموني في الحيوانات

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الخلاصة

يقوم أيقاع الساعة البايلوجية بتنظيم العديد من الآليات الفسلجية والسلوكية ، بما في ذلك دورات النوم والاستيقاظ وإفراز الهرمونات والتمثيل الغذائي بمعدل مدته ٢٤ ساعة. وقد يؤدي الاضطراب البيئي في الإيقاعات اليومية إلى آثار سلبية على صحة الحيوانات والدواجن وكذلك البشر وبخاصة العاملين بنظام المناوبات. يتكون النظام العصبي الذي يتحكم في النظم اليومية من الساعة البيولوجية ومسارات الإدخال و الإخراج. تنشأ الساعة البيولوجية من زوج من النوى فوق التصالبية في منطقة ما تحت المهاد وتستشعر العصي والمخاريط ومجموعة من الخلايا العقدية الشبكية الحساسة للضوء ،الضوء من أجل النظم اليومي المتقطع .وهناك مجموعة من الجينات تسمى مجتمعة "جينات الساعة" ، تتحكم أيضًا في إيقاعات الساعة البيولوجية.اما في الطيورفتحتوي الغدة الصنوبرية على واحد أو أكثر من المذبذبات اليومية التي تلعب دورًا مهمًا في التنظيم الزمني العام. وهناك الكثيرمن الأمراض الشائعة تشارك فيها إيقاعات الساعة البيولوجية ، كما أن الخلل في النظم اليومي هو عامل مسبب للعديد من الأمراض المزمنة. وعلى الرغم من التطور الحاصل في العشرين عامًا الماضية في اكتشاف آليات الساعة البيولوجية ، إلا أن هناك الكثير المتبقي يمكن معرفته حول الساعة البايولوجية.

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