Sleep and the Endocrine System

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KEYWORDS

• Circadian rhythms • Sleep apnea • Endocrine abnormalities • Hormonal regulation
• Sleep disorders • Sleep deprivation • Critical illness • Critical care

KEY POINTS

- The endocrine system is influenced by both circadian rhythms and sleep-wake state.
- Hormonal abnormalities can contribute to sleep disruption and disorders.
- Sleep disorders can lead to hormonal dysregulation, resulting in endocrine abnormalities.
- Sleep fragmentation and deprivation are common in critically ill patients and may be associated with various hormonal disturbances.

INTRODUCTION

The endocrine system is a group of specialized organs or glands that secrete hormones directly into the circulation. These hormones are instrumental in growth, metabolism, and maintaining homeostasis. Similarly, sleep plays an important role in human homeostasis. Some hormonal secretion patterns are controlled mainly by the body's internal circadian pacemaker, located in the hypothalamus within the suprachiasmatic nucleus (SCN), whereas other hormones are primarily affected by the sleep-wake state. Sleep and the endocrine system are closely intertwined, with many hormonal secretions influenced by sleep. In addition, sleep quality and duration affect hormonal function such that sleep disorders and sleep fragmentation can contribute to endocrine abnormalities. Conversely, endocrine dysfunction can significantly affect sleep. In this article, the effect of sleep and sleep disorders on endocrine function and the influence of endocrine abnormalities on sleep are discussed. Sleep disruption and its associated endocrine consequences in the critically ill patient are also reviewed.

CIRCADIAN RHYTHM AND SLEEP-WAKE STATE CONTROL OF HORMONAL SECRETION

The primarily circadian-regulated hormones include those produced by the hypothalamic-pituitary axis, such as adrenocorticotropic hormone (ACTH) and cortisol, thyroid stimulating hormone, and melatonin. Growth hormone (GH), prolactin (PRL), and renin secretion are sleep related. Sleep, especially slow wave sleep (SWS), is associated with increased GH, growth hormone–releasing hormone (GHRH), and ghrelin levels.

Adrenocorticotropic Hormone and Cortisol

The hypothalamic-pituitary-adrenal axis (HPA) is primarily under circadian rhythm control. Cortisol and ACTH levels peak in the early morning and decline during the day. The primary circadian

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control is evidenced by the fact that daytime sleep does not significantly inhibit cortisol secretion. This diurnal variation in cortisol secretion persists even when sleep is altered and is not significantly affected by the absence of sleep or by sleep at an unusual time of day. The 24-hour periodicity of corticotropic activity is therefore primarily controlled by circadian rhythmicity.

However, secretion is also weakly modulated by the sleep-wake state. Sleep onset is normally associated with a decrease in cortisol secretion and nadir levels of cortisol and ACTH levels occur during the first part of sleep. Cortisol secretion is already low in the late evening, and sleep initiation results in prolongation of the low secretory state. At the end of sleep, morning awakening is associated with a burst of cortisol secretion. In sleep deprivation, the cortisol secretion pattern seems to be dampened such that the nadir of cortisol secretion is higher and the maximum morning cortisol level is lower than during nocturnal sleep.[1]

Melatonin

Melatonin release is controlled by the light-dark cycle and SCN through a series of complex polysynaptic pathways. It is produced and released from the pineal gland directly into the blood and cerebrospinal fluid. Melatonin levels start to increase in the evening and peak in the early morning. Melatonin is postulated to promote sleep by decreasing the firing rate of SCN neurons. Its production is suppressed by exposure to bright light.

Thyroid-Stimulating Hormone

Thyroid-stimulating hormone (TSH) is primarily under circadian control but is significantly influenced by the sleep-wake state. During daylight, TSH levels are low and stable. Starting in the early evening, TSH levels increase quickly and peak shortly before sleep onset. Sleep inhibits TSH levels from increasing further. Therefore, sleep has an inhibitory effect on TSH secretion, most notable during SWS. During the latter part of the sleep period, there is a progressive decline in TSH levels. The circadian effect on TSH secretion is predominant with some influence from sleep. For example, sleep deprivation results in higher TSH levels during the night because of the lack of sleep's inhibitory effect. But this inhibitory effect of sleep on TSH secretion seems to depend on time of day because daytime sleep does not seem to have this same suppressive effect on daytime TSH secretion.

Growth Hormone

GH secretion is largely influenced by sleep. The release of GH from the anterior pituitary gland is stimulated by hypothalamic GHRH and inhibited by somatostatin. In addition, ghrelin, a peptide produced by the stomach, acts as a potent endogenous stimulus for GH secretion by binding to the GH secretagogue receptor. GH secretion increases during sleep with less influence by the time of day. The sleep-onset GH pulse is the largest in men. Most GH secretion is associated with SWS (stage N3), although GH secretion also occurs in the absence of SWS. The amount of GH secretion closely correlates with the duration of stage N3 sleep. In older age, both N3 sleep and GH release decrease.

Prolactin

PRL secretion is strongly linked to sleep. Levels increase shortly after sleep, regardless of the time of day, although this stimulatory effect is greatest at night. During nocturnal sleep, the PRL levels peak around the middle of the sleep period. Awakenings associated with sleep disruption inhibit nocturnal PRL release. Therefore, the secretion of PRL is mainly sleep dependent.

In addition, a potential role of PRL in regulating rapid eye movement (REM) or SWS has been suggested because of a close temporal relationship between increased PRL secretion and SWS. However, this correlation is not as close as that seen with GH, and the normal secretory pattern of PRL does not decline with age despite a decline in SWS.

Gonadotropic Hormones

Gonadotropic hormone secretion seems to have both circadian rhythmicity and sleep influences. Gonadotropin-releasing hormone from the hypothalamus controls the secretion of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) by the anterior pituitary. In men, LH is responsible for testosterone secretion, whereas FSH stimulates spermatogenesis. In women, the gonadotropins regulate the release of estrogen and progesterone and control the menstrual cycle.

The 24-hour patterns of gonadotropin release and gonadal steroid levels vary according to gender and the stage of life. There is a pulsatile increase in LH and FSH levels at sleep onset in children. As the child approaches puberty, the amplitude of the nocturnal pulses increases, which is one marker of puberty.

Testosterone production varies diurnally, but its production depends directly on sleep, with testosterone levels normally increasing at sleep onset. In young adult men, a notable diurnal rhythm in circulating testosterone levels exists, with minimal levels in the late evening and a clear nocturnal