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Altered diurnal pattern of steroid hormones in relation to various behaviors, external factors and pathologies: A review

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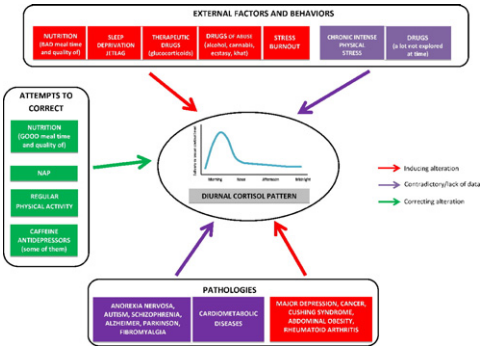
HIGHLIGHTS

- Alteration in diurnal cortisol pattern occurs in many behaviors and pathologies.
- Impact of these factors on the other stress hormone patterns requires further work.
- Link between altered rhythmicity and development of disease needs to be highlighted.
- Attempts to correct altered steroid hormone patterns have been proposed recently.
- In this prospect, regular physical activity appears very promising.

GRAPHICAL ABSTRACT



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ABSTRACT

The adrenal and gonadal stress steroids [i.e., cortisol, testosterone and dehydroepiandrosterone (DHEA)] have gathered considerable attention in the last few decades due to their very broad physiological and psychological actions. Their diurnal patterns have become a particular focus following new data implicating altered diurnal hormone patterns in various endocrine, behavioral and cardiovascular risk profiles. In this review of the current literature, we present a brief overview of the altered diurnal patterns of these hormones that may occur in relation to chronic stress, nutritional behaviors, physical exercise, drugs and sleep deprivation/shift. We also present data on the altered diurnal hormone patterns implicated in cardiometabolic and psychiatric/neurologic diseases, cancer and other complex pathologies. We consider the occasionally discrepant results of the studies, and summarize the current knowledge in this new field of interest, underlining the potential effects on both biological and psychological functioning, and assess the implications of these effects. Last, we conclude with some practical considerations and perspectives.

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Contents

1. Introduction

The role of the adrenal and gonadal stress steroids [i.e., cortisol, testosterone and dehydroepiandrosterone (DHEA)] has been a focus of research for several decades as these hormones imply very broad physiological and psychological actions, including effects on metabolism, glucose utilization, muscle mass and strength, adiposity, physical performance and well-being. In healthy subjects without external stressors, cortisol, DHEA (including its sulfate DHEA-S) and testosterone (this last hormone only in men) are secreted in a circadian pattern [1–5], with the highest concentrations observed in the morning and the lowest in the evening. For cortisol [3,6], but not for DHEA and testosterone [7,9], there is evidence of an awakening effect, with a peak within 30–45 min of waking that has been termed the cortisol awakening response (CAR). In addition to pituitary adrenocorticotropic hormone (ACTH), another signal seems implicated in regulating CAR [3], and evidence suggests that the signal emanates from the hypothalamic suprachiasmatic nucleus [3,6]. The daily cortisol pattern seems unaffected by gender, weight, season or time of waking [2,10–12], although a lack of studies precludes any conclusion about how these factors affect the diurnal patterns of DHEA and testosterone [10,13]. While time of day and menstrual cycle have no effect on the low testosterone concentrations found in women [14–15], age seems to have a strong impact on cortisol, DHEA and testosterone patterns [8,16–23]. Indeed, cortisol, testosterone, and DHEA rhythms in pubertal boys and girls are related to the stage of sexual maturation [8,17]. Moreover, in aging subjects, a flattening of the cortisol slope with higher cortisol levels in the evening and at night and a decreased acrophase has usually [18–20], but not always [21] been reported. Recently, two curves of diurnal cortisol secretion have been found. In 73% of the participants, the curve is described as normative, with a lower CAR, and 27% of the participants have a diurnal cortisol and flatter pattern of release [22]. A strong decrease in DHEA concentrations was also reported in the elderly, with a disappearance of the DHEA pattern [21]. The fluctuations of testosterone also decrease with age [23]. Last, chronotype profiles (morning-, evening-, or neither-type) might impact the diurnal steroid pattern, higher cortisol levels are found in morning chronotype subjects after awakening. However, additional studies are required to confirm the exact impact of chronotype profile on CAR [24].

Concern has recently intensified with determining these daily steroid hormone patterns considering new data highlighting the probable relationship between altered diurnal hormone patterns and various adverse endocrine, behavioral and cardiometabolic risk profiles. Although blood remains the classic body fluid for steroid hormone analysis, saliva samples are now increasingly used for diurnal pattern determination [25–29]. We therefore reviewed the current literature and present