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The Impact of Digital Stress on The Hypothalamic-Pituitary-Ovarian Axis and Menstrual Cycle – A Systematic Review with Implications of Digital Health Technologies

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ABSTRACT

The growing use of digital technology has created a new form of chronic psychological stress. Digital stress significantly affects female hormonal and reproductive health. This systematic review explores how digital and lifestyle related stress affects the hypothalamic-pituitary-adrenal (HPA) axis. It also examines the HPA and hypothalamic-pituitary-ovarian (HPO) axes relationship, specifically how it influences menstrual cycle regulation. A comprehensive literature search was performed using PubMed-indexed studies from January 2022 through March 2026 to identify relevant studies on all aspects of stress, neuroendocrinology, and menstrual health. These results indicate that chronic stress causes prolonged activation of the HPA axis resulting in increased cortisol levels and disrupts the negative feedback loops of hormones that are normally involved in the regulation of the menstrual cycle. This disruption prevents normal secretion of Gonadotrophin releasing hormone (GnRH) which disrupts Luteinising Hormone (LH) and Follicle Stimulating Hormone (FSH) activity which contributes to menstrual disorders or anovulatory cycles. There is emerging data suggesting that certain types of digital stressors such as excessive screen time, social media or sleep disturbance may contribute to these outcomes by creating chronic stress states and circadian disruptions. Despite providing new avenues for identifying menstrual and stress related fluctuations through digital health technologies, there continue to be limitations and validations required for these tools. Collectively, the review demonstrates a complex interplay among modern lifestyle characteristics and endocrine regulation supporting continued investigation into the role of digital stress in women's reproductive health.

Keywords: Digital stress, hypothalamic-pituitary-ovarian axis, menstrual cycle, cortisol, hormonal imbalances, digital health technologies

1. Introduction

Digital innovation over the past few decades has dramatically influenced the way everyday existence is approached. As a result, people spend significantly more time interacting with screens and using digital technologies and social media platforms. On the one hand, digital innovations have created opportunities in terms of communication and service delivery. On the other hand, they have produced unique mental stresses known as "digital stress" or "technostress". Digital stress can affect large numbers of people, especially those who are women of childbearing age. However, recent scientific literature indicates that frequent use of digital devices may be associated with levels of long-term psychological stress, disrupted sleep patterns, increased emotional reactivity, and other forms of physical body dysregulation due to prolonged exposure to digital environments (Saadedine et al., 2025). A series of studies that were conducted based on samples from larger populations have recently demonstrated a connection between various digital behaviours such as late-night smartphone use and lower-quality sleep along with an increased incidence of menstrual disturbances. Together these findings suggest a clear association between digital exposure, disruptions to the circadian rhythm and problems related to reproductive health (Severinsen et al., 2023).

Disruptions to circadian rhythms have been linked to alterations in cortisol secretion patterns and altered regulation of hormones involved in reproduction as well as to the potential for chronic exposure to digital environments to create conditions conducive to endocrine dysfunction (Severinsen et al., 2023; Haase et al., 2024).

Stress affects the body through the HPA axis. When the hypothalamus perceives stressful stimuli, it releases corticotropin releasing factor (CRF) causing the pituitary gland to release adrenocorticotrophic hormone (ACTH) resulting in an increase in cortisol secretion by the adrenal cortex. Cortisol is critical in maintaining homeostasis when responding to acute stress. However, persistent activation of the HPA axis causes chronically elevated cortisol levels affecting multiple body functions such as metabolic, immunological or reproductive ones creating dysfunctional states within each (Haase et al., 2024; Klusmann et al., 2022). It is worth

noting that there is a bi-directional interaction between the female reproductive system and stress responsiveness. Research has indicated that there are differences in HPA axis function throughout the menstrual cycle (Klusmann et al., 2023).

The female reproductive system is regulated by the hypothalamic-pituitary-ovarian (HPO) axis. The HPO axis is a complex endocrine mechanism responsible for regulating the menstrual cycle and fertility. Gonadotrophin-releasing hormone (GnRH) is released by the hypothalamus in a pulsatile manner stimulating the anterior pituitary to release luteinizing hormone (LH) and follicle-stimulating hormone (FSH). LH and FSH stimulate the maturation of oocytes within the ovaries as well as the production of sex steroid hormones. The balance of GnRH secretion is extremely delicate and responsive to a wide variety of internal and external influences. Activation of the HPA axis inhibits GnRH pulse frequency and subsequently suppresses gonadotrophin release, thus disrupting ovulation and menstrual cyclicity (Saadedine et al., 2025). In humans, this phenomenon is clinically manifested as irregular menstrual cycles, anovulatory menstrual cycles or functional hypothalamic amenorrhea - all common consequences of chronic exposure to stressful stimuli (Anto-Ocrah et al., 2023; Ozimek et al., 2022). Reports suggest that nearly half of all menstruating females will report menstrual symptoms consistent with menstrual disorders secondary to increased levels of psychosocial stress (Anto-Ocrah et al., 2023; Ozimek et al., 2022). Evidence of an association between mental stress and irregularities in the menstrual cycle has been identified by a new systematic review. The evidence also shows that as adults are exposed to chronic stress it will negatively affect both cycle regularity and reproductive function (Poitras et al., 2024).

There is strong evidence that psychological stress affects hormonal health and prompts menstrual disturbances. However, the extent to which digital stress contributes specifically to this issue as a low-level and ubiquitous source of stress remains underexplored. Currently, there is a significant void in research regarding the integration of digital exposure with circadian disruptions and their combined effect on the regulatory mechanisms involving the HPA and HPO axes. Consequently, the impact of stress-inducing factors related to technology on everyday life and their possible effects on determining menstrual health is becoming increasingly relevant and emerging field of study. Thus, this systematic review seeks to assess the available evidence associated with the relationship between digital and psychological stress influence on neuroendocrine regulation and menstrual health among females.

2. Methodology

A literature review was performed using the PubMed database in order to identify the most applicable articles on hypothalamic-pituitary-ovarian axis, physiological and digital induced stress pathways and following hormonal imbalances. The research included publications from January 2022 to March 2026.

The search strategy has been refined by using specific keywords and combinations such as “digital stress’, ‘hypothalamic-pituitary-ovarian axis”, “menstrual cycle”, “cortisol”, “hormonal imbalances”, “digital health technologies”.

This study contains original research papers and reviews in English about the relationship between digital and psychological stressors and their effects on the neuroendocrine system regulating menstruation focusing particularly on the HPA and HPO axis. A large portion of this study has been focused on how modern lifestyle factors such as the increased amount of time spent using digital technologies have affected woman's hormonal balance and the ability to maintain an uninterrupted menstrual cycle.

Studies published prior to 2022 or that were not directly related to stress induced hormonal imbalances and digital technologies were excluded.

Titles and abstracts were checked for relevance and chosen articles were fully analyzed. 20 of 65 articles met the inclusion criteria and were included in the final study.

The analysis of gathered data was performed with an emphasis on modern technology-induced stress and its influence on hormonal health in women.

3. Results

3.1. Stress induced hypothalamic-pituitary-ovarian axis dysregulation

Stress is known to affect the function of the hypothalamic-pituitary-ovarian (HPO) axis. The effects are largely due to stimulation of the HPA axis by release of Corticotrophin-Releasing Hormone (CRH) and Glucocorticoids which suppress the pulsatile discharge of Gonadotrophin-Releasing Hormone (GnRH) from the hypothalamus. Suppression of GnRH leads to suppression of Luteinising Hormone (LH) and Follicle-Stimulating Hormone (FSH) resulting in impaired follicular maturation and ovulation (Saadedine et al., 2025; Mbiydzenyuy & Qulu, 2024).

There are both experimental and clinical data showing that changes in the responsiveness of the HPA axis to stress stimuli vary throughout the menstrual cycle. Specifically, there is greater cortisol production when disruptions to normal endocrine function are present during the cycle

and this results in a higher risk for menstrual irregularity (Haase et al., 2024; Klusmann et al., 2023; Klusmann et al., 2022).

The association between high levels of perceived stress and menstrual dysfunction has been consistently demonstrated in observational studies using measures of menstrual frequency, menstrual duration and presence or absence of menstruation and functional hypothalamic amenorrhea. In particular, oligomenorrhea, anovulation and functional hypothalamic amenorrhea were common menstrual disorders reported in these studies (Petrine et al., 2025; Anto- Ocrah et al., 2023; Ozimek et al., 2022).

Therefore, it can be concluded that chronic stress including recent emergent forms of stress such as digital stress acts as a consistent neuroendocrine modulator and impairs the balance required for optimal functioning of the HPO axis.

3.2. Changes in menstrual cycle

The trend is clearly emerging that psychological and lifestyle related sources of stress including digital technology can significantly impact menstrual cycle regularity and characteristics. Studies that have monitored women's menstrual cycles that were influenced by a large amount of occurring stress, such as during the Covid 19 pandemic, found that various menstrual disturbances were observed. Specifically, the menstrual cycle lengths became less predictable than normal, many women experienced changes in their bleeding patterns and for many of them their pre-menstrual syndrome (PMS) symptoms became worse (Anto-Ocrah et al., 2023; Ozimek et al., 2022; Tufail et al., 2022). The changes to the menstrual cycles were found to be directly proportional to the degree of stress being felt by each woman which implies that the amount of stress has a direct correlation with how well each woman’s reproductive system undergoes disturbances. Furthermore, the long term effects of modern lifestyle factors such as excessive screen time, disruptions to the circadian rhythm or lack of sleep can lead to continuous stimulation of the body’s sympathetic response and therefore can disrupt hormone balance ultimately affecting the ability to ovulate (Seo et al., 2025; Saadedine et al., 2025). Altered cortisol secretion and circadian dysfunction have also been shown to affect the regulation of ovarian cycles and may result in either anovulation or functional hypothalamic amenorrhea (Petrine et al., 2025). Overall, this study suggests that the type of stress caused from using digital technology accompanied by living a stressful lifestyle may cause large amounts of variation in menstrual health over both the short and long term.

3.3. Impact on reproductive system

The chronic effects of psychological stress on women's reproductive function are well-documented and include a wide range of influences on all aspects of female hormonal health. The relationship between psychological stress, particularly the type of chronic nature experienced in contemporary digital lifestyles, HPA axis activation which results in chronically heightened circulating concentrations of cortisol and subsequent suppression of GnRH release from the hypothalamus and alteration of LH and FSH production from the pituitary form the basis for much of the evidence suggesting that chronic psychological stress can negatively affect female fertility. Chronic HPA axis activation has been shown to suppress GnRH release and alter LH and FSH production thereby impairing follicular development, ovulatory frequency and corpus luteum (CL) function (Saadedine et al., 2025; Mbiydzenyuy & Qulu, 2024). Studies examining clinical associations have clearly shown that increased levels of perceived stress correlate with an increased risk of menstrual cycle irregularity as well as decreased fecundability, longer times-to-conception and an increased prevalence of Functional Hypothalamic Amenorrhea (Anto-ocrah et al., 2023; Petrine et al., 2025). In addition to these direct relationships, altered patterns of circadian rhythms such as those caused by excessive use of electronic screens or sleep disturbances have been identified as additional pathways by which stress affects fertility and reproduction (Seo et al., 2025).

4. Discussion

4.1. Stress related hormonal imbalances

Embracing the fact that long-term and repeated stressors of all kinds are being linked to the disruption of hormones due to prolonged activation of hypothalamic-pituitary-adrenal (HPA) axis has impacted the way endocrine dysregulation mechanisms are perceived. The prolonged elevation of cortisol from the exposure to stressors can disrupt the physiological regulation mechanisms for maintaining homeostasis within human endocrine system. In addition, this elevated cortisol level has been shown to disrupt the hypothalamic-pituitary-gonadal (HPG) axis by causing imbalances in the release of GnRH, thereby fluctuating LH and FSH levels. These changes result in disruptions in ovarian steroidogenesis as well as irregularities in menstrual cyclical patterns. Meta-analytic studies have demonstrated that there are significant differences in cortisol levels during different phases of the menstrual cycle. Therefore, it is reasonable to assume that the effects of stress on hormonal imbalance may be both dependent on the phase of the menstrual cycle as well as accumulative. Clinical and observational studies have also indicated that increased levels of psychological stress are correlated with increased

endocrine dysfunction, particularly regarding imbalances in estrogen and progesterone levels. Such imbalances may contribute to disorders such as premenstrual dysphoric disorder and anovulatory cycles. Menstrual cycle phases and related symptoms were found to impact reported levels of stress, sleep quality, and recovery patterns based on a longitudinal study conducted with elite female athletes. This demonstrates how physiological reproductive cycles interact with responses to mental and lifestyle-induced stress (Kulik et al., 2025). Experimental and literature reviews have also demonstrated that chronic stress alters reproductive cyclical patterns through HPA and HPG cross-talk, supporting the theory that chronic stress functions as a systemic modulator of endocrine function. Overall, these data suggest that stress-induced hormonal imbalance serves as a critical link connecting lifestyle factors resulting from modernization and impaired reproductive and menstrual function. Different mechanisms responsible for stress-induced menstrual cycle dysregulation have been compared in the table below (Table 1).

Table 1. Mechanisms in stress-induced menstrual cycle dysregulation.

Mechanism	Pathway Description	Key Hormones Involved	Clinical Outcome
HPA axis activation	Stress stimulates CRH, ACTH and consequently cortisol release	CRH, ACTH, cortisol	Chronic hypercortisolemia, endocrine imbalance
Inhibition of GnRH pulsatility	Elevated cortisol suppresses hypothalamic GnRH secretion	GnRH, cortisol	Disrupted LH and FSH release, anovulation
Altered gonadotropin secretion	Reduced GnRH leads to impaired LH and FSH dynamics	LH, FSH	Impaired folliculogenesis, irregular cycles
Ovarian steroid disruption	Impaired LH and FSH signaling affects estrogen and	Estrogen, progesterone	Luteal phase defects, PMS/PMDD symptoms

	progesterone production		
Circadian rhythm disruption	Digital exposure and poor sleep alter cortisol rhythm	Cortisol, melatonin	Hormonal dysregulation, cycle variability
Chronic low-grade digital stress	Continuous exposure to digital stimuli sustains HPA activation	Cortisol	Persistent endocrine dysregulation
HPA and HPO axis cross-talk	Interaction between stress and reproductive axes	Cortisol, GnRH, LH, FSH	Menstrual irregularities, amenorrhea

ACTH – Adrenocorticotropic hormone, CRH – Corticotropin-releasing hormone, FSH – Follicle-stimulating hormone, GnRH – Gonadotropin-releasing hormone, HPA – Hypothalamic-pituitary-adrenal (axis), HPO – Hypothalamic-pituitary-ovarian (axis), LH – Luteinizing hormone, PMDD – Premenstrual dysphoric disorder, PMS – Premenstrual syndrome

Based on data gathered in: Barone JC, Ho A, Osborne LM, Eisenlohr-Moul TA, Morrow AL, Payne JL, Epperson CN, Hantsoo L. (2024). Luteal phase sertraline treatment of premenstrual dysphoric disorder (PMDD): Effects on markers of hypothalamic pituitary adrenal (HPA) axis activation and inflammation ; Haase L, Vehlen A, Strojny J, Domes G. (2024). Effects of menstrual cycle phase on the salivary cortisol awakening response; Klusmann H, Luecking N, Engel S, Blecker MK, Knaevelsrud C, Schumacher S. (2023). Menstrual cycle-related changes in HPA axis reactivity to acute psychosocial and physiological stressors: A systematic review and meta-analysis of longitudinal studies; Klusmann H, Schulze L, Engel S, Bücklein E, Daehn D, Lozza-Fiacco S, Geiling A, Meyer C, Andersen E, Knaevelsrud C, Schumacher S. (2022). HPA axis activity across the menstrual cycle: A systematic review and meta-analysisof longitudinal studies; Mbiydzenyuy NE, Qulu LA. (2024). Stress, hypothalamic-pituitary-

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4.2. Digital health technologies in monitoring menstrual cycle

There have been many changes in how women can track their menstrual health because of the fast growth of digital health technologies. Many women now use mobile health applications to track their cycles and record symptoms in real time. mHealth applications allow women to continuously follow and monitor their own menstrual bleeding patterns, timing of ovulation, and related symptoms over time. This provides women with unique information about their personal health and also allows researchers to collect data from thousands of women for large scale studies on menstrual health analysis (Jukic et al., 2022; Dantas et al., 2022).

Most importantly, mHealth applications provide an ongoing method of collecting data directly from users through continued input by women rather than relying solely on retrospectively reporting as is commonly done in clinical environments. This allows for better documentation and more detailed information of the range of variability found in each woman's menstrual cycle.

Additionally, many of the most recently evaluated mHealth applications include various additional functions including tracking of symptoms, access to educational materials, and prediction based on past experiences. All of these elements may increase the level of participation and interest in using mHealth applications among women.

However, there are several issues surrounding the increased usage of mHealth applications. There is still concern for both the medical quality and reliability of these products due to the wide variability found among different types of applications currently being available (Nielsen-Tehranchian et al., 2023).

Furthermore, mHealth applications provide a new opportunity to combine behavioral and lifestyle factors such as exposure to stress and sleeping patterns which could contribute to

understanding the causes of menstrual health problems. Thus, even though mHealth technology represents a potentially positive addition to the way reproductive health is evaluated at the personal level and population level, advanced development and regulation will be needed before they can be integrated into clinical practice effectively.

4.3. Stress management techniques in hormonal balance restoration

The significance of effective stress management techniques to restore hormonal balance and ultimately improve reproductive health outcomes is now being recognized given the documented disruption to neuroendocrine regulatory processes by chronic stress. The persistent activation of the hypothalamic-pituitary-adrenal (HPA) axis resulting in cortisol dysregulation has been found to adversely impact the hypothalamic-pituitary-ovarian (HPO) axis demonstrating the necessity of implementing stress-reducing interventions to normalize endocrine function (Saadedine et al., 2025; Mbiydzenyuy & Qulu, 2024).

Non-pharmacologic interventions such as cognitive-behavioral therapy (CBT) and mindfulness-based therapies have shown considerable promise in managing individuals' perceptions of stress and subsequently modulating cortisol production. Studies have suggested that mindfulness-based activities such as meditation or deep breathing may reduce HPA axis hyperactivity and thus provide a degree of stability to hormones involved in menstrual cycle and premenstrual symptomatology (Petrine et al., 2025). In addition, CBT based on modifying an individual's perceptions of stress and developing more adaptive coping mechanisms have demonstrated improvement in both psychological well-being and measures of reproductive health.

Physical activity has also played a central role in stress reduction and promoting hormonal balance. A moderate level of physical activity has been shown to suppress cortisol levels, increase endorphins and stabilize metabolism and endocrine system. On the other hand, excessive or high intensity physical activity can lead to adverse effects on HPO axis functioning and can result in menstrual irregularities, particularly when combined with inadequate nutrition and energy deficit. Thus, physical activity programs should be tailored to each individual to optimize hormonal status.

Additionally, maintaining good sleep habits and circadian rhythm regulation will also play a significant role in achieving and maintaining endocrine homeostasis. Altered sleep patterns that are related to prolonged exposure to screens and stress from digital communication have resulted in alterations to cortisol secretion patterns and disrupted secretion of reproductive hormones. Improving sleep quality through minimizing blue light exposure prior to falling

asleep and establishing consistent sleep-wake schedules can help maintain the natural balance of hormones (Seo et al., 2025).

Lastly, emerging research indicates that digital health technologies may serve as a tool for supporting individuals' efforts to manage stress and monitor their reproductive health. For example, mobile applications and wearable devices allow users to track their levels of stress, sleep patterns, and menstrual cycle patterns. As a tool for providing personalized feedback regarding the levels of stress and potential disruptions in hormone function, this technology offers much promise as a resource for integrated health care management. However, additional validation of this technology is necessary to assess its clinical utility.

Overall, the development of a multi-faceted approach utilizing psychological, behavioral and lifestyle changes appear to be the best strategy for alleviating stress-induced hormonal imbalance. Through addressing both the source of the stress response and its physiological effects, these strategies may aid in the reestablishment of balance within the HPA and HPO axes and promote better reproductive health.

4.4. Inter-Individual Differences in Stress Response and Menstrual Cycle Impact

A key factor in how the relationship between stress and menstrual cycle is perceived stands for the large amount of variability among females in terms of their response to stressful stimuli. There are no two females who have been exposed to the same level of stress both from psychological and digital causes who will experience the same reproductive problems. This implies that there are numerous biological and psychosocial moderators that can affect an individual's susceptibility to experiencing stress-related menstrual irregularities. Variables such as age, baseline mental health, BMI and pre-existing endocrine conditions have all been found to modulate a female's risk for developing stress related menstrual irregularities (Saadedine et al., 2025; Petrine et al., 2025). Individual differences in the sensitivity of the HPA axis to cortisol stimulation also vary and may explain why different individuals respond uniquely to the hypothalamic-pituitary-ovarian (HPO) axis dysregulations (Klusmann et al., 2022; Klusmann et al., 2023). The results of these studies illustrate the need for more personalized approaches to study the relationships between stress and reproductive health and recommend further research into identifying specific risk profiles and biomarkers that would identify which individuals are most susceptible to stress related menstrual irregularities.

4.5. Hormonal Birth Control and the Regulation of Stress Responses

Hormonal birth control has a significant yet often unaddressed effect on how the body responds to stress relative to its menstrual cycle. The main mechanism by which hormonal birth control works is to suppress the hypothalamus-pituitary-ovary axis to alter normal patterns of fluctuation for hormones within the body and possibly affect its physiological reaction to stress. Research published recently indicates that hormonal birth control may impact both the level of activity of the Hypothalamic-Pituitary Axis and how women perceive symptoms associated with menses such as masked or reduced menstrual disorders due to stress (Petrine et al. , 2025). As a result, hormonal birth control can also be shown to interact with stress related pathways in the body to affect cortisol levels and emotional regulation. Therefore, it is very important to include whether or not a woman uses hormonal birth control when conducting research on stress related outcomes in the reproductive system because using this information could complicate the association being studied.

4.6. Limitations of current evidence and research gaps

A number of very significant limitations exist within the current body of evidence that links stress with menstrual health. The majority of existing research uses self-reporting methods, such as questionnaires and mobile applications that track menstrual cycles. These self-reporting methods are subject to potential recall bias and therefore lack objectivity (Nielsen Tehranchian et al., 2023; Dantas et al., 2022). There is also significant variability among study designs, populations studied and outcomes measured. As a result, comparative analyses can be difficult. While it has been extensively demonstrated that generalized psychological stress impacts reproductive health, the role of digital stress specifically as an independently measurable and quantifiable risk factor has not received sufficient investigation. Only few studies have included objective biomarkers such as cortisol profiles or reproductive hormones along side digital behavior measures. Therefore, this represents a major void in the scientific literature and highlights the necessity for well-conceptualized longitudinal studies that integrate both physiological, behavioral and digital exposure measures to better understand causal relationships.

5. Conclusion

To conclude, this review has demonstrated that chronic psychological stress, including novel forms of digital stress, is significantly involved in the disruption of neuroendocrine mechanisms which regulate female reproductive function. The mechanism through which stress impacts

female reproductive function is primarily through the chronic activation of the hypothalamic-pituitary-adrenal (HPA) axis and subsequent impact on the hypothalamic-pituitary-ovarian (HPO) axis leading to disruptions in hormone balance, menstrual cycle abnormalities and decreased fertility. As modern lifestyle factors have increased with excessive digital exposure and associated disrupted sleep, they can serve as chronic sources of stress thereby enhancing the potential negative impact on reproductive health from lifestyle related disturbances.

Digital health technologies also offer great promise as a way of providing tools for the real-time monitoring of menstrual cycles and various lifestyle-related variables. Therefore, they could be used as early warning systems to detect early signs of dysfunction and lead to tailored interventions.

However, there are many limitations to the evidence base currently available regarding the relationship between digital stress and the regulation of female reproductive functions. The most notable obstacle to the evidence base is the fluctuation among studies examining similar issues. This variability exists because many of the studies rely on participant reported data rather than using objective measures of stress. Additionally, very few studies examined whether or not digital stress is an independent variable impacting women's reproductive health.

Therefore, future research needs to be focused on conducting longitudinal and mechanistic studies that incorporate both objective biomarkers of stress and digital behaviour patterns along with hormonal profiling. Increasing the knowledge of how these factors interact allows to develop specific prevention methods and improves clinical treatment options for individuals experiencing stress-related reproductive disorders.

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