

## Effects on the menstrual cycle due to the COVID-19 lockdown

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### Abstract

The international lockdown as a result from the COVID-19 pandemic elevated the presence of seven explicit factors, which consequently brought negative effects on the female reproductive process of the menstrual cycle. Increased cortisol concentrations, shifted secretion rates of melatonin and resulting changes in circadian rhythm patterns, along with dietary and physical activity rate changes, decreased vitamin D, and the synchronization of cycles, points towards the connection with menstrual irregularities and various symptoms. The increase in zinc supplementation, prompted by the desire to increase immune protection against the virus amidst the duration of the lockdown, resulted in beneficial outcomes towards the menstrual cycle, with improvement of premenstrual syndrome symptoms such as anger, headaches, and extreme pain. Several of the factors that induced negative impacts on menstrual regularity and associated symptoms have relationships with the Hypothalamic-Pituitary-Adrenal (HPA) axis and Hypothalamic-Pituitary-Gonadal (HPG) axis, which in turn highlights the critical impacts abnormal routines established by the lockdown had on the female body, with specific influences directed at the menstrual cycle and its normality. In specificity, cortisol is an anxiety-related hormone, and with the increased rates of stress that were a result of the lockdown, abnormal cortisol concentrations, especially in the luteal phase of the menstrual cycle encouraged irregularity and increased symptoms. With daily routines shifting in many women, that included staying up later in the evening, the sleep-related hormone of melatonin experienced shifted secretion levels, which disrupted individual's circadian rhythms, consequently effecting the normalcy of the cycle, even generating polycystic-ovary syndrome in some women. Moreover, many women accepted unhealthy nutritional diets, which is believed to have led to increased severity of symptoms and abnormality; a decrease in exercise was also observed, with similar impacts being a result. Increased use in smartphones was cultivated in many people's lifestyles because of the lockdown, which increased the exposure of blue light, and decreased vitamin D levels, which aided in the formation of certain reproductive and menstrual-related diseases. Additionally, many family members/women quarantined together, possible leading to the synchronization of cycles, and the temporary shift in the timeframe between period cycles.

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## Introduction

With the recent international lockdown due to the global COVID-19 pandemic, many people have experienced negative impacts on their physical and psychological health. Many women have identified a possible change in their menstrual cycle regularity, and within this research paper, the lockdown in association with the COVID-19 pandemic is investigated and its possible influences on the menstrual cycle, such as the hormonal levels involved, along with the irregularities corresponding to the cycle's follicular and luteal phases. It is critical to investigate possible connections between the lockdown and the menstrual cycles' associated resulted symptoms because the long-term impacts from the COVID-19 lockdown are still not fully known.

The menstrual cycle is a natural process of ovulation and menstruation in most women, and begins at the time of puberty, with the start-time ranging from 10 to 16 years old, and its termination is identified as menopause, with an average age of 51 years old [1]. The typical menstruation cycle has blood flow for about 3-5 days, but there can be deviation from this range, with flows being as short as one day, or even up to 8 days [1], depending on the female. The cycle in its entirety is normally 28 days, but similar to the blood flow cycle, it can deviate from this average time span, and may be as short as 21 days, or as long as 37 days [2].

The overall cycle includes three phases: The follicular, ovulatory, and the luteal phase; the two main hormones associated with the menstrual cycle are estradiol and progesterone, with estradiol being the primary hormone within the follicular phase, and progesterone corresponding to the luteal phase [3]. In the follicular phase, estradiol levels gradually rise, reaching a climax of about 200 pg/mL, and during the time of this peak, ovulation is triggered by the negative feedback loop, influenced by the Hypothalamic-Pituitary-Ovarian axis (HPO axis), then transferring into a positive loop [3]. The follicular is 15.7 days on average, and the luteal phase 13.3 days; the luteal phase is after ovulation and transforms the main follicle into the corpus luteum [2]. When fertilization of the egg does not occur, the corpus luteum then becomes the corpus albicans, resulting in the decrease in the hormonal levels of estradiol and progesterone, which in turn sheds the endometrial lining and the return to that of the start of the cycle, which is at the beginning of the follicular phase [3]. The amount of blood that is lost throughout the days of blood flow are approximately 30mL, but can be below that or up to 80 mL; a cycle is identified as abnormal if it is above the 80 mL amount [1]. It is important to recognize that any disruption to the phases involved in the menstrual cycle, or any irregularities in association with the HPO axis can lead to menstrual irregularities, disorders, or heavy bleeding, since a mature HPO axis' effectively influences the normalcy of menstrual cycles [3]. It has been identified that women with depression and Premenstrual Dysphoric Disorder (PMDD) have negative impacts on their HPO axis [4], and the Hypothalamic-Pituitary-Adrenal Axis (HPA axis) additionally contributes towards mental illnesses, leading to the impact on the follicular and luteal phases of the menstrual cycle [5].

Many factors have the ability to influence possible irregularities corresponding to the menstrual cycle, and the COVID-19 lockdown may have promoted the furthered exposure to many of the existing influences of the cycle. The Coronavirus' initial exposure to the world started in December 2019 at a seafood market in China, where the virus is assumed to have originated [6]. Within the first year of the origination of COVID-19, about

two million people passed away, in addition to 100 million people being infected worldwide [7]. COVID-19 symptoms relate to that of a common cold or the flu, with the main symptoms being impaired smell and taste, sore throat, fever, cough, and weakness [8]. The main form of transmission of this virus is person-to-person by the means of coughing or sneezing, and although there are vaccines to limit the possibility of contracting the virus, there is no natural immune protection from infection [9]. With millions of women having experienced the global lockdown implemented by governments worldwide in the year 2020 to prevent viral infection, it is important to identify any possible changes that may have occurred to the menstrual cycle as a result from the lockdown. COVID-19's impact on the human population has not been fully researched due to its vast effect, but it has been identified that the pandemic led to psychological and physical symptoms in individuals worldwide [10]. In addition to the regular physical and psychological impacts before and during menstruation in women, with symptoms including increased appetite for sweets, depression, anger, sleepiness, skin blemishes, irritability, etc., the influences of the lockdown had the capability to heighten the overall severity of symptoms [10].

Seven factors promoted by the COVID-19 lockdown may have impacted the regularity of the menstrual cycle, consisting of the anxiety-related hormone of cortisol, the sleep-related hormone of melatonin, dietary changes, shifts in physical activity, the decrease in vitamin D/light exposure, closer proximity to other women during isolation and the synching of menstrual cycles, and zinc supplementation.

The hormone cortisol is related to the HPA axis, which in turn interconnects with the menstrual cycle, and cortisol levels increase during the luteal phase because of psychological stress even though the follicular phase has higher cortisol levels under healthy conditions. Furthermore, depression and PTSD have a connection with menstrual irregularities, and there has been research confirming the increase of cortisol levels during the COVID-19 lockdown. The hormone melatonin influences the circadian rhythm, and during the lockdown, there were observable shifts in the sleep-wake behavior; rhythm disruption ultimately impacts the Hypothalamic-Pituitary-Gonadal Axis (HPG axis), which in turn leads to the menstrual cycle disorder of Polycystic Ovary Syndrome (PCOS).

The dietary changes implemented by the influence of the lockdown affected the menstrual cycle as well; there is a natural need for energy, and particular food consumption during the lockdown impacted menstrual cycles. There is a relationship between a healthy diet and decreased severity of menstrual pain and symptoms, and it has been researched that unhealthy dietary habits created during the lockdown led to the deviation from regularity of the cycle. Additionally, physical activity changes coincide with impacts towards the HPO axis, which ultimately affects the menstrual cycle, as previously discussed. Many women that excessively exercised before the lockdown drifted from their physical activity routine, leading to possible menstrual irregularities.

The decrease in vitamin D light exposure is also correlated with the lockdown and menstrual cycles, with the lockdown increasing the use of phones, with statistics demonstrating the heightened exposure to blue light. Vitamin D deficient levels correlate with certain diseases, as well as an influence on melatonin/circadian rhythms and the anxiety-related hormone of cortisol. Overall, this complexity of the relationship between vi-

tamin D and multiple factors has the possibility to create a cyclic process of negative impacts on the menstrual cycle. Furthermore, with the lockdown forcing families to isolate together, the synching of menstrual cycles has been evident towards increase synching rates. Beneficially, zinc supplementation was a solution towards the protection of the immune system towards the coronavirus during the lockdown, and whether women were aware of the reproductive side-effects, zinc is demonstrated to lighten the severity of period pain and other aspects related to the menstrual cycle. Comprehensively, by forming connections with current research on these seven factors with analysis of the COVID-19 lockdown, there is evidence to suggest that the global lockdown created physiological issues related to the menstrual cycle.

### The anxiety-related hormone of cortisol

The COVID-19 lockdown brought stress and anxiety to many families, due to the unknown aspects of the virus and its overall impact, and stress is a factor that has the power to impact the menstrual cycle [11]. Cortisol is an anxiety-related hormone, and there are natural fluctuations of cortisol throughout the follicular and luteal phases of the menstrual cycle, with the follicular phase having higher cortisol levels [5]. So, under normal, healthy conditions, women can expect shifts in cortisol concentrations, which may impact their overall state of stress. Many women deal with stress daily, and within a study identifying the relationship between anxiety levels and the COVID-19 lockdown, over 23% of participants showcased moderate to severe anxiety problems [12], which displays the prevalence of cortisol during the time of the lockdown.

The Hypothalamus-Pituitary-Adrenal (HPA) axis has a connection with cortisol, while also interconnecting with the menstrual cycle, thus, each of these three aspects may directly influence one another, ultimately creating hormonal and blood flow-related imbalances within the menstruation phases. The HPA axis is stimulated by stress, which then produces the hormone of cortisol [13]; hormonal imbalances can occur with cortisol's influential presence, including reproductive hormones within the menstrual cycle [11]. Overall, menstrual irregularities can be promoted by depression due to its alteration towards the HPA axis [14]. Furthermore, it is important to note that the cortisol awakening response, which takes place upon the first hour of being awake, is the measure of HPA axis activity along with stress [15], and in young adults during the lockdown, there was an increase in loneliness, along with visible correlations with the cortisol awakening response [16]. This understanding points towards the possibility that the anxiety derived from the COVID-19 lockdown was prominent enough to have a negative impact on the HPA axis, along with its correlation with the cortisol awakening response, and these influential factors may have led to the imbalances of the menstrual cycle.

As previously mentioned, cortisol levels are naturally higher in the follicular phase, but because of psychological stress, cortisol levels rise in the luteal phase, which demonstrates the significant impact anxiety has on the hormonal balance within the menstrual cycle. Research has identified that cortisol is required for the early to middle timeframe of the follicular phase when both estrogen and progesterone are rather low, in order to adapt "physiological processes in response to environmental stimuli" [13]. Studies have showcased that under psychosocial stress, healthy women experience higher cortisol concentrations in the luteal phase of the menstrual cycle compared to that of the follicular phase [13]. It is suggested that characteristics

of the menstrual cycle and stress reactivity in association with the HPA axis activity should be investigated more thoroughly [17]. Depression and PTSD, which are anxiety-centered medical conditions have the capacity to impact menstrual irregularities as well. Menstrual abnormalities can be caused by depression, and depression can be a result from menstrual irregularities - they impact one another, and specifically, hormonal shifts during menopause have a significant influence towards the development of depression [14]. In a study with 52 women as participants, a total of 17 people had irregular menstrual cycles, and with further study, the researchers confirmed the "relationship between stress levels and the regularity of the menstrual cycle" [11], and to develop this point, the natural fluctuation of estrogen, progesterone and specific "psychoactive metabolites of progesterone" most likely influence the higher risk of PTSD in women [18]. During the follicular phase, estrogen and progesterone are low, with higher cortisol levels [13], and anxiety symptoms in women with PTSD have the tendency to increase [18], and research after the pandemic found that cortisol levels heavily increased as a result of "local lockdowns" and these increased levels were followed by overall negative social and emotional impacts on adults and adolescents [19]. The evidence compiled displays the connections between natural and unnatural cortisol level fluctuations throughout women's menstrual cycles and how anxiety from the COVID-19 lockdown had an influence towards menstrual irregularities.

### The sleep-related hormone of melatonin

Melatonin is a hormone that is secreted from the pineal gland when the environment is dark, and it is the signal encouraging sleep [20]. There are natural melatonin level fluctuations during the menstrual cycle, with levels being over four times higher in the luteal phase when compared to the follicular phase, and this increase promotes the production of progesterone as well as the laying of the foundation of the corpus luteum [20]. Melatonin concentration increases in the follicular fluid and reaches a climax right before ovulation occurs [21]. The secretion of melatonin is impacted by the duration of night length, and during the winter season when nights are longer, melatonin secretion accommodates these longer times of darkness [22]. It is said that the hormone of melatonin improves physical symptoms related in menopausal women when healthy levels are present [23]. Overall, three factors lead to the understanding that the COVID-19 lockdown and its influence on melatonin secretion resulted in menstrual irregularities; these aspects include: Observable shifts in sleep-wake behavior during the lockdown, noticed irregularities' direct relation to increased melatonin levels, and rhythm disruption's impact on the HPG axis, which in turn leads to Polycystic Ovary Syndrome (PCOS).

Researchers Dutta and Murugesan identified changes in sleep patterns during the pandemic and concluded that the sleep schedules were shifted from going to bed before 12:00 am to after 12:00 am. From these changes, the morning wake time was additionally shifted [24]. The habit of going to bed after 12:00 am increased considerably, but the duration of sleep was not largely changed [24]. This information reveals the changes in circadian rhythms due to shifts in sleep-wake behavior. Since people were encouraged to stay home, normal routines surrounding jobs were dissipated, allowing people the flexibility to stay up longer at night and not having to wake up significantly early.

Dutta and Murugesan analyzed results from their experiment and recognized that the irregularity of the menstrual cycle

“increased after COVID-19 lockdown period”, specifically either a cycle that lasted less than 24 days or more than 34 days [24]. These researchers concluded that the time of going to bed had a “significant relation with the irregularities of the menstrual cycle” [24]. When high melatonin levels are couple with progesterone, ovulation can be suppressed, leading to stagnant cycles, as well as the impact on oogenesis [22]. But on the other hand, a recent finding concludes that exogenous melatonin (melatonin that is not naturally produced by the body), has a significant impact on the reduced severity of Premenstrual Dysphoric Disorder (PMDD) symptoms [23]. Exogenous melatonin is generally consumed via supplements, and is not produced by the body, so perhaps naturally high levels of melatonin which the body produces leads to menstrual irregularities, but consumed melatonin beneficially helps decrease the severity of menstrual symptoms.

Rhythm disruption impacts the hypothalamic-pituitary-gonadal (HPG) axis, which in turn may lead to the gynecological disorder of PCOS (polycystic ovary syndrome). This syndrome is related to abnormal circadian rhythms [21]. Research has suggested that women struggling with PCOS have an overall lower concentration of melatonin in the “ovarian microenvironment” [21], highlighting the relationships between melatonin and the menstrual cycle and this related disorder. The HPS axis controls the reproductive processes, specifically by allowing fertility and the generation of female characteristics during puberty [25]. An abnormal circadian rhythm contributes to PCOS and other disorders relating to female reproduction, such as premature ovarian insufficiency [25]; by looking specifically at the hormones involved in the female cycle, estrogen and progesterone secretion are regulated by the internal circadian clock, and the detriment of this clock can lead to infertility and “ovarian dysfunction” [25]. To dive deeper, women who have jobs that require work during the night promotes the derailment of the circadian clock, and there is evidence that suggests the increase in “urinary metabolites of melatonin” in women with polycystic ovary syndrome [26]. Ultimately, circadian desynchronization can be harmful towards the regularity of the menstrual cycle, especially in women with PCOS, due to the alteration of the production of melatonin, which then results in an impact towards female hormonal levels. Previously mentioned, sleep-wake behavior shifted during the pandemic, with people staying up longer during the night and sleeping in later in the morning; these sleep changes tie into the evident irregularities in the menstrual cycle, confirming the theme that the COVID-19 lockdown led to changes in the menstrual cycle in women.

### Dietary changes

With enforced quarantine for citizens of most countries, people fell out of their regular routine, possibly changing diets, especially because many grocery stores and restaurants temporarily closed. Women have a natural need for energy and the menstrual cycle influences particular food consumption, with certain cravings most of the time, and there has been a visible connection with a healthy diet and the decreased severity of menstrual pain/symptoms; on the other hand, unhealthy diets created during the lockdown resulted in deviation from the timeframe of regular cycles [27].

For every woman, the intake of energy is crucial for the body’s natural processes, and the follicular and luteal phases require different amounts of energy intake [28]. Changes of energy intake increase from the follicular to the luteal phase due to certain hormonal and biological demands [28]; it is natural

for women to experience excess feelings of hunger during the luteal phase to upkeep healthy hormonal levels/menstrual homeostasis. It is interesting to note that there is a natural preference for sweet foods in the luteal phase than the follicular phase [28], which correlates to the notion that hunger preferences alter and cravings can naturally shift during the menstrual cycle. Many women take a harmful advantage of these cravings, and create the habit of an unhealthy diet, which is to be discussed in more detail.

Research has showcased that a healthy diet can aid in decreasing the severity of menstrual pain, and a Mediterranean diet was the center of many research studies. Women who adhere to the Mediterranean diet, with a low consumption of alcohol, were reported to have shorter cycles [29], and a plant-centered derivative of the Mediterranean diet has suggested to lead to the improvement of several chronic gynecological disorders [30]. It is also important to highlight healthy diets as necessary for the health of the next generation, because after fertilization and implantation of the egg, a nutritional/healthy environment for the baby may have the ability to positively “facilitate epigenetic signaling”, promoting the best health for the baby as possible [30]. Furthermore, many researchers encourage the improvement of a nutritional diet for women because it can decrease severe Premenstrual Syndrome (PMS) symptoms as well as the risk of developing PMS [31]. Overall, implementing a healthy diet in one’s life is critical, especially for women in regard to the menstrual cycle and its corresponding disorders, and many people took advantage of the pandemic to develop a more positive lifestyle, such as utilizing the extra time for learning how to cook healthy meals instead of relying on fast-food restaurants [32].

It can also be suggested that unhealthy diets were created during the lockdown, which led to the irregularity of menstrual cycles for many women due to a shift in nutritional intakes. The COVID-19 lockdown forced the isolation of many people, and quarantine instilled the trait of laziness within thousands of people due to the deviation from previous routines. Many people turned to the option of fast-food consumption and binge-eating since individual conviction dissipated due to the anxiety of the current state of the world. Additionally, many people decided to reward themselves, or make themselves feel better, by eating many sweet foods. Ten studies that provide evidence towards this topic were undergone during the time of quarantine, and they each reported an increase in the number of snacks consumed, with six of those ten studies displaying participants’ increase in the amount and frequency of meals eaten during the COVID-19 lockdown [32]. Nine of the ten studies showcased a decrease in the amount of produce consumed, along with six demonstrating an increase in the intake of comfort foods; the intake of sweets increased by 22% along with that of cakes being 20% [32]. Other studies have researched junk food’s impact on the menstrual cycle, and it has been identified that the consumption of junk food negatively influences the cycle, and there has been a strong correlation between the intake of sweet foods and fast-food with menstrual abnormalities [27]. Deviation from the menstrual cycle’s “normal physiological process” can lead to PCOS, infertility or even obesity [27]. Connections can be suggested between the research of both Bennett and Latif, and it can be concluded that a certain portion of women who shifted towards unhealthy eating during the time of the pandemic experienced abnormalities of their individual menstrual cycle. It is important for women to understand the significance a healthy diet and lifestyle have on their natural reproductive cycle, and

certain suggestions, such as the consumption of protein, vitamin B12 and vitamin D, along with other beneficial changes can prevent and/or decrease pain associated with the menstrual cycle, as well as premenstrual syndrome [33].

### Changes in physical activity rates

The lockdown may have also promoted shifts in routine exercise, thus leading to the influence on the menstrual cycle. Many previously active women grew inactive during the lockdown, and on the other hand, many inactive women became active due to extra time; there are multiple perspectives to be observed in order to identify the lockdown's impact on the menstrual cycle via changes in physical activity. Overall, there are differences visible through research on healthy people/athletes and the COVID-19 lockdown's consequences on their routine, and as well as that of inactive/obese people during the pandemic. Before discussing the demonstrated shifts in physical activity during the timespan of quarantine, it is critical to showcase the Hypothalamic-Pituitary-Ovarian (HPO) axis' relationship with the reproductive hormone of estrogen. The dysfunction and weak development of the HPO axis in women has the ability to influence low levels of estrogen, which furthermore presents issues such as negative effects on sexual function, fertility, and sexual maturation [34]. The HPO axis has control over the synthesis of estrogen during puberty [34], and inactive physical lifestyles result in the dysfunction and prevention of the HPO axis to develop into its mature, fully functioning state.

As mentioned before, there are multiple different scenarios of the status of individual women's physical activity state, such as being active, inactive, or even conducting excessive exercise. Although physical activity is recommended by almost all physicians, excessive exercise can lead to menstrual irregularities [35]; sports such as "gymnastics and endurance disciplines" had a higher rate of menstrual disorders [35]. There are two perspectives in regard to the lockdown that can be observed for women who exercised excessively before the pandemic occurred - some women may have decreased their activity towards a more moderate exercise routine, possibly leading to the establishment of more regular menstrual cycles, and there is also the possibility of women continuing excessive activity. The lockdown may have been beneficial for women who shifted to more moderate physical activity when considering menstrual cycle regularities, and it is possible that many women experienced these shifts due to most sports leagues/establishments temporarily closing for the lockdown.

Healthy women/athletes may have undergone negative impacts on their menstrual cycle due to the lockdown as a result of COVID-19. For a woman to be classified as an active person, they must exercise at least half an hour of vigorous activity five days per week [12]. Women athletes have interestingly reported fewer menstrual symptoms before and during periods when compared with sedentary women [36], and other studies have highlighted that higher levels of physical activity result in fewer problems associated with "heavy menstrual bleeding" [37]. Specifically, highly active women have a 10% lower change of developing heavy menstrual bleeding than women who are inactive/obese [37]. When considering the lockdown, the isolation of many physically active women resulted in the decrease in the amount of physical activity undergone, as well as the quality of sleep [38]. The disruption of the pandemic on the foundational routines of active women created an agitation towards the regularity of sleep, and ultimately on the menstrual cycle, since deviation from healthy amounts of exercise impacts

the healthy regularity of the cycle.

Before the COVID-19 lockdown, obese/inactive women already had a higher chance of irregular period and heavy menstrual bleeding than women with normal weight [37]. It is perceivable to identify the understanding that inactive women did not have a large shift of physical activity due to the lockdown, and some researchers observed how inactive participants did not experience considerable changes in activity [38]. Many active women shifted towards being identified as inactive women, with about 46% of females being active prior to the COVID-19 pandemic, but during isolation and the social-distancing period, this percentage lowered to 31% [12]. Before the pandemic, 9.5% of the population was considered "insufficiently active", and after the pandemic, this percentage increased to 23%, with an 129% increase in this identification for women [12]. Overall, inactive women did not experience a large shift in physical activity, remaining in the current state of high possibilities of irregular menstrual cycles and heavy bleeding, whereas a large percentage of active women significantly decreased physical activity rates, becoming titled as inactive women. By becoming inactive, chances of menstrual complications, such as irregularity and abnormal bleeding accompany this shift, confirming the notion that the lockdown negatively influenced the menstrual cycle and its associated symptoms for many women.

### Decrease in vitamin D light exposure and corresponding increase in blue light

One of the most influential outcomes of the COVID-19 enforced quarantine was the increase in the use of phones, and the associated exposure to emitted blue light, and the decrease in natural vitamin D (sunlight exposure). Along with the increase in the vulnerability to blue light, the increase in the use of smartphones resulted in physical symptoms as well; vitamin D deficiency is correlated with specific menstrual cycle-related diseases, such as PCOS, and it interestingly relates to previous aspects of melatonin and circadian rhythm and the anxiety-related hormone of cortisol. By directing promoting menstrual cycle disorders and influencing factors that negatively impact the menstrual cycle in their own ways, it is concluded that vitamin D deficiency and increased blue light exposure was dangerously influential towards the overall state of the female reproductive process, all catalyzed by the COVID-19 lockdown.

As a result of the pandemic, many people were not able to have face-to-face interactions with family members and friends due to implemented isolation protocols, and smartphones and communication devices were the solution to this problem, but there was a drastic increase in the use of technology, specifically smartphones, and overuse and addiction occurred [39]. Studies concluded that there was a 78.35% increase in screen time per day during the COVID-19 lockdown [24], with 96% of students increasing time spent on electronic devices, especially for school, which was shifted to online learning [10]. Smartphones emit blue light, which is within the wavelength of 400-480 nm [40], and with an increase in the use of smartphones/electronic devices, people had increased exposure to blue light.

High levels of blue light exposure have been correlated with menstrual symptoms as well as more general emotional and physical symptoms. After visible increases in the utilization of smartphones and the notion of emitted blue light, symptoms of fatigue, low back pain, and headaches associated with menstruation were seen with more occurrence and intensity [41]. Some of the premenstrual emotional symptoms observed in fe-

male students with increased smartphone usage were depression and irritability, and sleep patterns were thus distorted [41]. Furthermore, the usage of smartphones negatively impacted general physical symptoms such as eyestrain, stiffness of the back and neck, difficulty in being motivated, and increased stress [41].

With the increase in blue light exposure, many people experienced decreased exposure to vitamin D/sunlight, additionally linking with developed menstrual diseases. Hormones intertwined with vitamin D, such as 1,25-dihydroxyvitamin D, are involved in the hormonal aspects of the menstrual cycle, and a low amount of this vitamin D-related hormone results in lower estradiol levels throughout the menstrual cycle [42], which could lead to further imbalances of menstrual hormones. Within a recent study, 80% of participants had insufficient Vitamin D levels, and these participants had higher levels of associations with abnormal breast and uterus ultrasounds, along with negative reproductive diseases/disorders such as endometriosis, dysmenorrhea, higher risk of HPV infections in the uterus, and other gynecological diseases [43]. It is visible that deficient vitamin D exposure, an issue that was heightened during the lockdown, leads to many female reproductive issues, not only limited to the menstrual cycle; these issues have the capacity to influence the regularity of the menstrual cycle in their own ways. Additionally, women with Polycystic Ovary Syndrome (PCOS) and insufficient vitamin D levels experienced fertility issues and menstrual irregularities due to “calcium dysregulation and follicular arrest” [44]. Deficient vitamin D levels have serious menstrual-related diseases associated with it, and vitamin D supplementation has been confirmed to improve menstrual period regularity and bleeding, and “decreased blood testosterone levels” in women with PCOS, which overall improves the ability to reproduce [44]. To add onto this concept of supplementation, vitamin D consumption via supplements have also been found to reduce the intensity of dysmenorrhea, a disorder promoted by low vitamin D levels [45]. The enforced quarantine due to the Coronavirus promoted the isolation within housing, and many women decreased their time outside, in the sunlight, because many public stores and spaces were closed; staying indoors became the norm for populations of most countries, and boredom led to the addiction to electronic devices, and with their high levels of emitted blue light, it resulted in increased risk towards disorders corresponding to the female reproductive system, especially irregularities in the menstrual cycle. Blue light can impact the menstrual cycle indirectly by influencing changes in circadian rhythms and cortisol concentration. The increased use/addiction of smartphones has augmented the time at night in which electronic devices are utilized, and exposure to high levels of blue light at night influences the decreased secretion of melatonin [46]. As previously discussed, the disruption of the established circadian rhythm can distort menstrual regularity. Moreover, blue light exposure, especially at night, impacts cortisol concentration by increasing cortisol synthesis [47]. Blue light and its associated impact on cortisol promotes a “stimulatory effect” on the HPA axis, which thus has the power to cause irregularities of the reproductive cycle due to the unnatural fluctuation of cortisol levels in the follicular and luteal phases.

### Synchronization of cycles due to the proximity of women during quarantine

In the past few decades, research has speculated that women’s menstrual cycles sync when in proximity to other women

for long periods of time. The COVID-19 lockdown encouraged stay-at-home restrictions, with many family members living with one another [48]. Schools were closed and most parents and guardians had to work from home, which thus increased the time that family members/women were in proximity to one another, additionally because the lockdown occurred 3-4 full months for families at the very least [48]. Studies were conducted, and participants stated that more time was spent with family due to not being able to do “activities outside of the home” [48]. Although there is evidence suggesting that cycles do not sync, the evidence of the lockdown procedures connects to the possibility of the shifted timeframe of menstrual cycles for some women. Menstrual synchrony is titled the McClintock Effect and is caused by the influence of human pheromones when menstruating women live together, leading to simultaneous cycles [49]. In a recent study, 135 college girls who lived in a dorm community provided three updates per academic year on characteristics and timeframes of their individual period; the results demonstrated the accuracy of the theory of period syncing [49]. In a similar research investigation, females who shared a common environment provided information of their periods, and results concluded that about 55% of females were under the influence of menstrual synchrony [50]. Researchers established that long-term roommates and their resulting proximity can cause cycle synchrony, thus having a compelling implication for reproductive scheduling for procreation [50]. Comprehensively, recent evidence of the McClintock effect can be related to the lockdown and its encouraged proximity of family members/women as a result; although it has not been explicitly confirmed, it is reasonable to suggest that a certain percentage of women around the world experienced menstrual cycle synchrony during the timeframe of the lockdown. Although recent evidence can be linked to the lockdown, there is also testimony that documents that synced cycles do not occur, and this must be taken into account when considering COVID-19 lockdown’s impact on the menstrual cycle. It is previously thought that in ancient times, the menstrual cycle was synchronous with the moon, impacting reproductive behavior, but with the exposure of “artificial nocturnal light”, cycles lost this speculated synchrony [51]. During the initial identification on the McClintock Effect, a research investigation was conducted on 186 women who lived in dorms together, and after analyzing the timeframes of each of their cycles for one year, it was determined that their periods did not sync [49]. Mathematical calculations led to the conclusion that periods coincidentally overlap rather than syncing from the influence of pheromones [49]. Principally, there is no evidence that strongly confirms the theory of the McClintock effect, but there is a possibility that some women experienced a shift in their cycles as a result of syncing with other proximal women during the lockdown.

### Zinc supplementation

The protection of the immune system became a priority for many people when the COVID-19 pandemic occurred, and zinc supplementation became a common step towards prevention of the virus. There is evidence towards zinc’s beneficial impact on the menstrual cycle, and this may be one of the only factors that has led to the improvement of cycle symptoms during the pandemic’s associated lockdown.

Zinc is a mineral essential for the function of metabolism, and countless studies have proven zinc’s aid in the development and solid establishment of the immune system [8]. Zinc has the capacity to inhibit viral replication, thus playing a role in

protecting the body against the coronavirus to an efficient extent [8]. More specifically, zinc actively preserves tissue barriers which in turn prevents the entry of pathogens [8]. News segments across the world provided families information on these studies which identified zinc's ability to prevent the infection and progression of COVID-19 [8], resulting in many people to consume zinc supplements.

As previously mentioned, zinc plays important roles towards the immune system, but it also contributes towards other bodily processes, such as cell growth, the release of hormones (like progesterone), and reproduction [52]. One of zinc's beneficial impacts on the menstrual cycle's related symptoms include the reduction of dysmenorrhea (symptoms of extreme pain) before and during periods [52]. Other research concludes that zinc is associated with Premenstrual Syndrome (PMS) symptoms, and explicitly, after the consumption of zinc for about 24 weeks, there have been visible differences in symptoms such as depressed mood, anger, anxiety, weight gain, and headaches compared to those who are deficient in zinc levels [53]. Throughout the menstrual cycle, serum zinc concentrations differentiate between phases, and women who have Premenstrual Syndrome (PMS) have lower serum zinc concentrations compared to women without PMS [53]; zinc facilitates the release of progesterone, which is a hormone that heightens the risk of PMS [53]. Zinc supplements have been confirmed to reduce symptoms involved in premenstrual syndrome, overall preventing painful periods, along with supporting the efficiency of the immune system [53]. The anxiety that many women retrieved during the timeframe of the pandemic led them to act towards the protection of their immune system, and with zinc being a strong inhibitor towards the COVID-19 virus, many women consumed zinc supplements. Along with the support of the immune system, zinc supplements may have helped many women facing PMS with the reduction of menstruation pain. Zinc supplementation taken during the lockdown was beneficial towards the symptoms corresponding to the menstrual cycle.

### Conclusion

Upon researching several factors that arose from the international spread of the COVID-19 virus, it can be concluded that the menstrual cycle, among many women, received negative impacts, such as irregularity and increased symptoms of pain. Six factors led to these adverse influences, consisting of the anxiety-related hormone of cortisol, the sleep-related hormone of melatonin and its relationship with circadian rhythm, dietary changes, decreases in physical activity rates, decrease in vitamin D, and synchronization of cycles. The one factor that resulted in beneficial influences on the menstrual cycle was zinc supplementation.

The anxiety-related hormone of cortisol increased in many women during the lockdown due to external factors of stress in relation to the global lockdown/isolation, and separation from the established routines of life. Higher cortisol levels led to unnaturally high cortisol concentrations in the luteal phase, and with cortisol's relationship with the Hypothalamic-Pituitary-Adrenal (HPA) axis and a separate connection with Post-Traumatic Stress Disorder (PTSD), serious menstrual irregularities were a result. The sleep-related hormone of melatonin experienced shifted secretion rates due to many women changing their previous sleep patterns. Different sleep-wake behaviors than those before the lockdown contributed to irregularities in the menstrual cycle; circadian rhythm disruption additionally holds a relationship with the Hypothalamic-Pituitary-Gonadal (HPG) axis,

which thus causes the possibility of developing Polycystic-Ovary Syndrome (PCOS).

Due to many women deviating from their pre-pandemic routine, a considerable percentage of women who had healthy diets drifted to more unhealthy diets, resulting in irregular menstrual cycles. Healthy nutritional diets are correlated with reduced severity of menstrual pain, and with many establishments temporarily closing because of the pandemic, such as recreational gyms, and grocery stores, increase menstrual pain became more apparent due to the creation of unhealthier diets. Along with unhealthier diets, physical activities rates decreased among a large portion of women, additionally resulting in increased menstrual symptoms and their associated pain and irregularity. Obesity rates increased due to unhealthy lifestyles, increasing the risk of contracting the COVID-19 viral infection.

The implementation of stay-at-home procedures decreased the amount of time people were outside, with the use of electronic devices increasingly dramatically. With the projection of blue light from smartphones, the menstrual cycle was indirectly impacted from blue light's relationship with disrupting the circadian rhythm and the increase in cortisol concentration, which thus led to the pathway towards the irregularity of the reproductive cycle. Furthermore, many women obtained deficient levels of vitamin D, which connects with reproductive diseases such as PCOS and dysmenorrhea. Finally, the pandemic led to families quarantining together, and women's proximity to female family members may have led to period synchronization, which points towards temporary menstrual irregularity when in the process of establishing the synchronized cycle.

Interestingly, increased zinc supplementation during the COVID-19 lockdown was primarily utilized to strengthen the immune system from the coronavirus, but it also benefitted some women's menstrual cycles, since it is suggested to improve menstrual pain and other symptoms, such as anxiety, headaches, and anger.

Ultimately, it can be concluded that the COVID-19 lockdown was negatively influential towards the natural female reproduction process of the menstrual cycle, with the main impacts being the promotion of irregular cycles, and increased pain and other related symptoms.

### Future trends

Although the evidence compiled within this research investigation highlight the high probability that the COVID-19 lockdown promoted negative impacts on the menstrual cycle, more evidence still needs to be conducted on all seven of the considered factors. There is the considered limitation that there most likely cannot be research studies that can be conducted under the same exact environments that were created during the pandemic, since most countries have resorted back to normal lifestyles that were established before the pandemic. But it is important to note that many aspects of life have changed due to the lockdown and are more evident in the present-day as a result of the lockdown, such as the retained rates of the use of smartphones/electronic devices.

The presence of the coronavirus instilled fear within many people due to ever-present risks towards the immune system, resulting in many women not continuing annual visits to their Obstetrician/Gynecologist. Some OBGYN doctors desire to retrieve medical information associated with the pandemic and its resulting impacts on the female reproductive system, but

these doctors may not be able to obtain as much data as they would prefer.

Although most countries have returned to pre-pandemic routines, the increase in the use of smartphones and the associated exposure to blue light, dietary and physical activity changes instilled by the pandemic, and overall increased rates of anxiety and its correlated hormone of cortisol, have possibly led to unhealthy states of the average body. This change towards an unhealthier average female body has the influence to negatively impact the menstrual cycle by increasing the irregularity and symptoms. Since the lockdown has influenced multiple aspects of life that still linger to this day, there could be a greater impact that is not yet known; more research is necessary in order to confirm the long-term consequences the COVID-19 lockdown had towards the natural reproductive process of the menstrual cycle.

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