The Impact of Sleep Deprivation on Hormonal Balance and Women's Health: A study done in West Bengal.

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Abstract

Objective: This study aims to check the impacts of sleep deprivation on hormonal levels such as cortisol, melatonin, estrogen, and progesterone and their role on women's health.

Method: In this cross-sectional study 120 women within the age group of 25 to 45 years from West Bengal were considered. Two groups were created, the first consisted of women who slept for 7 - 9 hours/night and the second group had women with sleep deprivation (less than 6 hours/night). Blood samples were collected to perform tests of hormonal levels (cortisol, melatonin, estrogen, progesterone). The sleep quality was assessed by the Pittsburgh Sleep Quality Index (PSQI). Using t-tests and regression models of analysis, the correlation between sleep deprivation and hormonal imbalances was studied.

Results: Modulations in the cortisol levels were observed in sleep-deprived women as well as reduced melatonin secretion in sleep-deprived participants correlated with disrupted circadian rhythms. The levels of reproductive hormones such as estrogen and progesterone also decreased in sleep-deprived women, and menstrual irregularities were associated with it.

Conclusion: Indeed sleep deprivation can modulate the hormonal balance in women, which directly influences physical and mental health.

Keywords: Sleep deprivation, hormonal balance, melatonin, cortisol, estrogen, progesterone, women's health.

Introduction

Sleep is a fundamental biological process that is essential for homeostasis in the human body. It is the regulatory mechanism of numerous physiological functions like cognitive performance, immune response as well as hormonal equilibrium **(1)**. Sleep is predominantly controlling the interaction of the hypothalamic-pituitary-adrenal (HPA) axis, the reproductive hormones, and circadian rhythms in women **(2)**. It is found to have reflective effects on hormonal regulation, which eventually results in a collection of physiological and psychological consequences; the underlying etiological factors of disturbed sleeping patterns may derive from lifestyle, stress, or any specific underlying conditions.

Sleep deprivation affects the HPA axis, the system of the body in response to stress, extremely. In people who have insufficient or poor-quality sleep, cortisol, one of the key regulated hormones for the HPA axis, tends to be increased **(1).** Chronic stress, characterized by elevated cortisol levels, may affect immune function, increasing the risk of developing cardiovascular

disease as well as contributing to metabolic dysregulation **(3).** This chronic stress and high cortisol levels are responsible for the imbalance of the reproductive hormones (estrogen and progesterone) and can result in menstrual irregularities, infertility, and even lifelong health risks like osteoporosis **(2).** However, studies have also demonstrated that sleep deprivation also makes anxiety and depression worse, adding to the negative effects on the hormonal balance **(4).**

Inconsistent sleep disturbs the level of melatonin as well. Melatonin is vital for the regulation of the sleep-wake cycles. Circadian rhythms manipulate the melatonin secretion and sleep disruptions can cause a decrease in melatonin production worsening sleep disorders and deteriorating overall health **(5)**. For women, melatonin influences ovarian function and the regularity of the menstrual cycle **(2).** Additionally, melatonin can prevent oxidative stress, hence, it displays a protective role as well. In the case of sleep deprivation, level of melatonin levels decrease resulting in the development of chronic diseases like cancer and neurodegenerative disorders **(6).**

Estrogens and progesterone are studied to be extremely sensitive to sleep disturbance. These reproductive hormones are responsible for the maintenance of bone health as well as responsible for the maintenance of women's cardiovascular and cognitive health. Furthermore, these hormones influence the menstrual and pregnancy cycle as well **(2).** Poor sleep quality modulates the level of hormones leading to irregularity in the menstrual cycle, reduces fertility, and intensifies the perils for the development of osteoporosis and cardiovascular disease **(1).** Insufficient sleep deteriorates metabolic health, it is associated with insulin resistance and leptin levels, as well as related to the development of obesity **(3).**

Studies showed that poor sleep qualities and hormonal imbalances are worsened by lifestyle, diet, physical activity, and stress management. Poor dietary habits and lack of physical activity will worsen the effects of sleep deficiency on hormonal health **(8)**. But if stress is reduced along with regular exercise, this improves sleep quality and balances the hormonal level of the body **(9).** These findings emphasize the need for a solution to deal with excessive sleep deprivation that ultimately affects women’s health.

As sleep deprivation is studied to have adverse effects on hormonal balance and overall health, hence, in this study, we seek to learn the effects of sleep deprivation on key hormones such as cortisol, melatonin, progesterone, and estrogen and try to obtain a wider picture of women’s health. This research aims to show the importance of adequate sleep on the health of women.

Methods

Study Design

This study was carried out for a period of six months i.e. from January to June 2024 at a tertiary healthcare center and its affiliated clinics in West Bengal. It is a cross-sectional study. To

measure the difference in hormonal levels between women with adequate sleep and those with sleep deprivation at a single point in time, a cross-sectional design was used.

Participants and Sampling

A total of 120 women aged 25 to 45 years participated in this study. This study used stratified random sampling. The enlistment was carried out through advertisements in local healthcare centers, involvement with community outreach programs, and social media platforms. Participants were informed about the study's objectives, procedures, and provided with written informed consent. The ethical approval was obtained adhering to the guidelines.

Participants were categorized into two groups based on self-reported sleep duration over the past three months, which were tested using the Pittsburgh Sleep Quality Index (PSQI), which is as follows:

- Adequate Sleep Group (n = 60): This group includes women who reported sleeping 7–9 hours per night, as per the National Sleep Foundation's recommendations **(10).**
- Sleep-Deprived Group (n = 60): The women of this group slept for less than 6 hours per night regularly.

The inclusion criteria are as follows:

Women within the age group of 25–45 years residing in West Bengal with no history of diagnosed sleep disorders were included in this study. Furthermore, we also adhered to their willingness to participate and provide blood samples for this study

The exclusion criteria are as follows:

Pregnant women and women who were breastfeeding were excluded. Women diagnosed with endocrine disorders like polycystic ovary syndrome, thyroid dysfunction, and Cushing's syndrome were also not accepted. Again, women using hormonal contraceptives or hormone replacement therapy within the past three months were also exempted from this study. Women with a history of psychiatric conditions such as major depression or generalized anxiety disorder and shift workers or individuals with irregular sleep-wake schedules were again not included.

Sleep Assessment

Pittsburgh Sleep Quality Index (PSQI) was administered to assess the quality and duration of sleep **(11).** The PSQI is an identical as well as standardized, auto-verification questionnaire consisting of 19 items and covering seven components which are as follows:

- Subjective sleep quality
- Sleep latency (time taken to fall asleep)
- Sleep duration
- Habitual sleep efficiency
- Sleep disturbances
- Use of sleep medication

- Daytime dysfunction

Each component is recorded from 0 to 3 **(11).**

Hormonal Analysis

5 ml of venous blood was collected between the morning hours of 7:00 AM and 9:00 AM which was supposed to be followed by an overnight fast to lessen the circadian influences on the various hormone levels **(12).** Samples were processed immediately and stored at −80°C for further analysis and measurement of the Cortisol, Melatonin, Estrogen or Estradiol, and Progesterone.

Hormonal levels were measured using enzyme-linked immunosorbent assay (ELISA) **(13).** The assays were executed in triplicate for precision and to confirm reproducibility.

Statistical Analysis

The data were scrutinized and presented using IBM SPSS Statistics (version 26.0) and statistical significance was established at $p < 0.05$. The Mean (± standard deviation) was performed to review participant characteristics. Independent sample t-tests were conducted to compare the hormonal levels between the two groups. Pearson's correlation coefficient was used to assess the interrelationships between sleep quality (PSQI scores) and hormone levels. Finally, multiple linear regression analysis was used to adjust the potential cofactors such as age, body mass index (BMI), physical activity, and dietary habits.

Results

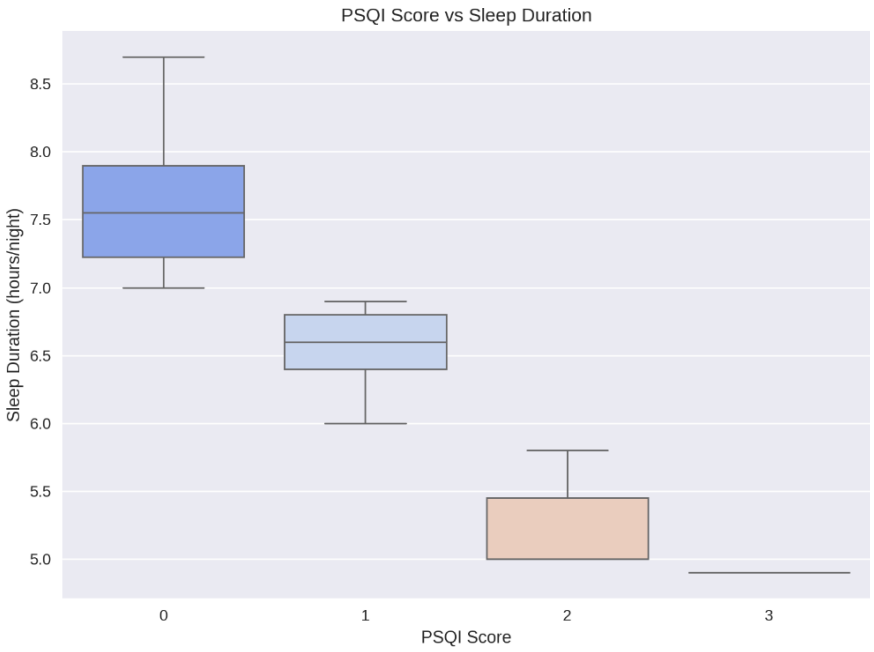

Fig 1: PSQI score

Fig 1 shows how sleep duration decreases as PSQI scores increase, with PSQI scores of 2-3 showing significantly lower sleep duration compared to scores of 0-1.

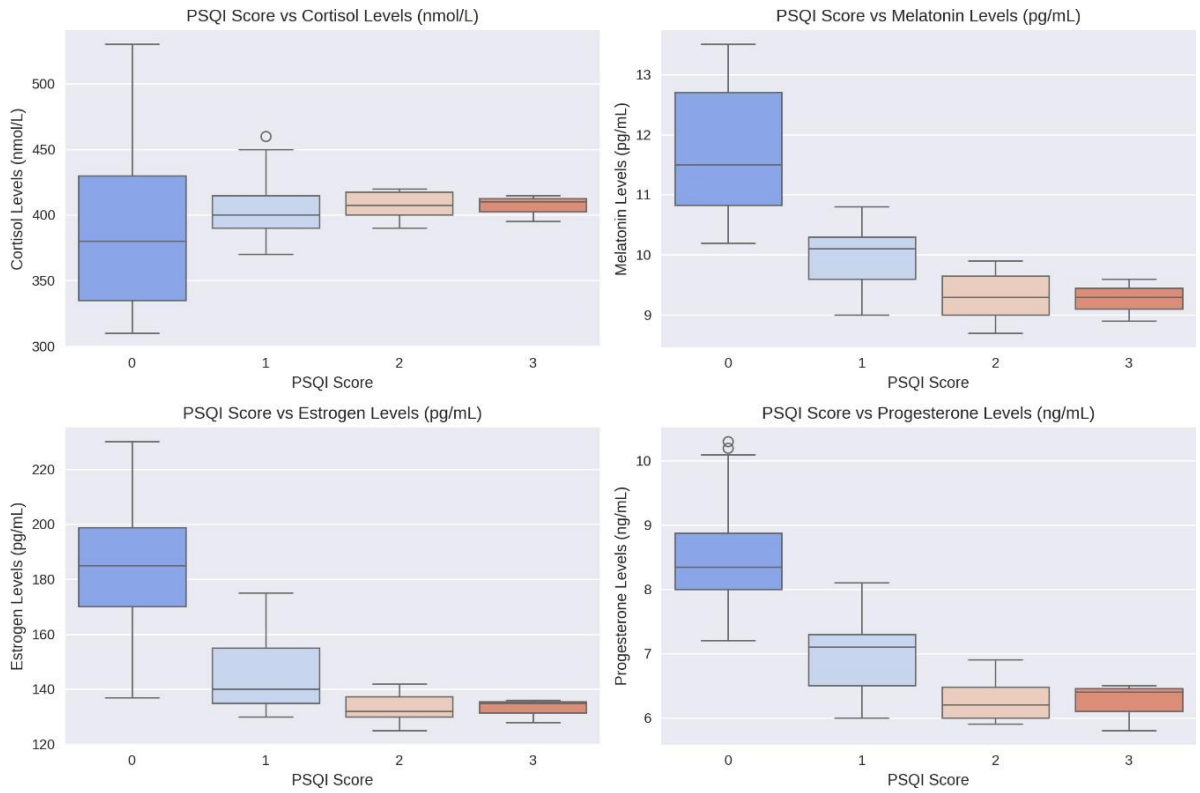

Fig 2: The relationship between PSQI scores and different hormone levels

The box plot indicates the median (middle line), quartiles (box), and range (whiskers) of hormone levels for each PSQI score. In sleep-deprived individuals, the cortisol levels are slightly increased. Whereas, melatonin levels are markedly lower in sleep-deprived individuals. Both Estrogen and Progesterone levels are also found to decrease in sleep-deprived individuals.

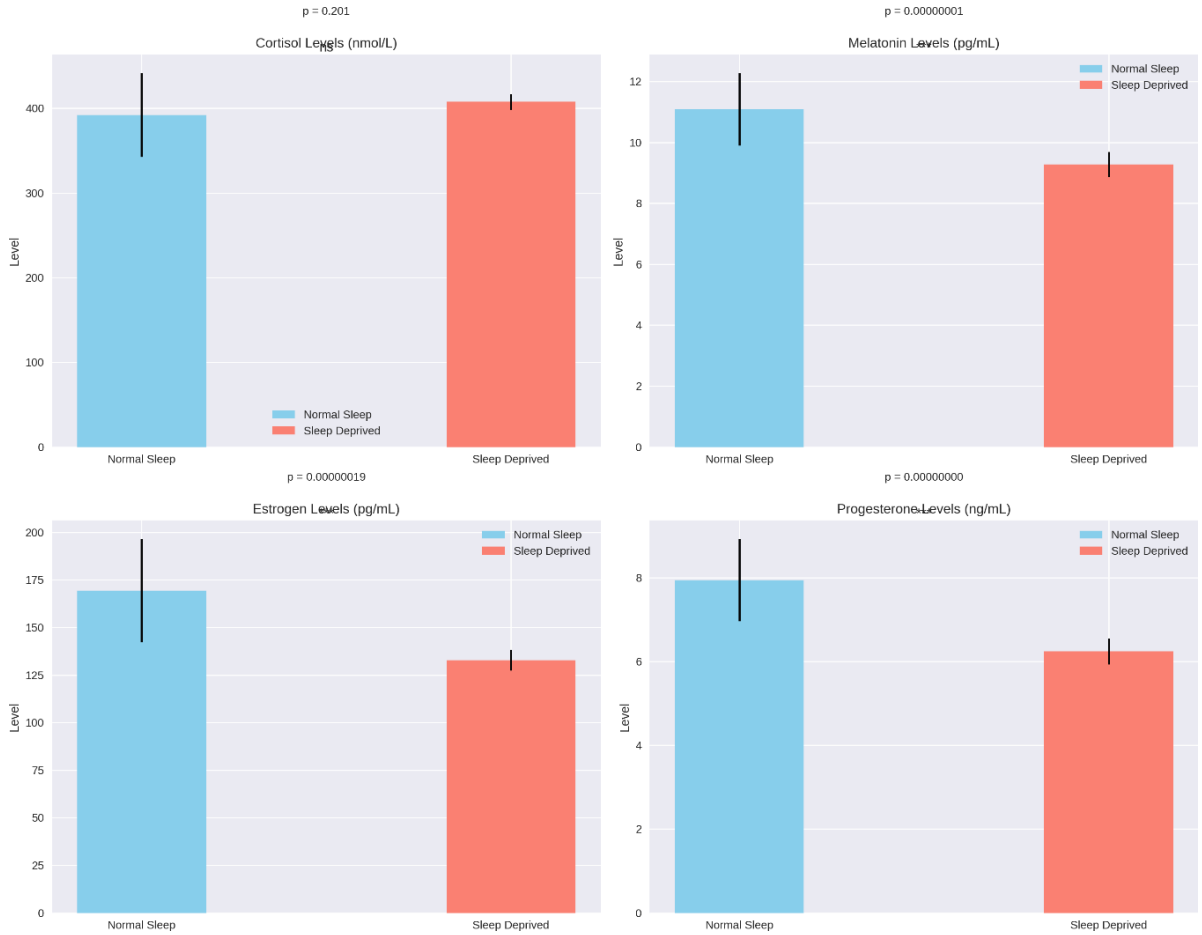

Fig 3: The different hormone levels in both the groups

This figure compares the hormonal levels between the group with normal sleep and the sleep-deprived group respectively, showing mean ± standard deviation, significance levels, and p-values for each hormone.

In the case of cortisol levels, no significant difference was observed between the groups ($p > 0.05$), indicating similar stress hormone levels.

Whereas, melatonin levels were significantly lower in the sleep-deprived group ($p < 0.001$), reflecting disrupted sleep-wake cycles.

The estrogen levels were found to be significantly reduced in the sleep-deprived group ($p < 0.001$), suggesting potential hormonal imbalances.

Again the level of progesterone was found to be significantly lower in the sleep-deprived group ($p < 0.001$), indicating further hormonal disruption.

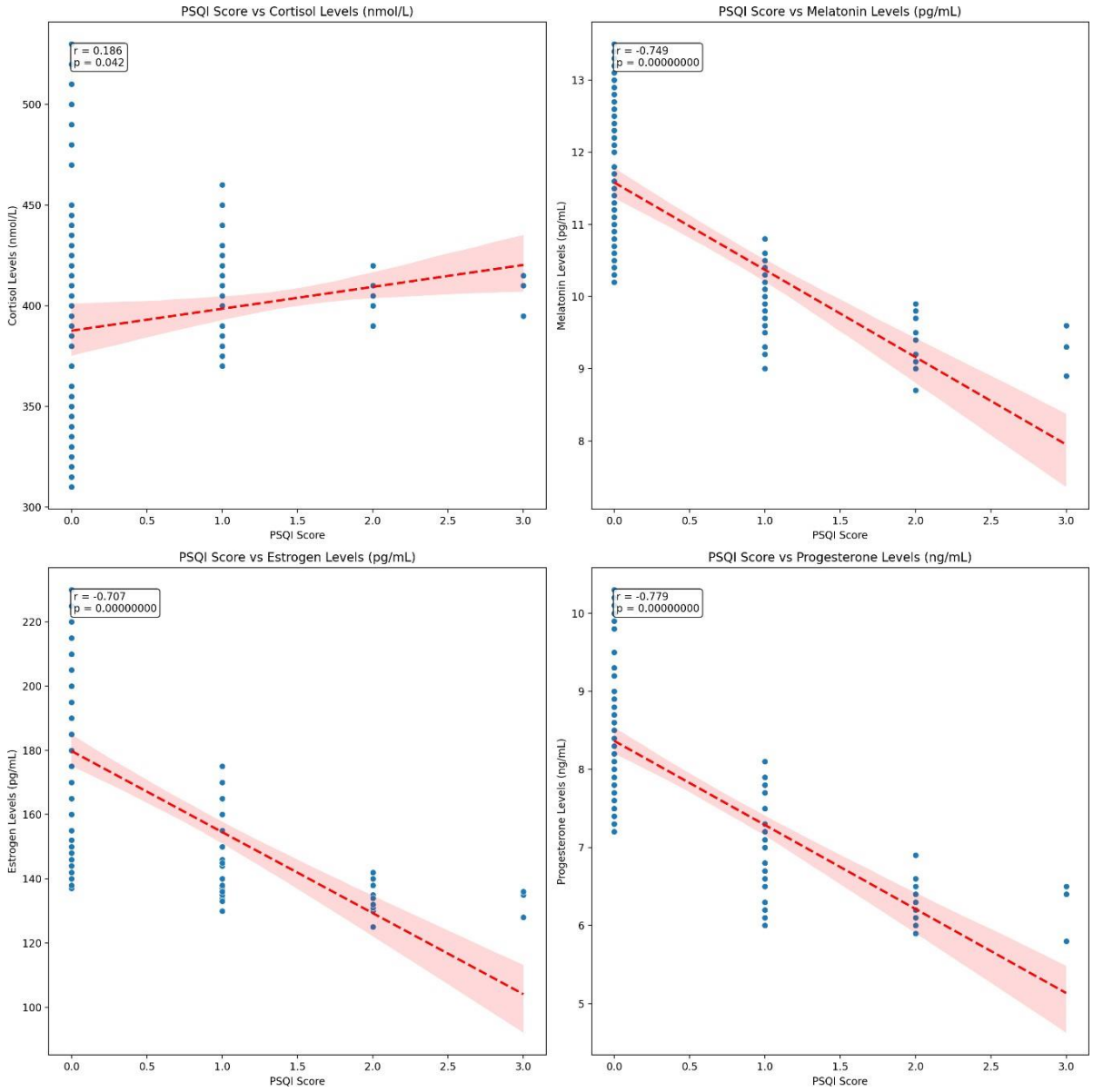

Fig 4: Pearson's Correlation plots (The relationship between PSQI scores and hormone levels)

Fig 4, shows the Scatter points which represent the individual measurements; the trend is represented by the red dashed regression line. The Pearson correlation coefficient is represented as (r). The p-value indicates statistical significance.

The results indicate:

- Weak positive correlation with Cortisol ($r = 0.186$, $p < 0.05$)
- Strong negative correlation with Melatonin ($r = -0.749$, $p < 0.001$)
- Strong negative correlation with Estrogen ($r = -0.707$, $p < 0.001$)
- Strong negative correlation with Progesterone ($r = -0.779$, $p < 0.001$)

These correlations show that as sleep quality deteriorates (higher PSQI scores), there's a noteworthy decline in the level of melatonin, estrogen, and progesterone, with a slight rise in the cortisol level.

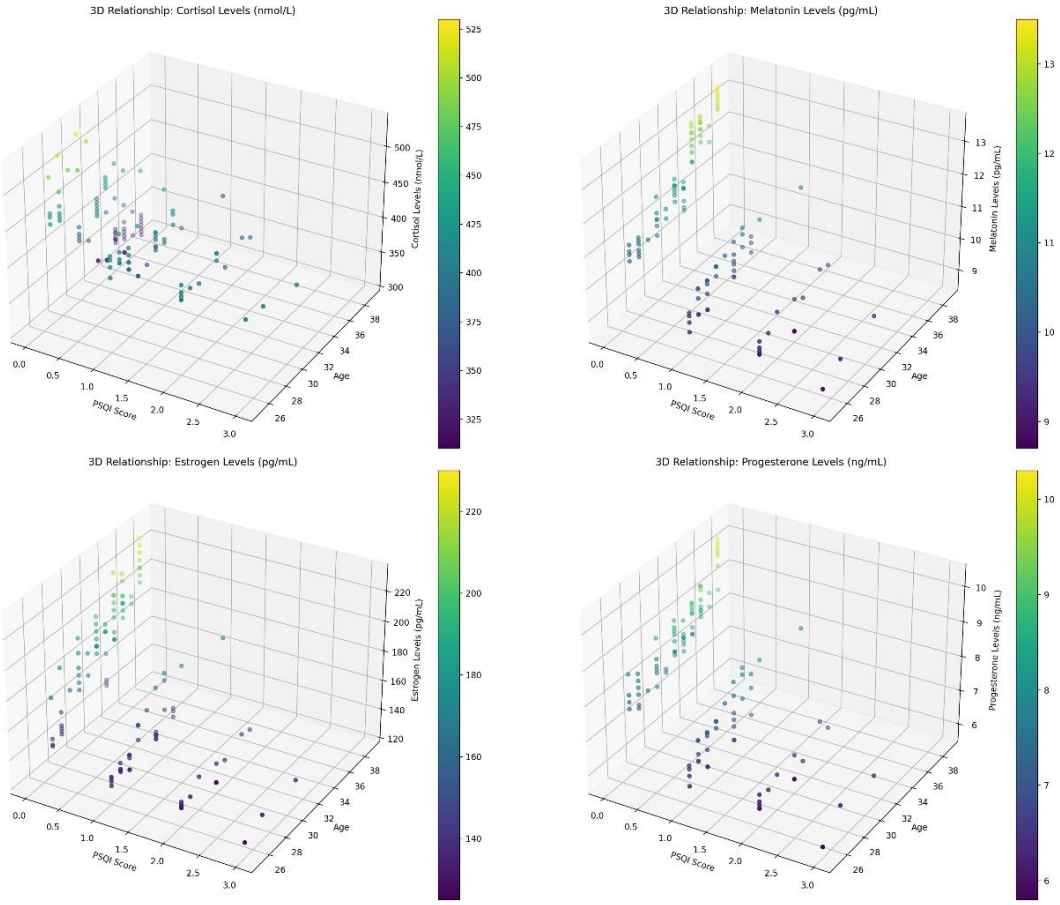

Fig 5: Regression analysis; 3D scatter plots showing the relationships between PSQI scores, age, and hormone levels.

The color gradients indicate the hormone concentration levels; Steeper slopes designate stronger relationships, and clear patterns are visible for melatonin, estrogen, and progesterone, whereas; cortisol displays a more scattered distribution.

The Multiple Linear Regression shows, that age has a significant negative effect ($p < 0.001$) PSQI Score effect is not significant ($p = 0.212$); in the case of melatonin, both PSQI Score (-0.793) and Age (0.205) have significant effects ($p < 0.001$) with a strong negative relationship between poor sleep quality. Again, for estrogen, PSQI Score has a strong negative effect (-15.93, $p < 0.001$) whereas, age has a positive effect (4.58, $p < 0.001$). For progesterone: R a strong negative relationship with PSQI Score (-0.758, $p < 0.001$)was recorded with a positive relationship with Age (0.157, $p < 0.001$)

Discussion

The findings of this study suggest lack of sleep affects the hormonal system in women and has an impact on the overall health of women. The results of the study showed a weak positive correlation between PSQI scores and cortisol levels. Cortisol, the stress hormone whose level

is regulated by the hypothalamic-pituitary-adrenal (HPA) axis, has been known to rise when one is tired or has poor sleep **(1).** Cortisol levels have been linked to chronic stress; it has adverse effects on the immune system, and the cardiovascular system, and also causes metabolic disorders **(3).** Although in this study there is no significant difference in the cortisol levels between the two groups, it can be concluded that poor sleep quality affects the stress response, especially for those with severe severe sleep deprivation. A strong negative correlation was observed between PSQI scores and melatonin and the melatonin level was found to be significantly lower in sleep deprived group. Melatonin, a hormone produced by the pineal gland, helps in the control of sleep and wakefulness state and also has a role in the control of circadian rhythms **(5).** Lower melatonin production results in disrupted circadian rhythms, which worsens sleeping disorders with consequent adverse effects on the whole body. Previous research has indicated that melatonin is an antioxidant, thus it helps in preventing oxidative stress. Hence, the depletion of this hormone by sleep deprivation may increase the chances of chronic diseases like cancer and neurodegenerative diseases **(6).**

It was found that PSQI scores correlated with estrogen and progesterone levels in strongly negative manners. Estrogen and progesterone are needed to maintain the reproductive health by regulating the menstrual cycle and maintaining pregnancy **(2).** A decline in the level of estrogen levels can affect bone density, and increase the risk of osteoporosis, and cardiovascular issues, while, on the other hand, a decrease in progesterone level is closely associated with irregularities of the menstrual cycle, infertility, and early pregnancy loss **(2).** The substantial decline in the levels of these hormones among sleep-deprived women highlights the damaging effect of poor sleep on reproductive health.

The multiple linear regression analysis revealed that age has a significant negative effect on melatonin levels and a positive effect on estrogen and progesterone levels indicating that hormonal responses to sleep deficiency may vary with age. Older women may experience more noticeable declines in melatonin levels, while younger women may be more vulnerable to falls in estrogen and progesterone levels respectively **(2).**

Although the metabolic effects have not been measured directly in this study, yet, the observed hormonal discrepancies, mainly the decrease in melatonin and reproductive hormone levels have consequences on metabolic health. Sleep deprivation has been connected to insulin resistance and, rise in leptin levels, and augments the risk of the development of obesity and metabolic syndrome (**1,7**). The strong negative correlations between PSQI scores and melatonin, estrogen, and progesterone levels indicate that sleep deprivation may lead to metabolic dysregulation, accentuating the need for enough sleep as a preventive measurement.

Conclusion

This study’s findings indicate that sleep deprivation and hormonal imbalance in women coincide and impair stress responses, circadian rhythms, reproductive health, and metabolic

regulation. Therefore, sleep is considered a modifiable lifestyle factor to improve women's health.

Limitations:

This study records data at a single point in time limiting the ability to establish underlying relationships between sleep deprivation and hormonal imbalances. Additionally, the consideration of self-reported information regarding duration of sleep and sleep quality from the Pittsburgh Sleep Quality Index (PSQI) may involve recall bias or inaccuracies of the procedures. The findings were also limited to West Bengal only limiting the findings. Other influencing factors should also be considered like environmental stressors or genetic predisposition.

Conflict of interests

This study was not supported by any funding agency and there were no conflicts of interest.

Authors' contribution

Monami Mukherjee Mondal performed the surveys and experiments, collected and analyzed the data, and drafted the manuscript.

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