International Journal of Research in Medical Sciences
Senapati A et al. Int J Res Med Sci. 2026 May;14(5):2043-2050
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012
DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20261346

Original Research Article

A study of central corneal thickness and psychological wellbeing: a menstrual cycle correlation

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Received: 13 April 2026
Revised: 21 April 2026
Accepted: 22 April 2026

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ABSTRACT

Background: Hormonal changes during the menstrual cycle can influence ocular physiology. Prior studies report mid-cycle increases in central corneal thickness (CCT) and modest intraocular pressure (IOP) changes. Mean CCT may rise ~5–6% at ovulation, whereas IOP differences are generally minor. These cyclical changes may affect clinical ocular measurements. This study aims to investigate variations in central corneal thickness (CCT) across different phases of the menstrual cycle and examine the potential associations between these variations and psychological factors such as stress, anxiety and depression.

Methods: Sixty healthy women (18–30 years) with regular 28–32-day cycles were recruited. Examinations were conducted in the early menstrual phase, midcycle and late luteal phase. Central corneal thickness was measured by pachymetry; IOP by Goldmann applanation tonometry; and visual acuity by a standardized logMAR chart. Psychological status was assessed at each phase using the depression, anxiety and stress scale (DASS-21). Correlation analyses were performed to explore associations between CCT and psychological scores. All measurements were taken in the morning to minimize diurnal variation.

Results: CCT was lowest in the early menstrual phase (530.6±8.9 µm), peaked at mid-cycle (561.3±10.1 µm) and decreased in the luteal phase (535.4±9.5 µm), with statistically significant differences ($p<0.001$). IOP and visual acuity remained stable throughout the cycle. DASS-21 scores were highest during the luteal phase (depression: 8.9±3.1, anxiety: 9.4±3.3, stress: 10.2±3.5) and CCT correlated negatively with anxiety ($r=–0.51$, $p=0.002$) and stress ($r=–0.46$, $p=0.004$).

Conclusions: Menstrual cycle-related hormonal changes cause temporary mid-cycle increases in CCT, while IOP and vision remain stable. Additionally, CCT variations are inversely related to psychological distress, highlighting the importance of considering both menstrual phase and emotional status in clinical ocular assessments.

Keywords: Central corneal thickness, Menstrual cycle, Pachymetry, Psychological status, Refractive surgery

INTRODUCTION

The menstrual cycle is a complex physiological process influenced by hormonal fluctuations that significantly affect various systemic and ocular parameters in women of reproductive age. The cyclical variations in estrogen and progesterone have been well documented to influence not only reproductive physiology but also ocular tissues, particularly the cornea, due to the presence of hormone receptors in corneal epithelium, stroma and endothelium. central corneal thickness (CCT), a key biomechanical parameter reflecting corneal hydration, endothelial function and intraocular pressure accuracy, is known to undergo subtle changes during different phases of the

menstrual cycle. These variations are attributed primarily to hormonal modulation of corneal collagen, osmotic balance and stromal hydration, especially under the influence of estrogen and progesterone surges during ovulation and the luteal phase.[1,2] Previous studies have shown that the cornea tends to be thicker during the ovulatory and luteal phases compared to the follicular phase, corresponding with peak estrogen and progesterone levels.[3]

These fluctuations can have clinical implications, especially in refractive surgery, contact lens fitting and intraocular pressure assessment, as over- or underestimation of CCT can lead to diagnostic inaccuracies in glaucoma and keratoconus screening.[4] Moreover, the menstrual cycle's hormonal influence extends beyond ocular physiology, as these hormones also affect mood, cognition and overall psychological wellbeing.[5] Estrogen, in particular, has neuroprotective and mood-stabilizing effects, enhancing serotonergic and dopaminergic activity, while progesterone's metabolites can influence gamma-aminobutyric acid (GABA) receptors, modulating anxiety and emotional regulation.[6]

The psychological wellbeing of women during the menstrual cycle is therefore closely tied to hormonal fluctuations, manifesting as premenstrual syndrome (PMS) or premenstrual dysphoric disorder (PMDD) in some individuals. These conditions are characterized by irritability, mood swings, anxiety and depressive symptoms occurring in the luteal phase and resolving with menstruation.[7] Emerging evidence suggests that hormonal variations may alter corneal physiology and emotional balance through shared neuroendocrine pathways, especially those involving the hypothalamic-pituitary-gonadal axis.[8] However, limited research has simultaneously examined both ocular and psychological changes throughout the menstrual cycle, despite the likelihood that both reflect systemic hormonal dynamics.[9]

Central corneal thickness has been explored as a sensitive biomarker in various physiological and pathological states, including pregnancy, oral contraceptive use and menopause, which also involve altered sex hormone levels. During pregnancy, for instance, corneal thickness increases due to estrogen-mediated water retention and collagen changes.[10] Similarly, women using hormonal contraceptives may experience reduced cyclical variations in CCT, indicating that hormonal steadiness minimizes corneal fluctuation.[11] These findings highlight the cornea's responsiveness to hormonal status and the potential for CCT to serve as an indicator of systemic hormonal balance.

Understanding this relationship during the natural menstrual cycle could improve interpretation of corneal measurements and provide insight into the neurohormonal regulation of ocular and psychological health. From a psychosomatic perspective, the interaction between ocular parameters like corneal thickness and psychological wellbeing may be explained by systemic endocrine and autonomic changes.[12] Cortisol and stress-induced hormonal alterations can influence tear secretion and corneal hydration, while mood disturbances can affect autonomic tone, further modifying ocular surface stability.[13] Therefore, integrating psychophysiological and ocular assessments during different menstrual phases may provide a comprehensive understanding of hormonal cyclicity and its systemic manifestations. The current study aims to explore the correlation between central corneal thickness and psychological wellbeing across different phases of the menstrual cycle. By identifying cyclical variations in both parameters, the study seeks to elucidate potential neuroendocrine mechanisms linking ocular physiology and psychological states in women. Such understanding may have clinical implications in personalized ocular assessment and in addressing hormonally influenced mood fluctuations, promoting a more holistic view of women's health.

METHODS

Study design

This research was conducted as a prospective observational study to investigate the correlation between CCT and psychological wellbeing across different phases of the menstrual cycle. The study aimed to determine physiological variations in CCT influenced by hormonal changes and to evaluate the relationship between these ocular changes and psychological parameters such as stress, anxiety and depression. Each participant was evaluated at three distinct phases of her menstrual cycle i.e. early menstrual, mid-cycle (ovulatory) and late luteal, allowing intra-individual comparison to reduce variability due to intersubject differences.

Study duration and setting

The study was carried out in the Department of Ophthalmology at a tertiary care teaching hospital; Hi-Tech Medical College and Hospital, Rourkela, Odisha, India. The study was conducted for a total duration of six months, from July 2025 to December 2025, encompassing the participant recruitment period, three-phase evaluations across the menstrual cycle, data entry and statistical analysis. Each subject was followed for one complete menstrual cycle, with assessments performed during three specific phases, early menstrual (days 1–3), mid-cycle (days 12–14) and late luteal (days 24–26). Timing of the phases was verified using menstrual history and, if necessary, urinary ovulation kits to confirm the mid-cycle phase.

Inclusion criteria

The study included healthy female participants aged 18–30 years who had regular menstrual cycles ranging from 28 to 32 days and were willing to participate by providing informed consent. Only those without any current ocular, systemic or psychological illness were considered eligible.

Exclusion criteria

Participants were excluded if they had a history of irregular menstruation, amenorrhea or any hormonal disorders. Individuals with known ocular pathologies, such as keratoconus, glaucoma or corneal dystrophies, were also excluded. Additional exclusion criteria comprised the use of hormonal contraceptives or systemic medications that could influence hormone levels, a history of ocular trauma or surgery, pregnancy or lactation and the use of contact lenses within two weeks prior to the examination.

Study sampling

A convenience sampling technique was employed to recruit eligible participants from the outpatient department and the local community. Each volunteer was screened according to inclusion and exclusion criteria. Participants were briefed regarding the purpose of the study and procedures involved. Only those who consented voluntarily were enrolled.

Study sample size

A total of 60 healthy women were included in the study. The sample size was determined considering similar previous studies evaluating corneal changes across menstrual phases, ensuring adequate power to detect clinically relevant differences. The inclusion of 60 subjects accounted for potential dropouts and ensured statistical robustness for correlation analysis between CCT and psychological parameters.

Study groups

Participants were assessed in three study groups corresponding to the three menstrual phases. Group I (early menstrual phase, days 1–3), Group II (mid-cycle or ovulatory phase, days 12–14) and Group III (late luteal phase, days 24–26). The same participants were evaluated in each phase, allowing intra-individual comparisons and minimizing inter-subject variability.

Study parameters

The primary study parameter was central corneal thickness (CCT), measured in micrometers (µm). Secondary parameters included intraocular pressure (IOP) that recorded in mmHg using Goldmann applanation tonometry and visual acuity (VA) assessed using a standardized logMAR chart. In addition, psychological status was evaluated using the Depression, Anxiety and Stress Scale (DASS-21) questionnaire, which measures the domains of depression, anxiety and stress on a four-point Likert scale.

Study procedure

Each participant attended three scheduled visits corresponding to the early menstrual, mid-cycle and late luteal phases. All examinations were performed between 9:00 AM and 11:00 AM to minimize the effect of diurnal variation on ocular parameters. Before measurement, participants were seated comfortably for five minutes to ensure stabilization of ocular physiology. Central corneal thickness was measured using pachymetry after instillation of topical 0.5% proparacaine hydrochloride as a local anesthetic. Three consecutive readings were obtained from the central cornea and the mean value was recorded to enhance accuracy. Intraocular pressure was measured using Goldmann applanation tonometry following standard sterilization and calibration protocols. Visual acuity was tested with a logMAR chart under uniform illumination conditions. Psychological wellbeing was evaluated at each phase using the DASS-21 questionnaire, administered in a quiet and private room. Participants were asked to rate how much each statement applied to them over the past week. Scores were calculated for each domain (depression, anxiety, stress) and interpreted according to established guidelines.

Study data collection

Data were recorded in a structured case record form including participant demographics, menstrual cycle details, ocular parameters and DASS-21 scores. To maintain reliability, the same trained investigator performed all CCT and IOP measurements throughout the study. Data were double-checked for consistency before entry into the electronic database. Each participant was assigned a unique identification code to ensure confidentiality.

Data analysis

Collected data were analyzed using Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics (mean±standard deviation) were calculated for continuous variables. The repeated-measures ANOVA test was applied to compare CCT, IOP and DASS-21 scores across the three menstrual phases. Pearson's correlation coefficient was used to assess the association between CCT and psychological variables (depression, anxiety, stress). A p value<0.05 was considered statistically significant for all tests.

Ethical considerations

The study protocol was approved by the Institutional Ethics Committee prior to initiation. Written informed consent was obtained from all participants after explaining the purpose, procedures, benefits and potential risks of the study in their local language. Participation was entirely voluntary and participants retained the right to withdraw at any point without prejudice. Data confidentiality was maintained by assigning coded identifiers and securely storing all records. The study was conducted in compliance with the principles of the Declaration of

Helsinki (2013) for biomedical research involving human subjects.

RESULTS

The present study included 60 healthy women aged 18–30 years with regular menstrual cycles of 28–32 days. Participants were examined during three phases of their menstrual cycle i.e. early menstrual phase (Group I), mid-cycle/ovulatory phase (Group II) and late luteal phase (Group III). Parameters such as CCT, IOP, Visual Acuity (logMAR) and psychological wellbeing (Depression, Anxiety and Stress Scale - DASS-21) were measured and statistically analyzed. Most participants (44%) were between 21-25 years, reflecting the reproductive age range suitable for observing hormonal variations. CCT was lowest in the early menstrual phase, peaked at ovulation and decreased again during the luteal phase. The difference between phases was statistically significant ($p<0.001$). But IOP remained relatively stable across all menstrual phases with no statistically significant difference ($p>0.05$). Visual acuity showed no significant variation across menstrual phases, indicating that corneal changes did not influence visual function.

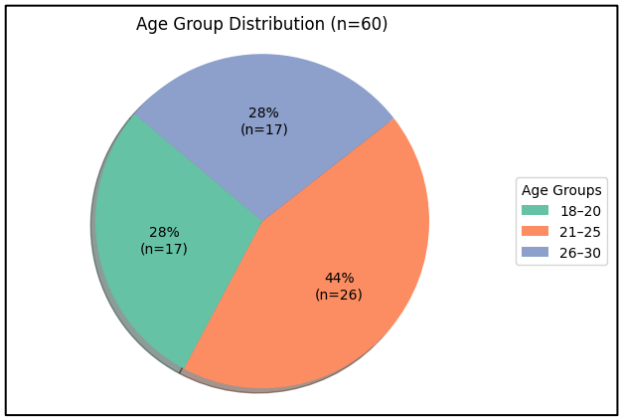

Figure 1: Age-wise distribution of study participants.

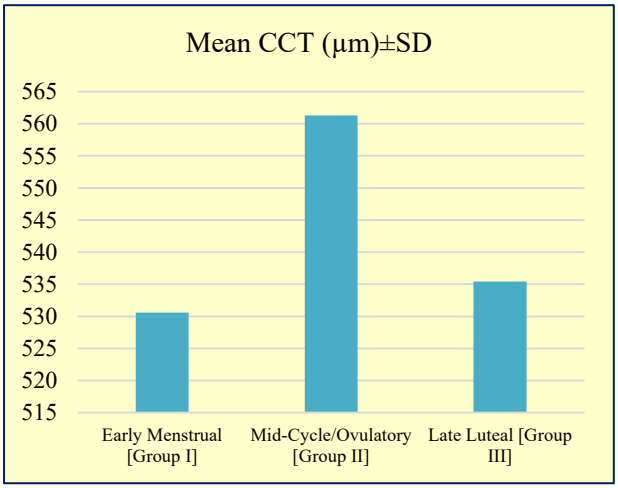

Figure 2: Phase-wise variation in mean CCT across the menstrual cycle.

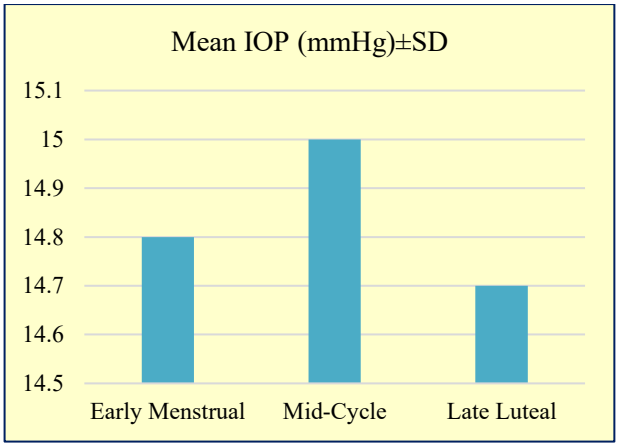

Figure 3: Phase-wise variation in mean Intra-Ocular Pressure (IOP) across the menstrual cycle.

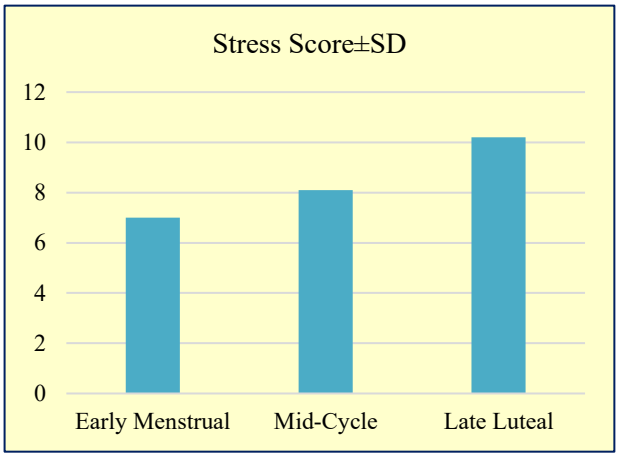

Figure 4: Phase-specific distribution of Stress Scores across the menstrual cycle.

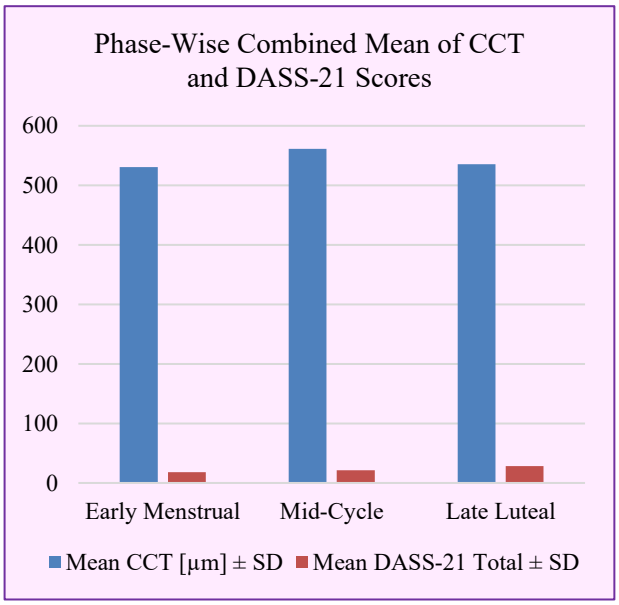

Figure 5: Comparative analysis of central corneal thickness and psychological stress scores by menstrual phase.

Depression scores were highest in the late luteal phase, indicating a premenstrual mood effect consistent with hormonal fluctuation patterns. Anxiety increased progressively across the cycle, peaking in the luteal phase, which aligns with hormonal imbalance and stress-related symptoms. Stress levels were significantly higher in the luteal phase, showing a cyclical pattern parallel to hormonal fluctuation. CCT demonstrated a negative correlation with anxiety and stress, implying that increased psychological distress is associated with thinner corneal measurements. A pattern of inverse relationship between CCT and total psychological distress was observed, especially evident in the late luteal phase.

Table 1: Comparison of mean central corneal thickness and intraocular pressure across menstrual phases.

Menstrual phase	Mean CCT (µm)±SD	P value	Mean IOP (mmHg)±SD	P value
Early menstrual (group I)	530.6±8.9		14.8±2.1	
Mid-cycle/ovulatory (group II)	561.3±10.1	<0.001	15.0±1.9	
Late luteal (group III)	535.4±9.5		14.7±2.2	0.462

Table 2: Comparison of visual acuity (logMAR) across phases.

Menstrual phase	Mean visual acuity (logMAR)±SD	P value
Early menstrual	0.00±0.01	
Mid-cycle	0.00±0.00	0.218
Late luteal	0.01±0.01	

Table 3: Mean depression scores, anxiety scores and stress scores (DASS-21) across phases.

Menstrual phase	Depression score±SD	P value	Anxiety score±SD	P value	Stress score±SD	P value
Early menstrual	5.1±2.4		6.2±2.5		7.0±3.0	
Mid-cycle	6.3±2.8	<0.01	7.1±2.9	<0.01	8.1±3.2	<0.01
Late luteal	8.9±3.1		9.4±3.3		10.2±3.5	

Table 4: Correlation between CCT and psychological parameters.

Parameter	Correlation coefficient (r)	P value	Interpretation
CCT vs depression	-0.42	0.008	Moderate negative correlation
CCT vs anxiety	-0.51	0.002	Significant negative correlation
CCT vs stress	-0.46	0.004	Moderate negative correlation

Table 5: Phase-wise combined mean of CCT and DASS-21 Scores.

Phase	Mean CCT (µm)±SD	Mean DASS-21 Total±SD
Early menstrual	530.6±8.9	18.3±4.9
Mid-cycle	561.3±10.1	21.5±5.2
Late luteal	535.4±9.5	28.5±6.1

DISCUSSION

The present study was conducted to assess cyclical variations in CCT and their association with psychological wellbeing across different menstrual phases in healthy women aged 18–30 years. Hormonal fluctuations during the menstrual cycle are known to influence various ocular parameters, including corneal hydration, curvature and tear film stability, primarily due to the presence of estrogen and progesterone receptors in ocular tissues. In the current study, CCT exhibited statistically significant variations across menstrual phases, while IOP and visual acuity remained stable. The mean CCT was found to be 530.6±8.9 µm in the early menstrual phase, 561.3±10.1 µm during mid-cycle (ovulatory phase) and 535.4±9.5 µm in the late luteal phase ($p<0.001$). This pattern of increased corneal thickness during ovulation followed by a decrease toward the end of the cycle supports the influence of cyclic estrogen and progesterone levels on corneal physiology.

These findings are consistent with the results of Ghahfarokhi et al who investigated 50 healthy women and observed mean CCT values of 541.40±11.36 µm (days 1–3), 556.50±7.11 µm at ovulation and 536.38±12.83 µm at the end of the cycle, with statistically significant differences across phases.[14] Similar to the current findings, their study concluded that the thickest cornea was observed at ovulation and the thinnest toward the end of

the cycle, emphasizing that such variations should be considered when planning corneal refractive surgery. The current study's mid-cycle peak in corneal thickness (561.3 µm) aligns closely with Ghahfarokhi's mid-cycle observation (556.50 µm), confirming the reproducibility of cyclical hormonal influences on corneal structure.

Likewise, Mishra et al conducted a prospective observational study in 126 Indian women, reporting mean CCT values of 541.76±4.21 µm, 559.21±4.50 µm and 544.52±8.06 µm at the beginning, mid and end of the cycle, respectively, showing a statistically significant difference ($p<0.001$).[15] Their results mirror those of the present study, which also demonstrated a statistically significant increase in CCT during the ovulatory phase. Both studies recommend documenting menstrual history when performing corneal measurements or planning refractive procedures, as failure to account for hormonal variations could lead to misinterpretation of corneal metrics.

Further supporting evidence is provided by Giuffrè et al who studied 16 women and found that the cornea was thinnest at the beginning of the cycle (536 µm), increased at ovulation (549 µm) and became thickest at the end (559 µm).[18] Although Giuffrè's data showed a continued increase through the late phase rather than a decline, the underlying trend of mid-cycle thickening due to hormonal activity was consistent with both our findings and those of Ghahfarokhi and Mishra.[14,15]

The minor discrepancy between studies regarding the luteal phase can likely be attributed to interindividual variations in hormonal profiles and the timing of ovulation determination, as well as differences in population demographics. The physiological explanation for the observed CCT variations centers around the influence of estrogen and progesterone on corneal metabolism and hydration. Estrogen promotes fluid retention and collagen synthesis, increasing stromal thickness, whereas progesterone induces diuretic effects and modulates epithelial permeability. During ovulation, elevated estrogen levels enhance mucopolysaccharide accumulation and stromal hydration, resulting in transient thickening of the cornea.

Conversely, the luteal phase, dominated by progesterone, promotes corneal thinning by reducing stromal hydration. These hormonal actions are supported by the findings of Cavdar et al, who demonstrated that fluctuations in estrogen levels influenced ocular surface equilibrium and subjective dry eye symptoms in premenopausal women.[16] Cavdar found significant correlations between estrogen levels and keratometric changes ($r=–0.5$, $p=0.03$) during different phases, confirming that oestrogen fluctuations produce measurable alterations in ocular physiology even in the absence of structural corneal changes. In the present study, IOP remained relatively stable throughout the menstrual cycle, with mean values of 14.8±2.1 mmHg during the early phase, 15.0±1.9 mmHg mid-cycle and 14.7±2.2 mmHg during the luteal phase ($p=0.462$). This finding aligns with Hoffmann et al, who in a large German cohort of 4,698 participants, reported a positive correlation between CCT and IOP, where each 10 µm increase in CCT resulted in an IOP rise of 0.35–0.38 mmHg ($p<0.0001$).[17] However, they also observed that CCT variations did not significantly affect IOP within physiological limits. The absence of major IOP fluctuations across the menstrual cycle in our study supports the notion that hormonal influences primarily affect corneal thickness rather than intraocular pressure, consistent with Hoffmann's conclusion. The findings on psychological wellbeing are particularly noteworthy.

The present study observed that depression, anxiety and stress scores measured using the DASS-21 scale were lowest during the early menstrual phase (depression: 5.1±2.4; anxiety: 6.2±2.5; stress: 7.0±3.0) and highest during the late luteal phase (depression: 8.9±3.1; anxiety: 9.4±3.3; stress: 10.2±3.5), with all changes reaching statistical significance ($p<0.01$). This cyclical mood variation reflects the impact of hormonal changes, particularly progesterone and its neuroactive metabolites, which influence GABAergic transmission and emotional regulation. The negative correlation between CCT and psychological scores (CCT vs anxiety: $r=–0.51$, $p=0.002$; CCT vs stress: $r=–0.46$, $p=0.004$) suggests that greater psychological distress is associated with a relative decrease in corneal thickness. This may be explained by cortisol-mediated physiological stress responses, which affect collagen metabolism and corneal hydration, leading to subtle thinning of the cornea during heightened stress states.

Although prior studies did not explore psychological correlates directly, the present study introduces a novel perspective by linking ocular physiological changes with emotional parameters. This integration highlights the importance of considering psychophysiological interactions in clinical ophthalmology. Hormonal fluctuations that influence both corneal biomechanics and emotional regulation could represent an integrated system reflecting systemic homeostasis.

Comparing across all referenced studies, the pattern of cyclic CCT fluctuation is consistently observed. Ghahfarokhi et al, Mishra et al and Giuffrè et al, all reported that corneal thickness increases around ovulation, while Hoffmann et al confirmed the strong dependence of IOP on CCT values across a large population.[14-18] Cavdar et al, further reinforced the influence of estrogen on ocular surface stability, correlating hormone levels with ocular discomfort and keratometric variations.[16] The current study aligns closely with these findings but expands upon them by demonstrating that these ocular changes also correlate with psychological states, suggesting a broader systemic influence of menstrual physiology. The clinical implications are significant. Since CCT is a critical determinant in glaucoma risk assessment, refractive surgery planning and IOP correction, understanding its

cyclic variation is essential. An increased CCT during ovulation could result in overestimation of IOP or under correction during refractive surgery, whereas decreased CCT in the luteal phase may yield the opposite effect. Therefore, ophthalmologists should routinely document menstrual cycle phases when interpreting corneal or tonometric readings in women of reproductive age.

Moreover, recognizing that stress and anxiety may further modulate CCT underscores the need for a holistic assessment of both physiological and psychological status during ophthalmic evaluations. The findings of the present study substantiate previous research by confirming cyclical variations in central corneal thickness during the menstrual cycle, with maximum thickness at ovulation and minimum values in the luteal phase, while IOP and visual acuity remain stable. These observations are in strong agreement with Ghahfarokhi et al, Mishra et al and Giuffrè et al and physiologically supported by the estrogen-related corneal modulation reported by Cavdar et al.[14-18] Hoffmann et al, large-scale evidence further validates the corneal–IOP interrelationship observed in this study.[17] The novel contribution of the present research lies in establishing a negative correlation between CCT and psychological wellbeing, indicating that hormonal and emotional fluctuations exert a combined influence on ocular physiology. Thus, both menstrual phase and psychological status should be considered essential contextual factors in ocular diagnostics, particularly for procedures requiring precise pachymetric assessment.

Strengths

The study uses a prospective design with intra-individual comparison across menstrual phases, reducing variability and improving validity. Standardized tools (pachymetry, Goldmann tonometry, DASS-21) and controlled timing enhance reliability. Its key strength is the novel integration of ocular and psychological parameters, adding clinical and research relevance.

Limitations

The small sample size and convenience sampling limit generalizability. Restriction to young healthy women reduces external validity. Lack of direct hormonal measurements and reliance on self-reported psychological scales may introduce bias and assessment over a single menstrual cycle limits long-term inference.

Implications for practice and policy

The study highlights important clinical and research implications. Clinically, it emphasizes the need to consider menstrual cycle phase when measuring CCT to avoid misinterpretation in glaucoma assessment and refractive surgery planning. The observed link between psychological status and CCT suggests that emotional wellbeing may influence ocular parameters, supporting a more holistic patient evaluation. From a research perspective, the findings open avenues for interdisciplinary studies integrating endocrinology, ophthalmology and mental health and underscore the need for larger, hormone-based longitudinal studies to validate these associations.

CONCLUSION

In conclusion, the present study demonstrates that central corneal thickness undergoes significant cyclical variations across the menstrual cycle, reaching its peak during ovulation and decreasing toward the late luteal phase, while intraocular pressure and visual acuity remain largely stable. Furthermore, CCT changes were found to be negatively correlated with psychological parameters, including stress and anxiety, highlighting the interconnected influence of hormonal fluctuations and emotional wellbeing on ocular physiology. These findings underscore the importance of considering menstrual phase and psychological status when evaluating corneal parameters, particularly in clinical settings such as refractive surgery planning or glaucoma assessment, to ensure accurate measurements and optimize patient care.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Senapati A, Panigrahi S, Giri S. A study of central corneal thickness and psychological wellbeing: a menstrual cycle correlation. Int J Res Med Sci 2026;14:2043-50.