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Review Article

Influence of menstrual cycle phases on intraocular pressure: a narrative review

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Summary

Intraocular pressure (IOP) is a dynamic physiological parameter influenced by circadian rhythm, systemic health, corneal biomechanics, and hormonal status. In women of reproductive age, cyclical variations in estrogen and progesterone during the menstrual cycle may modulate aqueous humor dynamics. The available evidence, however, remains heterogeneous. This updated narrative review synthesizes human studies published between 2000 and 2024 that evaluate IOP across menstrual cycle phases and integrates contemporary endocrine – ocular literature. A structured search identified 214 records, of which 38 underwent full-text review, and 13 phase-specific human studies met eligibility criteria for core synthesis. Across studies, reported IOP changes were generally modest (1–3 mmHg) and frequently within the range of normal diurnal variation or tonometric measurement error. Some investigations report slightly lower IOPs around ovulation or in the mid-luteal phase, whereas others demonstrate no statistically significant phase-dependent differences. Methodological heterogeneity –particularly in menstrual phase verification, sample size, and tonometric technique – limits the strength of conclusions. Current evidence does not support routine clinical modification of IOP measurement timing based solely on menstrual phase. Greater methodological rigor, including biochemical phase confirmation and standardized ocular biometry, is required to determine whether hormonal fluctuations exert clinically meaningful effects on IOP.

Key words: Corneal biomechanics, estrogen, intraocular pressure, menstrual cycle, ocular physiology, progesterone

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Introduction

Intraocular pressure (IOP) is central to ocular physiology and glaucoma management and varies with circadian rhythm, posture, systemic factors, and measurement technique (Samal et al. 2024). Beyond these determinants, endocrine influences, particularly ovarian sex steroids, have been proposed as modulators of IOP in women of reproductive age, yet remain incompletely characterized.

The menstrual cycle is governed by cyclical changes in estradiol and progesterone under hypothalamic–pituitary–ovarian control. Estradiol peaks peri-ovulation, while progesterone predominates in the luteal phase. These hormones influence endothelial function, vascular tone, extracellular matrix remodeling, and fluid homeostasis - mechanisms that may plausibly affect aqueous humor production, trabecular outflow resistance, episcleral venous pressure, and corneal biomechanics (Wickham et al. 2000; Behrendt and Ganz 2002; Zhao 2025).

Recent population-level and experimental ophthalmic research increasingly recognizes sex hormones as modulators of ocular physiology beyond reproductive contexts. Large epidemiologic studies report sex-specific differences in intraocular pressure and glaucoma prevalence, suggesting that the endocrine milieu may influence ocular hydrodynamics across the lifespan (Vajaranant et al. 2012; Zhao 2025). Contemporary imaging and biometric studies further demonstrate that hormonal fluctuations affect corneal biomechanics, retinal microvasculature, and ocular blood flow, reinforcing the plausibility of menstrual cycle–related ocular variation (Goldich et al. 2011; Reis et al. 2024).

However, modern population-based analyses indicate that typical exogenous hormonal exposure, such as oral contraceptive use, is not associated with clinically meaningful alterations in IOP after adjustment for systemic confounders (Liu et al. 2022; Kasiri et al. 2025). These findings underscore the need to contextualize early phase-dependent observations within a broader endocrine and vascular framework.

Early investigations suggested modest reductions in IOP during estrogen-dominant phases and slightly higher values during menstruation or early follicular phases (Qureshi 1995; Sator et al. 1996). However, these studies were limited by small samples, imprecise phase classification, and variable tonometry. Contemporary work has yielded mixed findings: some cohorts demonstrate subtle mid-cycle trends (Brindha et al. 2016; Adhikari et al. 2021), whereas others report no statistically significant phase-dependent differences (Fortepiani et al. 2021). Large population-based analyses further indicate that exogenous hormonal exposure through oral contraceptives does not meaningfully alter IOP after adjustment for confounders (Kasiri et al. 2025).

This narrative review synthesizes human evidence from 2000 to 2024, integrates modern endocrine-ocular literature, evaluates the magnitude and clinical relevance of menstrual cycle–related IOP variation, and identifies methodological limitations and research priorities for the future. A schematic summary of generalized hormonal trends and reported IOP patterns is presented in Fig. 1. Generalized estrogen and progesterone fluctuations across the menstrual cycle and their reported associations with intraocular pressure. Estrogen peaks around ovulation, and several studies report modest reductions in IOP (Qureshi et al. 1998; Brindha et al. 2016). The luteal phase is associated with mild corneal thickening (Goldich et al. 2011; Kelly et al. 2023), which may artifactually elevate applanation readings. Considerable inter-individual variability is evident, and contemporary data demonstrate no uniform phase-dependent IOP shift (Fortepiani et al. 2021).

Methods

Search strategy

A narrative review was conducted using PubMed, Scopus, and Google Scholar for January 2000 to December 2024. Search terms included “intraocular pressure," "menstrual cycle," "estrogen," "progesterone," "sex hormones," "oral contraceptive," "ocular physiology," and "central corneal thickness." Reference lists of eligible articles were hand-searched.

Eligibility criteria

Inclusion: (1) human studies; (2) quantitative IOP measured across ≥ 2 defined menstrual phases; (3) peer-reviewed original research.

Exclusion: (1) animal-only or in vitro studies; (2) case reports, editorials, and non-data commentaries; (3) studies without phase-specific IOP or a clear phase definition.

Screening and synthesis

The search yielded 214 records. After title/abstract screening, 38 articles underwent full-text review. Twenty-five were excluded – most commonly for lacking phase stratification, relying exclusively on hormonal therapy populations without natural cycle assessment, or not reporting quantitative IOP. Thirteen studies met all criteria for phase-specific synthesis. Because of heterogeneity in phase definition (calendar vs. biochemical), tonometry, and adjunctive measures (e.g., CCT), quantitative pooling was not feasible; results were synthesized narratively and contextualized with contemporary endocrine-ocular literature.

Review of clinical studies

Early and mid-period evidence

Sator et al. (1996) reported lower IOP during the luteal phase in 30 women, without biochemical confirmation of the luteal phase. Qureshi (1995) observed higher IOP during menstruation and lower values around ovulation using non-contact tonometry. Using Goldmann applanation, Brindha et al. (2016) identified the lowest IOP at ovulation in 40 women. Kelly et al. (2023) demonstrated mild luteal-phase increases in central corneal thickness (CCT), suggesting measurement-related IOP inflation. Samal et al. (2024) reported greater IOP variability in ocular hypertensive women, implying heightened susceptibility in compromised outflow systems. Across these studies, differences were typically 1–3 mmHg, overlapping with normal diurnal variation.

Adhikari et al. (2021) reported statistically significant differences in IOP across menstrual phases in a larger cohort with structured phase stratification. On the other hand, Schiotz tonometry and a younger population may limit generalizability.

Fortepiani et al. (2021) as modern anchor

Fortepiani et al. (2021) evaluated IOP, CCT, and foveal thickness in men and in cycling women (oral contraceptive users) during defined follicular and luteal phases. No statistically significant IOP differences were observed between phases among cycling women, although small trends toward luteal elevation were noted. The study emphasized inter-individual heterogeneity and the moderating role of hormonal contraception, demonstrating that when modern protocols and broader stratification are applied, cycle-dependent IOP differences are subtle and inconsistent.

Beyond phase-specific cohorts, contemporary population studies provide essential context. Liu et al. (2022) reported lower mean IOP in premenopausal than in postmenopausal women, suggesting that endogenous estrogen may exert a modest protective effect. Vajaranant et al. (2012) further highlighted sex hormone-related differences in glaucoma risk, though direct causal relationships with IOP remain incompletely defined.

Kasiri et al. (2025), analyzing a large population dataset, demonstrated no significant association between oral contraceptive use and IOP after controlling for age, body mass index, hypertension, and family history of glaucoma. These data suggest that while endogenous cyclical hormonal fluctuations may produce subtle physiologic effects, routine exogenous hormone exposure does not significantly alter IOP in clinical populations.

Contemporary context (2023–2025)

Population-based data show no significant association between oral contraceptive use and IOP after adjustment for age, BMI, and vascular risk (Kasiri et al. 2025). Endocrine-ocular reviews highlight complex, multifactorial hormonal modulation of ocular physiology beyond estradiol and progesterone alone (Zhao 2025). Together, these findings reinforce that menstrual phase–related IOP variation, when present, is modest, inconsistent, and frequently confounded by corneal and methodological factors. Key findings are summarized in Table 1.

Mechanisms of hormonal influence on iop

A schematic overview of generalized hormonal fluctuations across the menstrual cycle and their reported associations with intraocular pressure is presented in Fig. 1.

Hormone receptors in ocular tissues

Molecular studies demonstrate estrogen and progesterone receptor expression in the ciliary epithelium, trabecular meshwork, and retina (Ogueta et al. 1999; Wickham et al. 2000). These data support the biological plausibility that ovarian steroids may directly influence aqueous humor dynamics and outflow pathways.

Aqueous humor dynamics

Earlier drafts misattributed the modulation of matrix metalloproteinase (MMP) activity to Ogueta et al. (1999). Their study documented receptor expression only. Claims regarding estrogen-induced MMP activity had therefore been removed unless independently supported. Experimental primate studies indicate that estrogen and progesterone can alter aqueous production and outflow (Rasmussen et al. 2007), but translation to human physiology remains debatable. In clinical cohorts, phase-dependent IOP changes are small and inconsistent (Fortepiani et al. 2021), suggesting that any endocrine effects on aqueous dynamics are modest.

Table 1. Summary of studies evaluating intraocular pressure (IOP) across menstrual phases.

Study / Year	Population / Sample	Phase definition / Hormonal status	Tonometry / Measures	Main IOP findings
Sator et al. 1996	30 healthy women	Calendar-based phases	Goldmann	Lower IOP in luteal phase; no biochemical confirmation
Qureshi 1995	50 healthy women	Calendar phases	Non-contact	Higher IOP during menstruation; lower near ovulation
Qureshi 1998	60 healthy women	Calendar phases	Non-contact	Modest mid-cycle IOP reduction
Kelly et al. 2023	25 healthy women	Calendar phases	Goldmann + CCT	Luteal CCT increase may inflate IOP
Samal et al. 2024	45 women (normal + OHT)	Calendar phases	Goldmann	Greater IOP variability in ocular hypertension
Brindha et al. 2016	40 healthy women	Calendar phases	Goldmann	Lowest IOP at ovulation
Adhikari et al. 2021	100 young women	Menstrual/proliferative/secretory	Schiotz	Significant phase-related IOP differences
Fortepiani et al. 2021	60 (cycling, OCP users, men)	Defined follicular/luteal	Goldmann + CCT	No significant phase-dependent IOP change
Liu et al. 2022	Multi-ethnic cohort	Premenopausal vs postmenopausal	Mixed	Lower mean IOP in premenopausal women
Kasiri et al. 2025	>3,000 women	OCP users vs non-users	Mixed	No significant OCP–IOP association
Goldich et al. 2011	52 women	Calendar phases	Goldmann + biomechanics	Luteal corneal thickening affects IOP
Leach et al. 1971	30 women	Calendar phases	—	Corneal hydration varies across cycle
Alkhaldi et al. 2025	Adult women	Multi-hormone profiling	Goldmann	Endocrine factors beyond estrogen influence IOP
Ribeiro Reis et al. 2024	Healthy women	Cycle-based	Imaging + IOP	Retinal microvascular changes across cycle

Abbreviations: IOP – intraocular pressure; CCT – central corneal thickness; OHT – ocular hypertension; OCP – oral contraceptive pill.

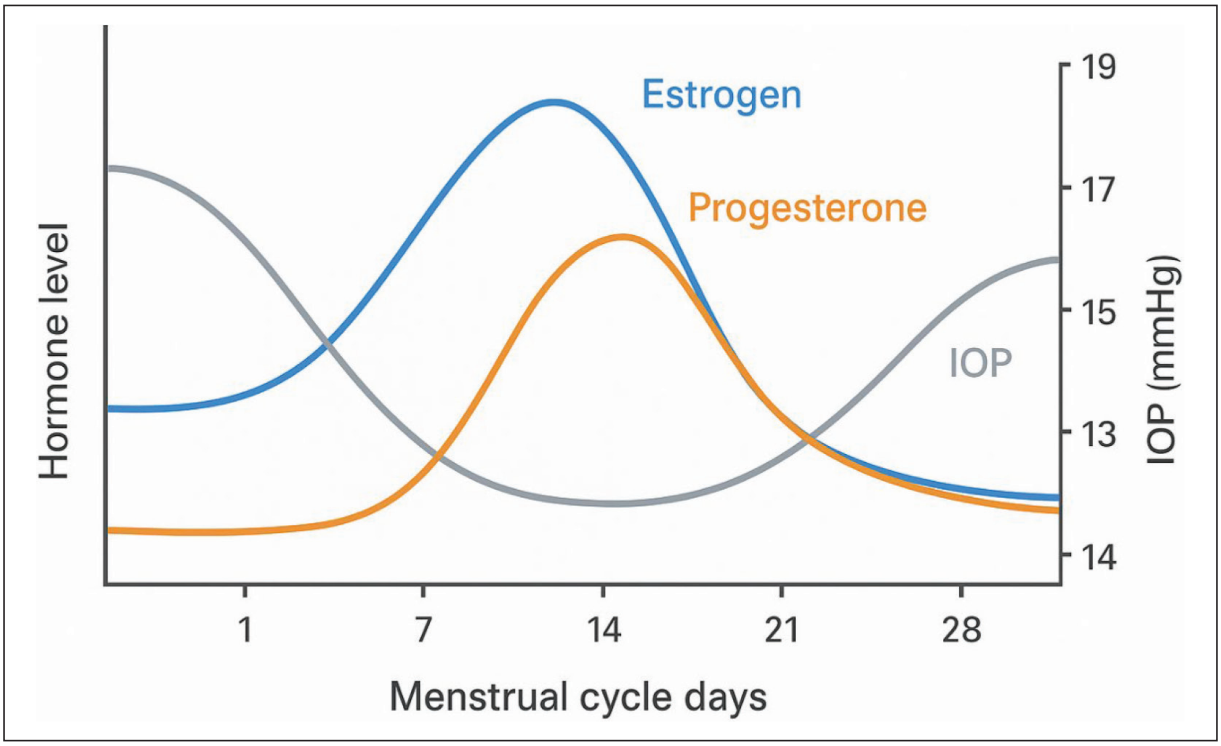

Figure 1. Schematic illustration of generalized estrogen and progesterone fluctuations across the menstrual cycle and their reported associations with intraocular pressure. This figure is intended for conceptual illustration only and does not represent uniform or quantitatively consistent findings across studies.

Vascular and nitric oxide–mediated pathways

Estrogen enhances endothelial nitric oxide synthase activity and nitric oxide bioavailability, promoting vasodilation (Behrendt and Ganz 2002). Nitric oxide participates in trabecular and Schlemm's canal outflow regulation. Reduced episcleral venous pressure during estrogen-dominant phases could theoretically facilitate aqueous drainage and lower IOP. However, direct evidence linking phase-specific estradiol levels, nitric oxide activity, and IOP in humans is limited, and current support is inferential.

Progesterone and counter-regulation

Progesterone's ocular effects are less defined. While primate models suggest progesterone-related modulation of aqueous dynamics (Rasmussen et al. 2007), human studies do not demonstrate consistent luteal-phase IOP elevation or suppression (Kelly et al. 2023; Fortepiani et al. 2021). Progesterone likely contributes to inter-individual variability rather than uniform phase-dependent change.

Corneal biomechanics and measurement effects

Multiple studies report mild luteal-phase increases in central corneal thickness (Goldich et al. 2011; Adhikari et al. 2021; Kelly et al. 2023). Because applanation tonometry is sensitive to corneal properties, such changes can artifactually elevate IOP. This measurement effect plausibly explains part of the heterogeneity across studies and underscores the need for concurrent corneal assessment.

Recent experimental and imaging studies extend this framework by demonstrating menstrual cycle–related changes in retinal microvasculature and ocular perfusion (Reis et al. 2024), implying systemic neurovascular modulation of ocular tissues. Multi-hormone analyses further suggest that endocrine influences on IOP extend beyond estradiol and progesterone, encompassing thyroid hormones, androgens, and oxytocin (Alkhaldi et al. 2025). These findings support a multifactorial neuroendocrine model in which menstrual cycle–related IOP variation represents only one dimension of broader hormonal-ocular interaction.

Clinical implications

Population-level evidence indicates that endogenous estrogen may be associated with lower IOP and reduced glaucoma risk in premenopausal women (Vajaranant et al. 2012; Liu et al. 2022). Conversely, routine oral contraceptive use does not appear to influence IOP meaningfully (Kasiri et al. 2025). These data reinforce that menstrual cycle-related IOP variation, when present, is subtle and should not drive routine clinical decision-making.

IOP measurement in glaucoma evaluation

Cycle-related IOP variations are small and fall within the range of physiologic fluctuations (Fortepiani et al. 2021; Samal et al. 2024). Contemporary population data show no meaningful association between oral contraceptive use and IOP (Kasiri et al. 2025). Routine adjustment of IOP measurement timing based on menstrual phase is therefore not supported.

Refractive surgery and corneal assessment

Because corneal biomechanics may vary slightly across the cycle, standardizing preoperative measurements to a consistent phase may improve reproducibility in borderline corneas (Goldich et al. 2011).

Contact lens tolerance

Luteal-phase ocular surface changes, including mild corneal edema and tear-film instability, may affect comfort in some women (Leach et al. 1971).

Glaucoma suspects

Women with ocular hypertension exhibit greater IOP variability (Samal et al. 2024). In such cases, consistent-phase monitoring may improve interpretability, although evidence remains limited.

Future directions

Future investigations should include larger cohorts, biochemical phase confirmation, standardized tonometry with concurrent corneal biomechanics, and longitudinal designs. Hormonal contraception and hormone therapy must be evaluated as modifiers. Integration of aqueous biomarkers and vascular metrics may clarify mechanistic pathways.

Conclusion

Menstrual cycle-related hormonal fluctuations may produce small variations in intraocular pressure; however, these changes rarely exceed normal physiologic diurnal variation or the inherent error of tonometric measurement. Contemporary evidence indicates that phase-dependent IOP differences are subtle, inconsistent, and highly variable between individuals. At present, there is insufficient justification for routine cycle-based timing of IOP measurements in clinical practice. Awareness of potential variability may assist in interpreting borderline findings, particularly in glaucoma suspects, but further large, methodologically rigorous studies are required before clinical guidelines can be established.

Additional information

Conflict of interest

The author has declared that no competing interests exist.

Ethical statements

The author declared that no clinical trials were used in the present study.

The authors declared that no experiments on humans or human tissues were performed for the present study.

The authors declared that no informed consent was obtained from the humans, donors or donors' representatives participating in the study.

The authors declared that no experiments on animals were performed for the present study.

The authors declared that no commercially available immortalised human and animal cell lines were used in the present study.

Use of AI

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Data availability

All of the data that support the findings of this study are available in the main text.

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