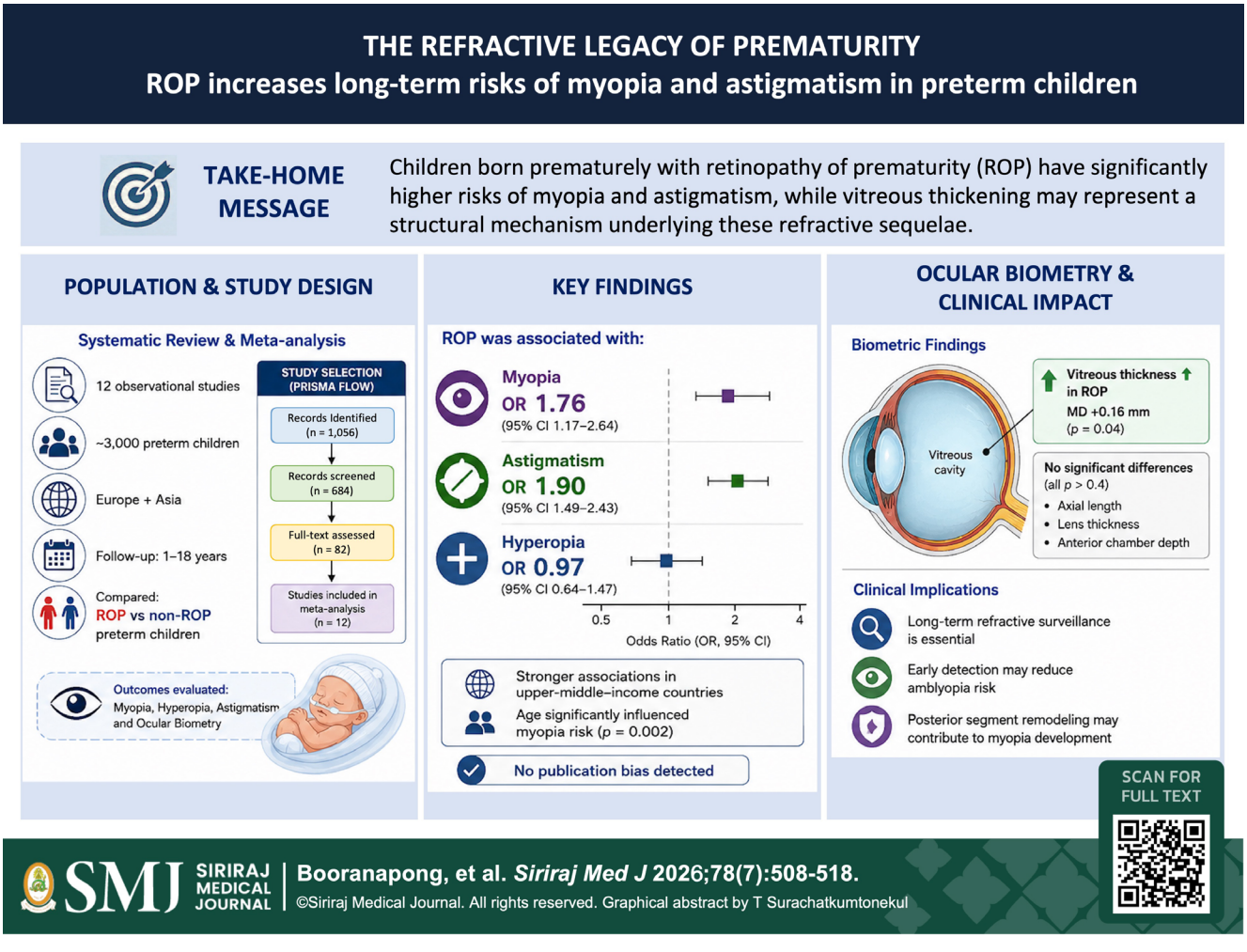
The Refractive Legacy of Prematurity: A Systematic Review and Meta-Analysis of Refractive Errors and Ocular Biometry in Infants With and Without Retinopathy of Prematurity

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ABSTRACT

Objective: To compare the prevalence of refractive errors in children born prematurely with and without retinopathy of prematurity (ROP) and to identify potential factors contributing to heterogeneity.

Materials and Methods: Relevant literature was systematically searched in PubMed, EMBASE, and CINAHL for studies available through January 2025. Studies were eligible if they used cross-sectional, cohort, or case-control designs and reported refractive outcomes among preterm children stratified by ROP status. Effect estimates were synthesized using random-effects models and expressed as pooled odds ratios and mean differences. Between-study variability was evaluated using Cochran's Q statistic and the I^2 metric. Additional analyses included subgroup comparisons, meta-regression, and assessment of potential publication bias.

Results: Twelve studies were included. ROP was significantly associated with myopia (OR, 1.76; 95% CI, 1.17–2.64; p = 0.01) and astigmatism (OR, 1.90; 95% CI, 1.49–2.43; p < 0.001), but not hyperopia (OR, 0.97; 95% CI, 0.64–1.47; p = 0.89). Strong associations were observed in upper-middle–income countries. Age significantly modified the ROP–myopia association (p = 0.002). Biometric analysis showed greater vitreous thickness in ROP children (mean difference, 0.16 mm; p = 0.04), while axial length, lens thickness, and anterior chamber depth were not significantly different (all p > 0.4). No publication bias was detected.

Conclusions: ROP is associated with increased risks of myopia and astigmatism, with effects influenced by age and socioeconomic context. Vitreous thickness was the only biometric parameter significantly affected, suggesting a potential mechanism underlying refractive sequelae, although this requires further validation.

Keywords: Retinopathy of prematurity; preterm; myopia; hyperopia; astigmatism; meta-analysis; ocular biometry
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INTRODUCTION

Improvements in neonatal medicine over recent decades have markedly increased survival among infants born preterm.[1,2] However, preterm birth remains associated with an elevated risk of various visual and ocular abnormalities.[3,4] Among these, retinopathy of prematurity (ROP) remains a major contributor to visual impairment and blindness in childhood worldwide.[5,6] ROP primarily affects infants born at a gestational age (GA) of less than 32 weeks or with a birth weight (BW) below 1,500 grams, resulting in abnormal retinal vascular development and subsequent retinal ischemia or scarring.[4,7] Beyond these acute retinal changes, children born prematurely frequently develop refractive errors, such as myopia, hyperopia, and astigmatism, later in life.[3,8,9] These refractive anomalies are thought to arise from disrupted postnatal ocular growth, particularly involving anterior segment underdevelopment (e.g., reduced anterior chamber depth) and posterior segment remodeling (e.g., altered axial length and vitreous length).[10,11]

Understanding long-term refractive outcomes in this population is essential for predicting visual prognosis, optimizing early screening, and implementing timely interventions to prevent amblyopia and irreversible vision loss.[9,12]

Despite numerous cohort and population-based studies conducted across Asia and Europe, variations in study design, sample size, and refractive measurement techniques have led to inconsistent findings.[3,8,13] Therefore, a quantitative synthesis is needed to better estimate the prevalence and magnitude of refractive errors among individuals born prematurely and to identify the ocular biometric parameters most strongly associated with these outcomes.

The present study was designed to synthesize available evidence on: (1) the relationship between ROP and refractive errors in children born prematurely; (2) evaluate ocular biometric differences between children with and without ROP, and (3) explore sources of heterogeneity, including age at follow-up and country income classification.

MATERIALS AND METHODS

Study design and Registration

This review followed the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) reporting framework for systematic reviews and meta-analyses. The protocol was registered in PROSPERO under reference CRD42023262977.

Search strategy

We performed a structured database search to identify studies examining refractive outcomes in relation to ROP.

Relevant studies published up to January 2025 were identified through comprehensive searches of PubMed, EMBASE and CINAHL databases.

For PubMed, the following search strategy was utilized:

("Infant, Premature"[Mesh] OR preterm OR prematurity) AND ("Retinopathy of Prematurity"[Mesh] OR "Retinopathy of Prematurity" OR ROP) AND ("Refractive Errors"[Mesh] OR "Refractive errors" OR "Refractive Error").

For EMBASE, the search terms included:

('prematurity'/exp OR prematurity OR preterm) AND ('retrolental fibroplasia'/exp OR 'retrolental fibroplasia' OR 'retinopathy of prematurity'/exp OR 'retinopathy of prematurity' OR ROP) AND ('refraction error'/exp OR 'refraction error' OR 'refractive errors'/exp OR 'refractive errors' OR 'refractive error'/exp OR 'refractive error').

For CINAHL, the search terms included:

(MH "Infant, Premature") OR prematurity OR preterm AND (MH "Retinopathy of Prematurity") OR "retrolental fibroplasia" OR "retinopathy of prematurity" OR "retinopathy of prematurity" OR rop AND (MH "Refractive Errors+") OR "refraction error" OR "refractive errors".

Study eligibility criteria

Studies were considered eligible if they employed cross-sectional, cohort, or case-control designs that reported the prevalence of refractive errors in premature infants with versus without retinopathy of prematurity (ROP). Only studies published between 2000 and 2025 with a sample size greater than 70 eyes were included to ensure adequate statistical power. Eligible studies focused on non-treatment ROP, evaluating the natural progression of refractive outcomes rather than the effects of interventions such as laser photocoagulation or anti-VEGF therapy. Additionally, studies were required to report the prevalence of specific refractive error types, including myopia, hyperopia, and astigmatism, separately. Studies were excluded if they were non-English, unpublished, conference abstracts without full text, or case series lacking a control group of premature infants without ROP. Studies conducted in non-human species were also excluded.

Study selection

All retrieved records from the databases were initially imported into EndNote for reference management and subsequently exported to Covidence for deduplication and systematic screening. The remaining studies were randomly assigned and independently evaluated by two reviewers, both trained in ophthalmology. The screening process involved two stages: initial assessment of titles and abstracts, followed by full-text review, with both stages conducted according to predefined inclusion and exclusion criteria. Each study was categorized within Covidence as "include," "exclude," or "potentially include." Any discrepancies between reviewers were resolved through discussion and consensus, with consultation from a pediatric ophthalmologist when necessary to make a final decision.

Data Extraction

Data from eligible articles were organized in Covidence to support consistent extraction across reviewers. Two reviewers independently identified eligible articles and extracted relevant information into a Microsoft Excel spreadsheet. Extracted variables included study identification code, authors, title, year of publication, study design, total number of patients and eyes, mean age of the study population, country income classification, number of preterm patients with and without ROP, definitions of refractive errors, and biometric parameters, including axial length, anterior chamber depth, lens thickness, and vitreous thickness. Any disagreements between reviewers were addressed through discussion until a consensus was reached, ensuring the reliability of the extracted data.

Risk of Bias Assessment

Methodological quality was evaluated with the Newcastle–Ottawa Scale, which is commonly used for observational research. Each study was rated across three domains (Selection, Comparability, Outcome/Exposure), with total scores ranging from 0 to 9. Studies with scores ≥7 were classified as high quality, those scoring 5–6 as moderate quality, and those with scores ≤4 as low quality.

Statistical Analysis

For binary outcomes (myopia, hyperopia, astigmatism), pooled effect estimates were calculated as odds ratios (ORs) using a random-effects model based on the DerSimonian–Laird approach. Continuous outcomes (biometry) were analyzed using pooled mean differences. Between-study heterogeneity was evaluated using Cochran's Q test and quantified with the I^2 statistic. Subgroup analyses stratified studies by design and World Bank income classification. Meta-regression examined age at follow-up as a potential modifier. Publication bias was examined using Egger's test in conjunction with funnel plot assessment.

RESULTS

Literature search and study characteristics

The database search yielded 1,056 records in total (658 from Embase, 325 from PubMed and 73 from CINAHL), with no additional records obtained from other sources. Following removal of 372 duplicate records, 684 articles proceeded to title and abstract screening, of which 602 were excluded. Eighty-one studies were subsequently assessed for eligibility through full-text review, and all were successfully retrieved. Of these, 69 were excluded due to inappropriate patient population, outcomes, comparator, or study setting, or because full texts were unavailable. Ultimately, 12 studies met the predefined inclusion criteria and were included in the final systematic review (Fig 1).

Characteristics of Included Studies

The included studies comprised both prospective and retrospective cohorts, with the majority being prospective cohort or case-control studies conducted in Europe and Asia. Sample sizes varied considerably, with the number of eyes with retinopathy of prematurity (ROP) ranging from 38 to 153 and comparison groups without ROP ranging from 38 to 434 eyes. In total, 12 observational studies comprising approximately 3,000 premature children were analyzed, with follow-up durations ranging from 1 to 18 years.

The mean or median age at examination ranged from 5.5 to 11 years, reflecting school-aged to early adolescent populations. Definitions of refractive error were relatively consistent across studies, with myopia defined as less than −0.50 D (ranging to −3.00 D in some cohorts), astigmatism defined as cylindrical error greater than 1.00 D (up to 2.00 D), and hyperopia defined as greater than +1.00 D (up to +3.00 D). Criteria for prematurity varied by study but generally included gestational age

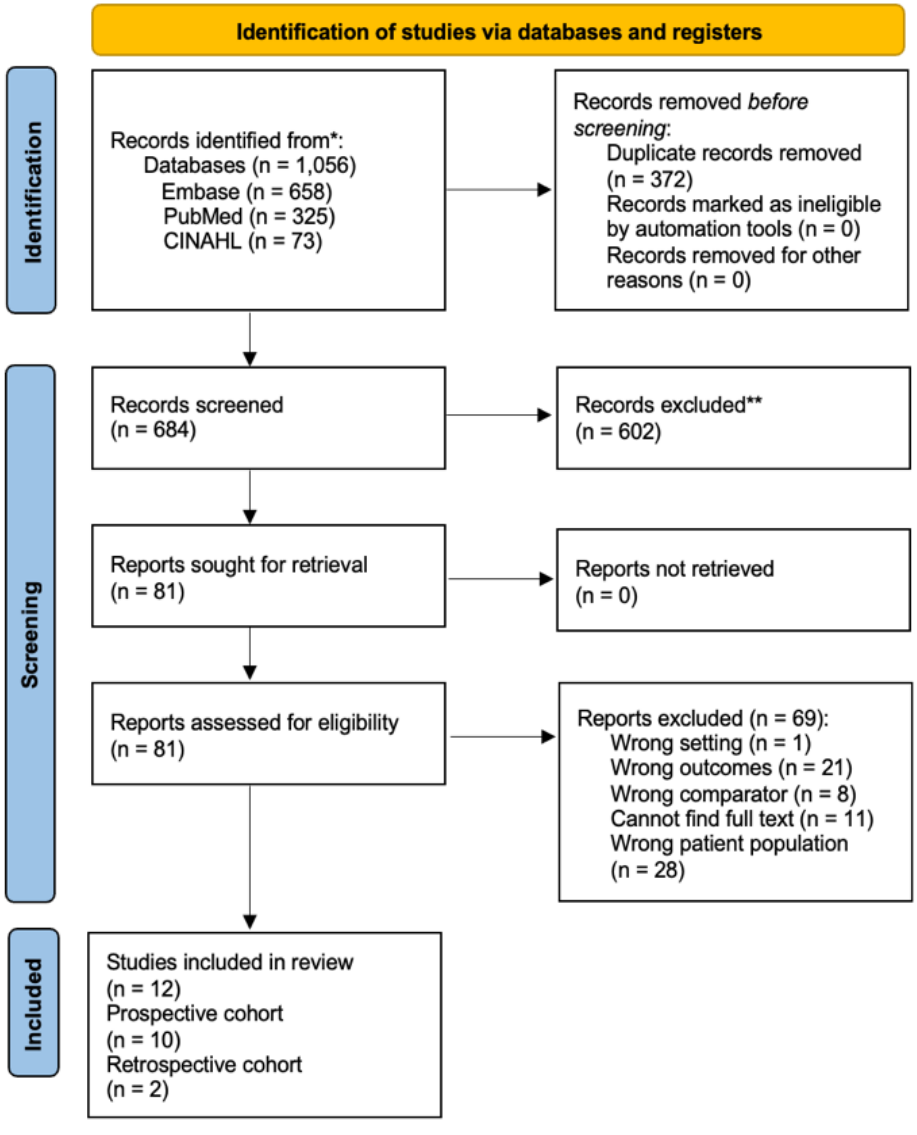


Fig 1. PRISMA 2020 flow diagram of study selection

thresholds between <32 and <37 weeks and/or low birth weight criteria ranging from <1,500 g to <2,500 g (Table 1).

Refractive Outcomes

Myopia Outcomes Pooled analysis showed that children with a history of ROP had significantly greater odds of developing myopia than those without ROP. Using a random-effects model, pooled analysis showed significantly higher odds of myopia among participants with ROP (odds ratio (OR) = 1.76; 95% confidence interval (CI), 1.17–2.64; p = 0.01), with moderate heterogeneity across studies (I^2 = 57%) (Fig 2). Age significantly modified this association (p = 0.002).

Subgroup analysis stratified by country income level revealed differing patterns between ROP and myopia (Fig 3). In high-income countries, the association between ROP and myopia was not statistically significant

TABLE 1. Characteristics of the included studies

Study	Study design	n ROP (eyes)	n non-ROP (eyes)	Age (Yrs)	Myopia (D)	Astigmatism (DC)	Hyperopia (D)	Prematurity criteria	Country
Larsson et al (2003)[9]	Prospective	80	133	10	< -0.50 D	> 1.00 DC	> +1.00 D	BW <1,500g	Sweden
Holmström et al (2005)[8]	Prospective	77	121	10	< -0.50 D	-	> +1.00 D	BW <1,500g	Sweden
O'Connor et al (2006)[3]	Prospective	134	155	11	< -1.00 D	-	> +1.00 D	BW <1,701g	UK
Fieß et al (2017)[17]	Prospective	55	184	6.94	< -3.00 D	> 1.00 DC	> +3.00 D	GA < 32 wk	Germany
Zhu et al (2017)[16]	Prospective	56	104	6.35	< -0.50 D	> 1.00 DC	> +2.00 D	GA < 37 wk, BW < 2,500g	China
Wang et al (2020)[13]	Prospective	50	110	7	< -0.50 D	> 1.00 DC	> +2.00 D	GA < 37 wk, BW < 2,500g	China
Rasoulinejad et al (2020)[18]	Prospective	122	56	5.5	< -3.00 D	> 2.00 DC	> +3.00 D	GA < 34 wk, BW < 2,000g	Iran
Pétursdóttir et al (2022)[21]	Prospective	50	68	10	< -1.00 D	> 1.00 DC	> +1.00 D	GA 24-34 wk, BW < 1,490	Sweden
Xie et al (2022)[19]	Prospective	153	324	7	< -0.50 D	> 1.00 DC	> +2.00 D	GA < 32 wk	China
Genc et al (2023)[22]	Prospective	38	38	9.3	< -0.50 D	> 1.00 DC	> +1.00 D	GA < 34 wk, BW < 1,750g	Turkey
Chen et al (2010)[14]	Retrospective	48	60	8.06	< -0.50 D	-	> +0.50 D	GA < 35 wk, BW < 1,500g	Taiwan
Al Oum Muna et al (2014)[15]	Retrospective	88	434	6	< -0.50 D	> 1.00 DC	> +0.50 D	GA < 32 wk, BW < 1,500g	Italy

Abbreviations: Yrs: Years, D: Diopters, DC: Diopters of Cylinder, BW: Birth weight, GA: Gestational age

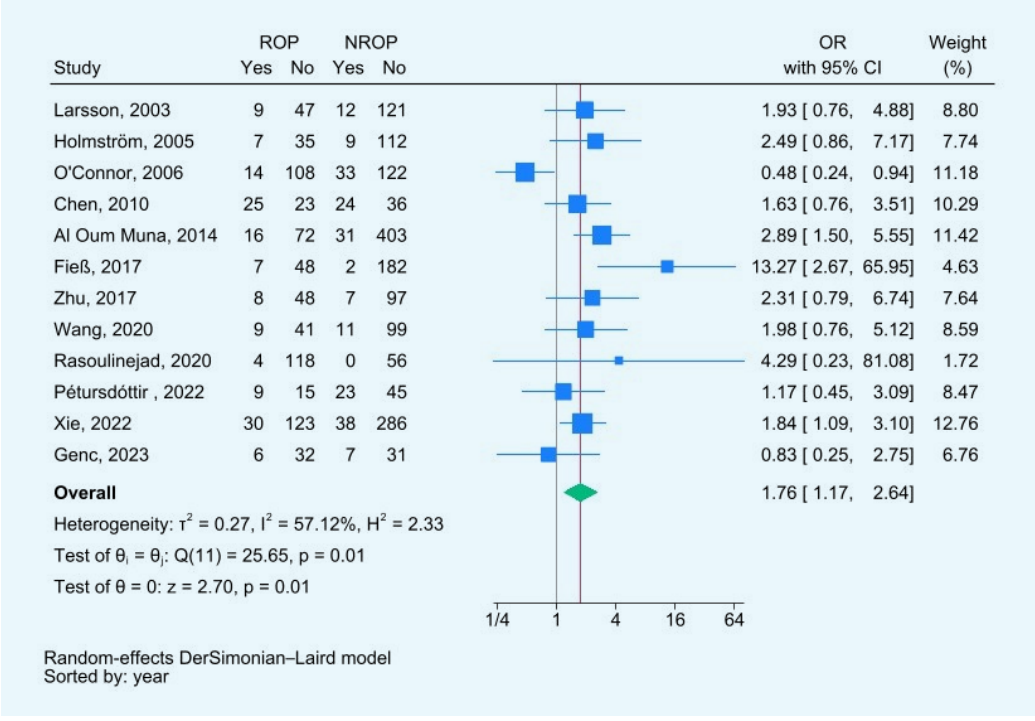


Fig 2. Forest plot comparing the association between myopia in eyes with retinopathy of prematurity (ROP) and those without ROP

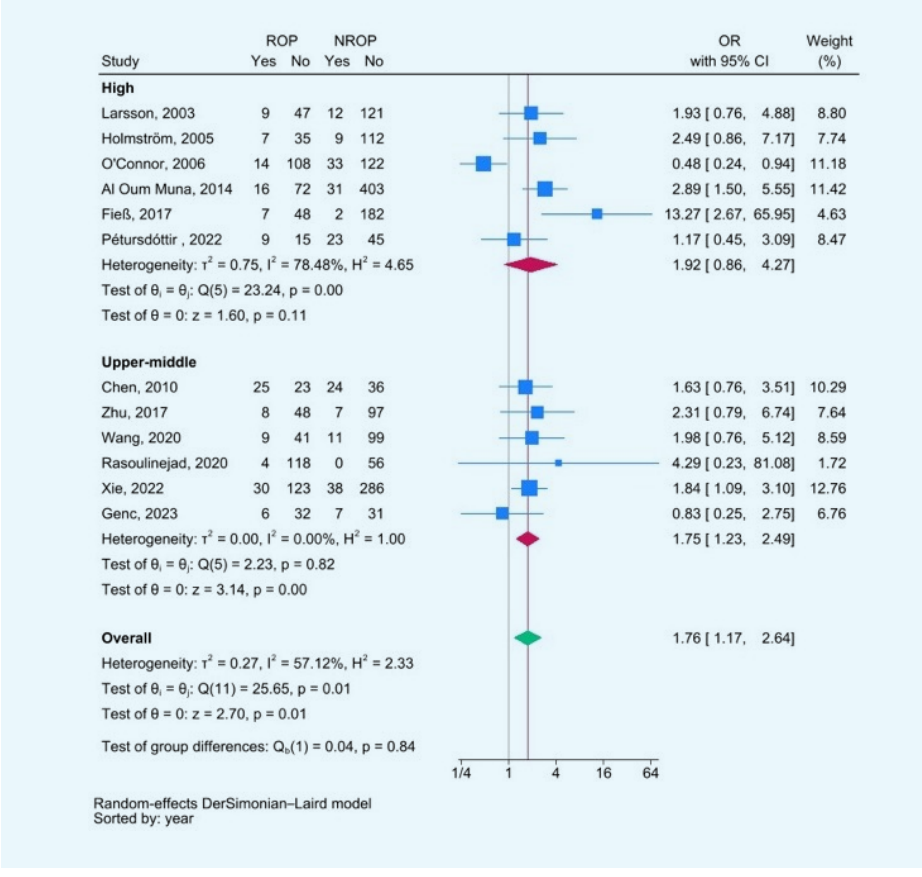


Fig 3. Forest plot of subgroup analysis by country income level for the association between myopia and retinopathy of prematurity (ROP) versus non-ROP

(OR = 1.92; 95% CI, 0.86–4.27), with substantial heterogeneity observed (I^2 = 78.5%). Conversely, studies conducted in upper-middle-income countries demonstrated a significantly increased odds of myopia among individuals with ROP (OR = 1.75; 95% CI, 1.23–2.49), with no observed heterogeneity (I^2 = 0%). However, there was no significant difference between income-level subgroups (p = 0.84).

Astigmatism Outcomes A significant relationship was also observed between ROP and astigmatism, with the pooled estimate indicating nearly two-fold higher odds (95% CI, 1.49–2.43; $p < 0.001$). Between-study heterogeneity for astigmatism was low (I^2 = 3.4%), indicating a high level of consistency among included studies (Fig 4).

Subgroup analysis by country income level showed significant associations in both high-income countries (OR = 1.46, 95% CI 1.02–2.08; p = 0.04) and upper-middle-income countries (OR = 2.35, 95% CI 1.71–3.22; p < 0.001), with negligible heterogeneity (I^2 = 0%). The test for subgroup differences was borderline significant (p = 0.05), suggesting a potentially stronger association in upper-middle-income settings. Overall, the findings support ROP as a significant risk factor for astigmatism across different economic contexts (Fig 5).

Hyperopia Outcomes In contrast, hyperopia prevalence did not differ significantly between the ROP and non-ROP groups (OR, 0.97; 95% CI, 0.64–1.47; p = 0.89) (Fig 6).

Ocular Biometry

Structural ocular parameters were compared between children with and without a history of retinopathy of prematurity (ROP). Meta-analysis demonstrated that vitreous thickness was significantly greater in the ROP group, with a pooled mean difference of 0.16 mm (95% confidence interval [CI], 0.01–0.31; p = 0.04), and no evidence of between-study heterogeneity (I^2 = 0%) (Fig 7). In contrast, axial length, lens thickness, and anterior chamber depth did not differ significantly between the two groups (all p > 0.40).

Risk of Bias

Of the 12 included studies, nine were rated as high quality (≥7 stars on the Newcastle–Ottawa Scale [NOS]), while three were of moderate quality. No studies were classified as low quality.

Selection: Most studies employed validated ophthalmic examination methods, with appropriate control group selection.

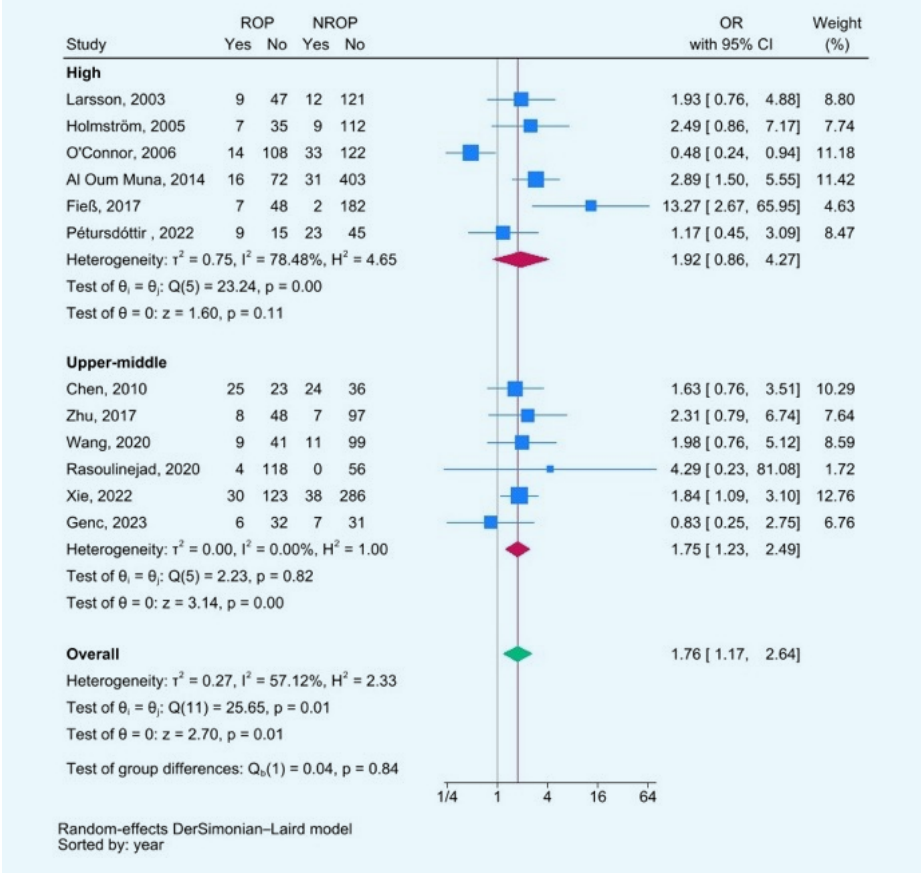


Fig 4. Forest plot comparing the association between astigmatism in eyes with retinopathy of prematurity (ROP) and those without ROP

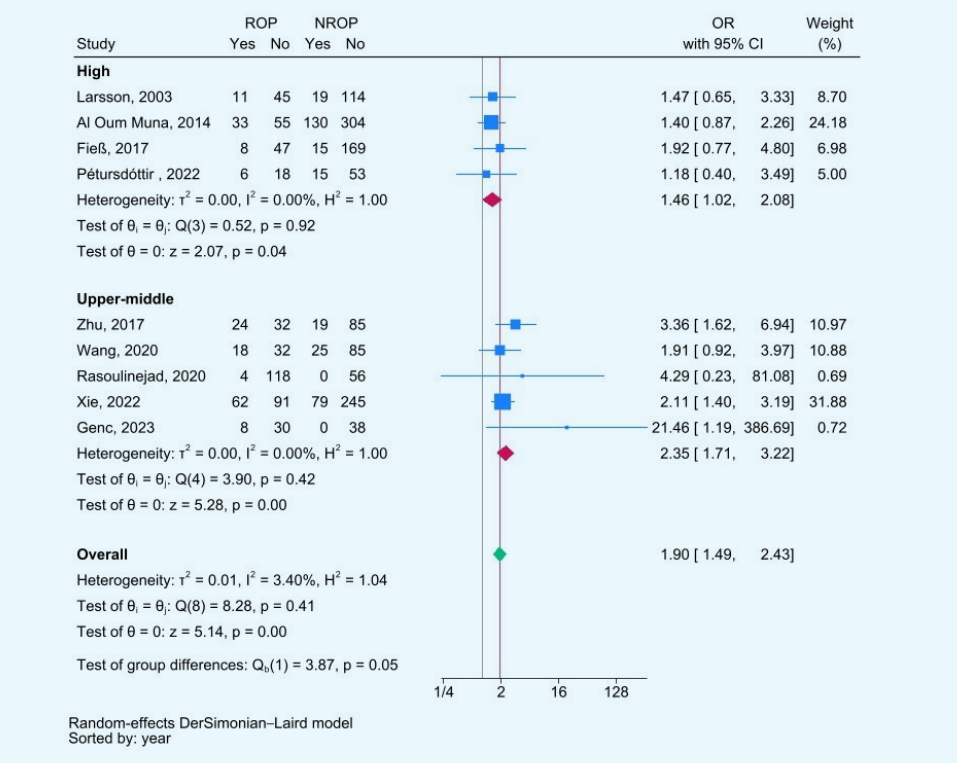


Fig 5. Forest plot of subgroup analysis by country income level for the association between astigmatism and retinopathy of prematurity (ROP) versus non-ROP

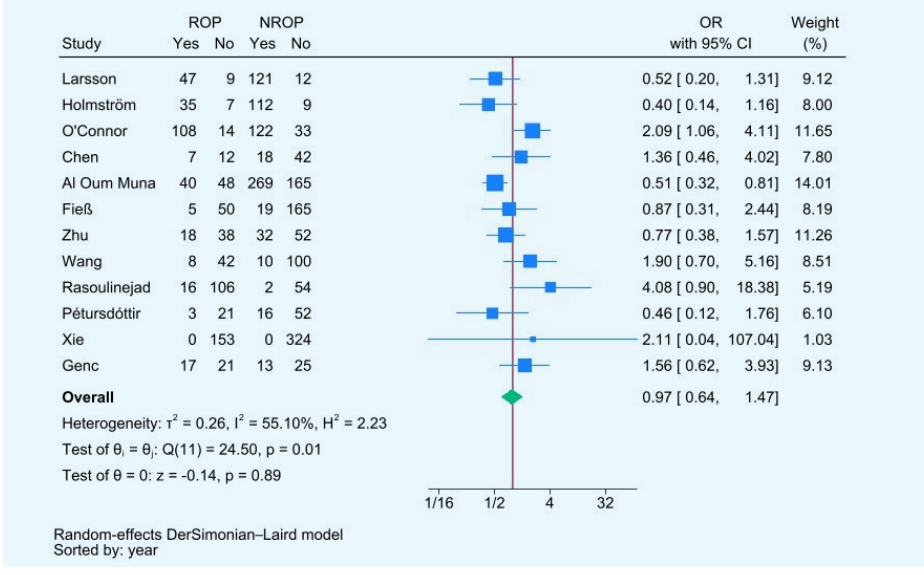


Fig 6. Forest plot comparing the association of hyperopia in eyes with retinopathy of prematurity (ROP) and those without ROP

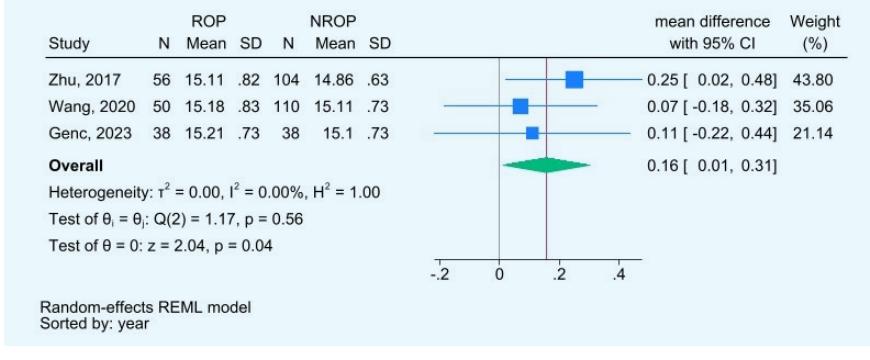


Fig 7. Forest plot comparing vitreous thickness between eyes with retinopathy of prematurity (ROP) and those without ROP

Comparability: Seven studies adequately adjusted for key confounders, including age at follow-up and gestational age.

Outcome/Exposure: Nine studies had follow-up durations exceeding five years, supporting reliable outcome assessment, whereas three had shorter follow-up periods, which may introduce a degree of outcome misclassification.

Sensitivity Analysis and Publication Bias

Leave-one-out sensitivity analyses confirmed robustness. Egger's test showed no evidence of small-study effects (Fig 8).

DISCUSSION

The present synthesis indicates that preterm children with ROP are more likely to develop myopia and astigmatism than their counterparts without ROP, whereas no association was observed with hyperopia. These findings reinforce the concept that ROP exerts selective and long-term effects on refractive development rather than inducing a generalized refractive shift.[8-10] The association between ROP and myopia was significantly modified by age, suggesting that refractive divergence between children with and without ROP evolves over time. This observation is consistent with longitudinal cohort studies indicating altered emmetropization trajectories in preterm children, particularly those with retinal vascular pathology.[8,9,13,16-21] Rather than representing a fixed refractive outcome established in early childhood, myopia in ROP appears to reflect a dynamic process influenced by ongoing ocular growth and remodeling.[9,13] Clinically, this underscores the importance of long-term refractive surveillance beyond early childhood in this population.

Socioeconomic context emerged as a potential effect modifier, with stronger associations between ROP and myopia observed in upper-middle–income countries. Although subgroup differences were not statistically significant, this pattern may reflect disparities in neonatal care quality, survival of more immature infants, variations in ROP screening thresholds, or differences in follow-up adherence.[1,5,6] In higher-income settings, earlier detection and optimized neonatal interventions may mitigate the downstream refractive impact of ROP, whereas in resource-limited contexts, subclinical or untreated retinal changes may exert greater influence on ocular development.[5] These findings highlight the need to interpret refractive outcomes of prematurity within broader healthcare system contexts.

This uniformity suggests a common underlying mechanism, potentially related to altered corneal or anterior segment development secondary to premature birth and retinal disease.[10,11,13,21] The strength and consistency of this association emphasize astigmatism as a key refractive sequela of ROP that warrants early detection and correction to reduce amblyopia risk.[12]

In contrast, hyperopia was not associated with ROP, indicating that posterior segment pathology does not uniformly disrupt refractive development in all directions.[3,10] This finding supports the notion that ROP-related refractive outcomes are not simply a consequence of arrested ocular growth but are instead shaped by specific structural alterations.[10,11]

Biometric analysis further supports this interpretation. Among the evaluated parameters, vitreous thickness was the only biometric measure significantly increased in children with ROP, whereas axial length, anterior chamber depth, and lens thickness did not differ between groups. These findings indicate that posterior segment remodeling may play a central role in the refractive sequelae of ROP, rather than global axial elongation or anterior segment underdevelopment.[10,11,13,21] Increased vitreous thickness may reflect abnormal posterior segment growth following early retinal ischemia and dysregulated vascular development.[11,13,21] This structural alteration provides a plausible explanation for the increased risk of myopia in the absence of axial elongation, a pattern that contrasts with typical school-age myopia.[21,22]

The observed association between ROP and myopia

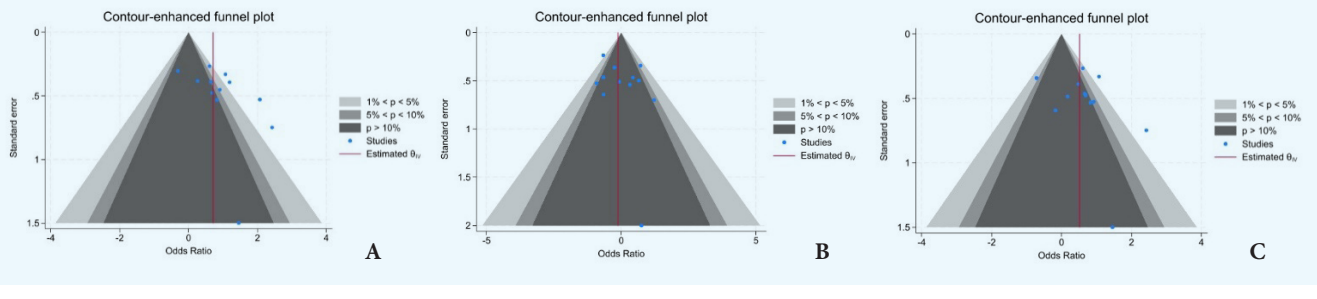


Fig 8. Contour-enhanced funnel plot for myopia (odds ratio) (A), astigmatism (odds ratio) (B), and hyperopia (odds ratio) (C)

may be explained, at least in part, by disruption of the normal emmetropization process. In healthy ocular development, visually guided feedback mechanisms originating from the retina regulate axial growth to achieve emmetropia.[23,24] In preterm infants, particularly those with ROP, retinal immaturity, ischemia, and aberrant vascular development may impair this feedback loop, leading to dysregulated ocular growth.[8,10,25] Rather than a simple increase in axial length, this dysregulation may involve altered coordination between anterior and posterior segment development, resulting in refractive error.[10,14]

The strengths of this study include its comprehensive synthesis of both refractive outcomes and ocular biometry, use of rigorous meta-analytic methods, assessment of effect modifiers through subgroup and meta-regression analyses, and low overall risk of bias across included studies. Importantly, this is one of the first meta-analyses to integrate biometric data into the evaluation of refractive outcomes in ROP.

However, several limitations should be acknowledged. Definitions of refractive errors varied across studies, which may have contributed to residual heterogeneity. The number of studies reporting biometric parameters was limited, restricting more granular analyses of ocular structure. Additionally, most data were derived from high- and upper-middle–income countries, potentially limiting generalizability to low-income settings where ROP epidemiology and care pathways differ substantially. Furthermore, our analysis did not fully account for the severity of ROP due to inconsistent reporting in primary studies. Given that more advanced stages of ROP are typically associated with a higher prevalence of myopia, our findings may partially reflect the influence of more severe disease. Furthermore, the potential impact of ROP treatment also remains an important consideration. Although this study focused on untreated or naturally progressing ROP, contemporary interventions such as laser photocoagulation or anti-VEGF therapy are known to alter refractive development. Specifically, laser treatment has been linked to increased myopic risk, whereas the long-term refractive profile of anti-VEGF therapy is still being elucidated. Therefore, these results may not fully represent refractive outcomes in modern clinical settings where active treatment is standard.

CONCLUSIONS

Preterm children who experienced ROP have a higher long-term likelihood of myopia and astigmatism, whereas hyperopia does not appear to be increased. These associations are influenced by age and socioeconomic context, underscoring the dynamic and multifactorial nature of refractive development following prematurity. Vitreous thickness was the only biometric parameter consistently altered in ROP, suggesting that posterior segment remodeling may underlie these refractive sequelae. Future longitudinal studies using standardized refractive definitions and comprehensive biometric profiling are needed to further elucidate mechanisms and to inform targeted screening and prevention strategies aimed at reducing lifelong visual morbidity in this vulnerable population.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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DECLARATIONS

Grants and Funding Information

None

Conflict of Interest

None

Registration number of clinical trial

The protocol was registered in PROSPERO under reference CRD42023262977.

Author Contributions

Conceptualization and methodology, N.B. and T.S. ; Investigation, N.B. and P.J. ; Formal analysis, N.B. and R.K. ; Visualization and writing – original draft, N.B. and P.J. ; Writing – review and editing, N.B. and T.S. ; Supervision, T.S. All authors have read and agreed to the final version of the manuscript.

Use of artificial intelligence

During preparation of the manuscript, the authors used Grammarly and ChatGPT 5.5 to refine grammar and enhance readability.

IRB Approval / COI Disclosure

This systematic review and meta-analysis study was approved by the Siriraj Institutional Review Board, Faculty of Medicine Siriraj Hospital (SIRB Protocol no. 096/2568 Exempt).

REFERENCES

1. Blencowe H, Cousens S, Chou D, Oestergaard M, Say L, Moller AB, et al. Born too soon: the global epidemiology of 15 million preterm births. Reproductive Health. 2013;10(Suppl 1):S2.
2. Stoll BJ, Hansen NI, Bell EF, Walsh MC, Carlo WA, Shankaran S, et al. Trends in Care Practices, Morbidity, and Mortality of Extremely Preterm Neonates, 1993-2012. JAMA. 2015;314(10): 1039-51.
3. O'Connor AR, Stephenson TJ, Johnson A, Tobin MJ, Ratib S, Fielder AR. Long-term ophthalmic outcome of low birth weight children with and without retinopathy of prematurity. Pediatrics. 2006;118(6):2329–39.
4. Sirivunnabood T, Wanitpongpan P, Yapan P. Incidence and risk factors of neonatal sepsis in preterm premature rupture of membranes before 34 weeks of gestation. Siriraj Med J. 2022; 74(3):169-77.
5. Quinn GE. Retinopathy of prematurity blindness worldwide: phenotypes in the third epidemic. Eye Brain. 2016;8:31-36.
6. Gilbert C, Foster A. Childhood blindness in the context of VISION 2020—the right to sight. Bull World Health Organ. 2001;79(3): 227–32.
7. Phruksarudee K, Sungprem K, Montriwet M. Association of oxygen therapy concentration and duration with retinopathy of prematurity incidence at Naresuan University Hospital. Siriraj Med J. 2024;76(3):160-6.
8. Holmström GE, Larsson EK. Development of spherical equivalent refraction in prematurely born children during the first 10 years of life: a population-based study. Arch Ophthalmol. 2005;123(10): 1404–11.
9. Larsson EK, Rydberg AC, Holmström GE. A population-based study of the refractive outcome in 10-year-old preterm and full-term children. Arch Ophthalmol. 2003;121(10):1430–6.
10. Cook A, White S, Batterbury M, Clark D. Ocular growth and refractive error development in premature infants with or without retinopathy of prematurity. Invest Ophthalmol Vis Sci. 2008;49(12):5199-207.
11. Cauduro R, de Moraes NSB, Goulart AL, Allemann N. Ocular biometry in preterm newborns in the neonatal intensive care unit environment of a referral hospital. Ophthalmol Sci. 2025;5(6):100829.
12. Webber AL, Wood J. Amblyopia: prevalence, natural history, functional effects and treatment. Clin Exp Optom. 2005;88(6): 365–75.
13. Wang Y, Pi LH, Zhao RL, Zhu XH, Ke N. Refractive status and optical components of premature babies with or without retinopathy of prematurity at 7 years old. Transl Pediatr. 2020;9(2):108–16.
14. Chen TC, Tsai TH, Shih YF, Yeh PT, Yang CH, Hu FC, et al. Long-term evaluation of refractive status and optical components in eyes of children born prematurely. Invest Ophthalmol Vis Sci. 2010;51(12):6140–8.
15. Al Oum M, Donati S, Cerri L, Agosti M, Azzolini C. Ocular alignment and refraction in preterm children at 1 and 6 years old. Clin Ophthalmol. 2014;8:1263–8.
16. Zhu X, Zhao R, Wang Y, Ouyang L, Yang J, Li Y, et al. Refractive state and optical compositions of preterm children with and without retinopathy of prematurity in the first 6 years of life. Medicine (Baltimore). 2017;96(45):e8565.
17. Fieß A, Kölb-Keerl R, Schuster AK, Knuf M, Kirchhof B, Muether PS, et al. Prevalence and associated factors of strabismus in former preterm and full-term infants between 4 and 10 years of age. BMC Ophthalmol. 2017;17:228.
18. Rasoulinejad SA, Pourdad P, Pourabdollah A, Arzani A, Geraili Z, Roshan HY. Ophthalmologic outcome of premature infants with or without retinopathy of prematurity at 5–6 years of age. J Family Med Prim Care. 2020;9(9):4582–6.
19. Xie X, Wang Y, Zhao R, Yang J, Zhu X, Ouyang L, et al. Refractive status and optical components in premature infants with and without retinopathy of prematurity: a 4- to 5-year cohort study. Front Pediatr. 2022;10:922303.
20. Pétursdóttir D, Holmström G, Larsson E. Refraction and its development in young adults born prematurely and screened for retinopathy of prematurity. Acta Ophthalmol. 2022;100(2): 189–95.
21. Genc CD, Yucel OE. Effects of prematurity and retinopathy of prematurity on refractive errors and biometric optic components in school children: results of a tertiary center from Turkey. Int Ophthalmol. 2023;43(11):4821–30.
22. Saluja G, Kaur K. Childhood Myopia and Ocular Development. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan. Available from: https://www.ncbi.nlm.nih.gov/books/NBK587350/
23. Wallman J, Winawer J. Homeostasis of eye growth and the question of myopia. Neuron. 2004;43(4):447–68.
24. Flitcroft DI. The complex interactions of retinal, optical and environmental factors in myopia aetiology. Prog Retin Eye Res. 2012;31(6):622–60.
25. Schaeffel F, Wildsoet C. Can the retina alone detect the sign of defocus? Ophthalmic Physiol Opt. 2013;33(3):362–7.