Review

A Comprehensive Scientific Review: Early Detection, Genetic Underpinnings, and Personalized Management of Pediatric Astigmatism and Its Synergistic Progression with Myopia

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Review

A Comprehensive Scientific Review: Early Detection, Genetic Underpinnings, and Personalized Management of Pediatric Astigmatism and Its Synergistic Progression with Myopia

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Abstract

Astigmatism, a common refractive error characterized by an irregular corneal or lenticular curvature, represents a significant pediatric public health concern with profound implications for visual development and long-term ocular health. This review synthesizes contemporary evidence on the complex, multifactorial etiology of astigmatism, emphasizing its critical and synergistic relationship with myopia progression. We delineate the substantial genetic component, with heritability estimates of 40-60%, involving polygenic inheritance patterns and specific SNPs in loci such as *PDGFRA* and *CTNNA2*. The pathophysiology is further explored through physiological triggers, including extraocular muscle imbalance, dynamic eyelid pressure, and corneal biomechanical weakening. Modern environmental accelerants, notably prolonged near work and digital device usage, are examined for their role in disrupting emmetropization. The core thesis of this manuscript advocates for a paradigm shift towards early infantile screening and personalized, multi-modal intervention strategies. We critically evaluate conventional therapies (spectacles, toric contact lenses, orthokeratology), emerging pharmacological agents (low-dose atropine), and evidence-based lifestyle modifications (increased outdoor exposure, nutritional optimization). Furthermore, we explore the integration of advanced diagnostics (anterior-segment OCT, Scheimpflug tomography, genetic risk profiling) and complementary approaches like Nutritional optimization and traditional medicine systems, such as Ayurvedic *Netra Tarpana* and yogic eye exercises, within a holistic management framework. The convergence of genetic insights, advanced biometry, and personalized medicine heralds a new era in preventing astigmatism-related amblyopia and mitigating its role in axial elongation, ultimately preserving lifelong visual function.

Keywords: astigmatism; myopia; early detection; genetic factors; corneal biomechanics; personalized medicine; outdoor time; pediatric ophthalmology; yogic eye exercises; ophthalmic nutrition

1. Introduction

1.1. Background and Significance

The visual system undergoes a critical period of postnatal development, a process termed emmetropization, wherein ocular components refine to achieve optimal focus for distant objects

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[Saunders, 2002]. Interference with this delicate process can result in refractive errors such as astigmatism and myopia, which are among the most prevalent ocular disorders worldwide. Astigmatism, defined as a condition where parallel rays of light fail to converge to a single focal point on the retina due to unequal refractive power across different meridians, is not merely an isolated optical defect. A robust and growing body of evidence positions it as a significant independent risk factor and potentiator for the development and progression of myopia, a condition associated with sight-threatening pathologies including retinal detachment, macular degeneration, and glaucoma [Gwiazda et al., 2000; Shing et al., 2025].

The global burden is substantial. Uncorrected refractive errors remain a leading cause of moderate to severe vision impairment, with astigmatism contributing significantly to this burden [Zhang et al., 2023]. Its prevalence is remarkably high in pediatric populations, affecting over half of all children in some demographic studies, with a notable escalation observed following lifestyle shifts during the COVID-19 pandemic [Wong et al., 2022; Weise et al., 2024]. This underscores the condition's sensitivity to environmental pressures.

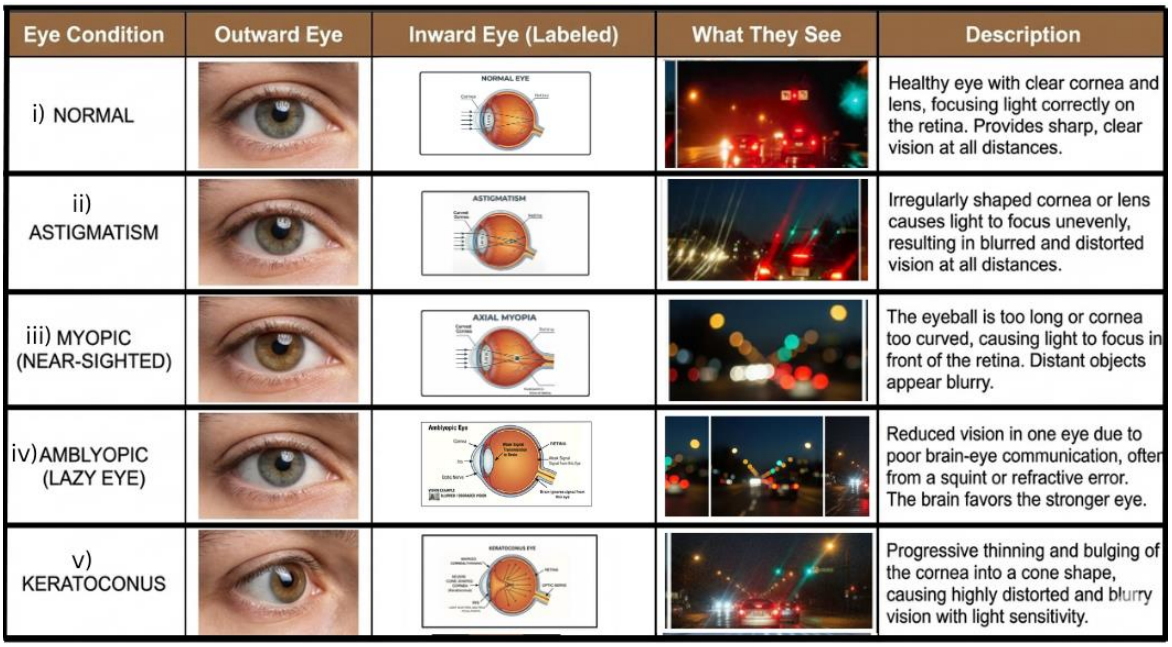

Figure 1. Common eye conditions, visualizing symptoms, internal pathology and effects (i): Normal Eye: When light rays strike the cornea and pass through the lens, the retina receives the single focal point, resulting in normal vision. (Figure S1) **(ii)** Astigmatic Eye: Multiple focal points fall on the retina when light rays strike the cornea and pass through the lens, causing distorted vision.(Figure S2). **(iii):** Myopic eye - The figure illustrates light ray convergence through the corneal and lenticular optical systems and the resultant refractive error in myopic eyes.(Figure S3) **(iv)**: Amblyopic Eye - The figure illustrates the amblyopic eye demonstrating weak afferent signaling through the optic nerve and subsequent cortical suppression of visual input. The brain preferentially processes signals from the non-amblyopic eye, resulting in functional vision impairment of the affected eye despite normal ocular anatomy and optical media.(Figure S4) **(v)**: Keratoconus Eye - The figure illustrates corneal thinning and cone-shaped protrusion characteristic of keratoconus, demonstrating marked corneal surface irregularity and multiple refractive axes. The distorted corneal geometry results in light scattering and multiple focal points, producing severe irregular astigmatism and reduced visual acuity.(Figure S5).

Historically, detection often occurred late, only after manifest visual or academic difficulties arose. This reactive model is insufficient, as the plasticity of the visual cortex diminishes with age, making interventions for conditions like amblyopia ("lazy eye")—a common sequela of uncorrected astigmatism—less effective after early childhood [Harvey et al., 2004; Fan et al., 2016]. Therefore, this review articulates a compelling argument for transitioning to a proactive model of pediatric eye care

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centered on early detection, sophisticated etiological understanding, and personalized, pre-emptive management to disrupt the astigmatism-myopia progression axis.

1.2. Objectives of the Review

This comprehensive review aims to:

1. Elucidate the complex, multifactorial etiology of pediatric astigmatism, integrating genetic, physiological, and environmental determinants.
2. Critically analyze the pathophysiological link between astigmatism and accelerated myopia progression.
3. Evaluate current and emerging diagnostic technologies for early detection and risk stratification.
4. Synthesize evidence on conventional, pharmacological, and lifestyle-based management strategies.
5. Explore the potential role of integrative and traditional medicine practices within a scientific framework.
6. Propose a holistic, personalized management algorithm and identify future research directions to mitigate the lifelong impact of pediatric astigmatism.

2. Genetic Architecture and Heritability of Astigmatism

2.1. Polygenic Risk and Genome-Wide Association Studies (GWAS)

Astigmatism is a classic polygenic trait, influenced by the cumulative effect of numerous genetic variants, each conferring a small increase in risk. Large-scale GWAS, such as those conducted by the CREAM Consortium, have identified multiple susceptibility loci [The CREAM Consortium et al., 2015]. These studies have revealed a significant genetic correlation between corneal astigmatism and spherical equivalent refractive error, indicating shared biological pathways for astigmatism and myopia.

The five major genomic regions identified through GWAS, including their corresponding refractive phenotypes and proposed molecular mechanisms. PDGFRA and BMP3 regulate corneal stromal development and matrix organization; CTNNA2 mediates cell-cell adhesion critical for corneal structure; ZC3H11B participates in gene regulation; HERC2 influences axial length through pigmentation-related pathways. These loci collectively represent diverse biological pathways underlying astigmatism pathogenesis. (Table 1)

Key genetic loci implicated include:

- PDGFRA (Platelet-Derived Growth Factor Receptor Alpha): Strongly associated with corneal curvature and astigmatism. This gene is crucial for neural crest cell migration and differentiation, which are fundamental to corneal and scleral development [Hideharu Fukasaku et al., 2023].
- ZC3H11B, BMP3, HERC2, PROX1-AS1: Other consistently identified genes involved in ocular development and connective tissue structure [ERICA SHING et al., 2025; Shing et al., 2024].

Table 1. Summary of prioritized gene loci and their mechanistic roles in eye development. The table highlights how specific genetic markers influence ocular biometry, ranging from the structural organization of the corneal stroma (PDGFRA, CTNNA2) to the signaling pathways that dictate tissue differentiation and pigmentation (BMP3, HERC2). These findings underscore the complex interplay between cell-cell adhesion, RNA metabolism, and molecular signaling in the pathogenesis of astigmatism and refractive error.

Gene Locus	Associated Trait	Proposed Biological Function
PDGFRA	Corneal Curvature, Astigmatism	Neural crest cell development, corneal stroma formation
ZC3H11B	Refractive Astigmatism	Gene regulation, RNA metabolism
BMP3	Corneal Astigmatism	Bone morphogenetic protein signaling, tissue differentiation
CTNNA2	Corneal Curvature	Cell-cell adhesion, structural integrity of tissues

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HERC2	Pigmentation & Refractive Error	Protein ubiquitination, pigmentation pathway (influences axial length)

2.2. Heritability Estimates and Inheritance Patterns

Twin and family studies provide robust estimates of heritability, quantifying the proportion of phenotypic variance attributable to genetic factors. For astigmatism, heritability is consistently estimated between 40% and 60% [Dirani M., 2008; Margarida C Lopes et al., 2013]. Monozygotic (identical) twins show a significantly higher concordance rate for astigmatism compared to dizygotic twins, confirming a strong genetic influence [Shing et al., 2024].

The inheritance is polygenic and complex, without Mendelian patterns in most cases. However, in conditions like keratoconus, a severe form of irregular astigmatism, familial aggregation is clearer, with first-degree relatives having a 3-4 times higher risk, suggesting contributions from both rare variants with larger effects and common polygenic risk. Additionally; strabismus, a vision condition where the eyes don't align to look at the same object, causing one eye to turn inward, outward, upward, or downward, impacting depth perception and potentially leading to lazy eye. This condition shares pleiotropic genetic susceptibility with astigmatism through common variants at the 17q25 locus (NPLOC4–TSPAN10–PDE6G cluster), suggesting overlapping biological pathways in the genetic architecture of ocular alignment and refractive disorders [Loukovitis et al., 2018; Safir et al., 2025].*(Figure S6)*

2.3. Gene-Environment Interactions (GxE)

Genetic predisposition does not operate in isolation. A child's genomic background modulates their sensitivity to environmental risk factors. This GxE interplay is pivotal in understanding disease progression.

- High Genetic Risk + Adverse Environment: Children with high polygenic risk scores who engage in prolonged near work (>3 hours/day) demonstrate significantly faster astigmatism progression and axial elongation [Shah et al., 2025; Fan et al., 2016].
- Protective Environment Mitigates Genetic Risk: Sufficient daily outdoor exposure (≥2 hours) appears to exert a protective effect that can partially offset genetic susceptibility, likely mediated by dopamine release and regulation of ocular growth signals [Biswas et al., 2024].
- Epigenetic Modifications: Environmental exposures (e.g., nutrition, pollution, light exposure) can induce epigenetic changes (DNA methylation, histone modification) that alter the expression of genes involved in eye growth without changing the DNA sequence itself, providing a mechanistic link between lifestyle and astigmatism progression [An et al., 2023].

3. Physiological and Biomechanical Triggers

3.1. Extraocular Muscle Imbalance and Orbital Mechanics

The six extraocular muscles (EOMs) are responsible for precise ocular alignment and movement. Chronic imbalance in EOM tonicity or insertions, such as in overaction of the medial rectus or underaction of a lateral rectus, can exert asymmetrical mechanical stress on the globe [Çakır et al., 2020]. This sustained, uneven pressure may contribute to alterations in corneal topography over time, inducing or exacerbating with-the-rule or oblique astigmatism. Orthoptic vision therapy aims to correct these imbalances, improving sensorimotor function and potentially reducing strain [Baratta et al., 2021]. *(Figure S7)*

3.2. Eyelid Pressure and Blink Dynamics

The cornea is a dynamic, viscoelastic structure susceptible to external forces. The upper eyelid exerts a consistent, localized pressure on the superior cornea during blinks and downgaze. Studies using corneal topography have documented transient and persistent corneal shape changes induced by eyelid mechanics [Shaw, Alyra J. B., 2009].

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- **Eyelid Morphology**: Individuals with wider palpebral apertures, lower lid positions, or conditions like ptosis (droopy eyelid) exhibit characteristic corneal flattening in the meridian perpendicular to the lid axis, often worsening pre-existing astigmatism [Lieberman et al., 2000; Read, Scott, Collins, Michael, & Carney, Leo, 2007].
- **Digital Device Use**: Prolonged downward gaze during smartphone/tablet use increases the contact area and pressure of the upper eyelid, potentially driving the observed increase in astigmatism prevalence in the digital era [Kroczek Marta et al., 2025].
- **Chronic Eye Rubbing**: A significant risk factor for keratoconus, eye rubbing delivers high, irregular mechanical stress, degrading corneal collagen and destabilizing its architecture [Prasida Unni et al., 2023].

3.3. Corneal Biomechanics and Progressive Weakening

The cornea's shape is maintained by the highly organized collagen fibrils within the stroma, embedded in a proteoglycan-rich matrix. "Biomechanics" refers to the tissue's responses to stress (resistance to deformation) and its ability to return to its original shape (hysteresis).

- **Astigmatism Progression**: In progressive astigmatism, often linked to subclinical keratoconus, localized biomechanical weakening occurs. This involves disruption of collagen cross-linking, altered proteoglycan composition, and enzymatic degradation (e.g., by matrix metalloproteinases), leading to reduced corneal hysteresis and increased deformability [David P. Piñero et al., 2011; Seyed-Farzad Mohammadi].
- **Advanced Diagnostics**: Devices like the Corneal Visualization Scheimpflug Technology (Corvis ST) and the Ocular Response Analyzer (ORA) provide in-vivo metrics of corneal biomechanics (e.g., corneal hysteresis, corneal resistance factor). These are critical for early detection of ectatic disorders and monitoring progression [Wang, 2025; Wei P. et al., 2025].
- **Corneal Cross-Linking (CXL)**: This evidence-based treatment uses ultraviolet-A light and riboflavin to create new covalent bonds between collagen fibrils, stiffening the cornea and halting the progression of ectatic diseases like keratoconus [Shinde et al., 2020].

3.4. Biomarkers for Early Detection of Progression of Astigmatism and Related Consequences

Recent genomic association studies have identified multiple Single Nucleotide Polymorphisms (SNPs) critical to ocular development and refractive error.

Corneal Astigmatism and Curvature:

The *PDGFRA* locus is a primary determinant of corneal geometry, with variants like **rs7677751** and **rs17084051** consistently linked to corneal astigmatism and curvature across populations (Table 2). Similarly, *VAX2* (**rs3771395**) influences the dorsoventral axis of the eye, directly affecting refractive astigmatism. Cytoskeletal organization via *FMNL2* (**rs1579050**) is also significantly associated with corneal curvature variations in children. Other implicated loci include *CMPK1* (**rs60078183**), which correlates with flatter corneal curvature, and *BMP3* (**rs1353386**), a growth factor regulating tissue morphogenesis.

Myopia and Axial Elongation:

For myopia, the *GJD2* locus (**rs524952**) is highly replicated, encoding connexin 36 to regulate retinal signaling and eye growth. This effect may be modulated by environmental factors like education. Potassium channel genes also play a role; *KCNQ5* (**rs7744813**) affects cell volume regulation and eye size, while *KCNMA1* (**rs10824518**) is linked to myopic macular degeneration. Retinal signaling pathways are further implicated through *RASGRF1* (**rs4778879**) and the glutamate receptor *GRIA4* (**rs11601239**), which facilitate retina-sclera communication. Additionally, *ZC3H11B* (**rs4373767**) and *ZMAT4* (**rs7829127**) are key markers for axial length elongation and high myopia risk in pediatric cohorts. Finally, *ZEB2* (**rs13382811**) and the *ADAMTS16* locus are specifically associated with high myopia severity and scleral ECM remodeling.

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Table 2. Summary of significant Single Nucleotide Polymorphisms (SNPs) associated with refractive errors and ocular biometry. The table categorizes genetic variants by their primary phenotypic associations, including corneal astigmatism, early-onset myopia, axial length elongation, and corneal curvature. Chromosomal locations, candidate genes, and key biological roles—such as extracellular matrix remodeling (e.g., ADAMTS16) and retinal signaling (e.g., GJD2)—are detailed alongside primary study references.

	SNP	Associated Gene/Locus	Chromosome	Associated Trait	Key Finding / Role	Reference
1. Astigmatism SNPs (Corneal Astigmatism)	**rs7677751**	*PDGFRA (Platelet-Derived Growth Factor Receptor Alpha)*	4	Corneal Astigmatism (CA), Corneal Curvature	One of the most consistently reported SNPs, particularly in Asian populations. PDGFRA variants are linked to eye size and corneal shape.	Fan et al. (2011) PLoS Genet. DOI: 10.1371/journal.pgen.1002402
	rs17084051	*PDGFRA*	4	Corneal Curvature, Astigmatism	Located in the same critical gene region as rs7677751, involved in eye structure development.	Fan et al. (2011) PLoS Genet. DOI: 10.1371/journal.pgen.1002402
	rs3771395	*VAX2 (Ventricular homeobox 2)*	2p13.3	Refractive Astigmatism (RA)	*VAX2 plays a vital role in the development of the dorsoventral axis of the eye (top-bottom structure).*	Lopes et al. (2013) Invest Ophthalmol Vis Sci. DOI: 10.1167/iovs.12-10463
	rs1579050	*FMNL2 (Formin-Like 2)*	2	Corneal Astigmatism (CA)	Associated with both corneal curvature and astigmatism, with significant associations reported in children.	Lopes et al. (2013) Invest Ophthalmol Vis Sci. DOI: 10.1167/iovs.12-10463
	rs1401327	*NRXN1 (Neurexin 1)*	2p12	Refractive Astigmatism	Identified in a large GWAS by the CREAM Consortium for Refractive Astigmatism.	MacGregor et al. (2015) Hum Genet. DOI: 10.1007/s00439-014-1500-y
2. Myopia / Early Onset Myopia SNPs	**rs524952**	*GJD2 (Gap Junction Protein Delta 2)*	1q41	Myopia, Spherical Equivalent Refraction (SE)	Highly replicated myopia locus. Studies suggest its effect on myopia is intensified by higher levels of education/near work (gene-environment interaction).	Verhoeven et al. (2013) Nat Genet. DOI: 10.1038/ng.2554
	rs7744813	*KCNQ5 (Potassium Voltage-Gated Channel Subfamily Q Member 5)*	6q14.1	Myopia, Axial Length	A significant genetic factor for refractive error, often studied in relation to myopia severity in children.	Verhoeven et al. (2013) Nat Genet. DOI: 10.1038/ng.2554
	rs4373767	*ZC3H11B (Zinc Finger CCCH Type Containing 11B)*	17	High Myopia, Axial Length	Confers a higher risk for high myopia. Research supports its role as a genetic factor for refractive error in children.	Fan et al. (2012) PLoS Genet. DOI: 10.1371/journal.pgen.1002753
	rs7829127	*ZMAT4 (Zinc Finger, Matrin Type 4)*	16	Myopia, Axial Length, SE	Associated with baseline measurements and longitudinal changes in ocular length and refractive error in children.	Verhoeven et al. (2013) Nat Genet. DOI: 10.1038/ng.2554
	rs2969180	*SHISA6-DNAH9 Locus*	17q25.3	Myopia, Refractive Error	Exhibits a strong association with myopia, particularly in individuals with higher education/near work exposure.	Verhoeven et al. (2013) Nat Genet. DOI: 10.1038/ng.2554
	rs11601239	*GRIA4 (Glutamate Ionotropic Receptor AMPA Type Subunit 4)*	11q22.2	Myopia, SE, Axial Length	Linked to myopia and axial length in children, suggesting a role in signaling pathways involved in eye growth.	Verhoeven et al. (2013) Nat Genet. DOI: 10.1038/ng.2554
3. Axial Length (AL) & Myopia SNPs (Eye Elongation)	**rs524952**	*GJD2 (Gap Junction Protein Delta 2)*	15q14	Myopia, AL, Refractive Error (SE)	One of the most significant and highly replicated myopia loci. Encodes connexin 36, critical for retinal signal transmission and control of eye growth.	Verhoeven et al. (2013) Nat Genet. DOI: 10.1038/ng.2554
	rs7744813	*KCNQ5 (Potassium Voltage-Gated Channel Subfamily Q Member 5)*	6q14.1	Myopia, AL	Involved in cell excitability and volume regulation, potentially impacting the regulation of eye size. Highly replicated in multiple populations.	Verhoeven et al. (2013) Nat Genet. DOI: 10.1038/ng.2554

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	rs4778879	*RASGRF1 (Ras-Guanine Nucleotide Releasing Factor 1)*	15q25	Myopia, AL	Located near a transcription site expressed in the retina. Involved in synaptic transmission and memory consolidation, suggesting a link to the visual processing feedback loop.	-
	rs4373767	*ZC3H11B (Zinc Finger CCCH Type Containing 11B)*	17	AL, High Myopia	Associated with increased axial length, suggesting a role in cellular regulation that contributes to excessive eye growth.	Fan et al. (2012) PLoS Genet. DOI: 10.1371/journal.pgen.1002753
	rs11601239	*GRIA4 (Glutamate Receptor, Ionotropic, AMPA 4)*	11q22.2	AL, Refractive Error	Implicated in glutamate signaling, which is essential for the retina's ability to communicate with the sclera (the outer wall) to control growth.	Verhoeven et al. (2013) Nat Genet. DOI: 10.1038/ng.2554
	rs13382811	*ZEB2 (Zinc Finger E-Box Binding Homeobox 2)*	2q22.3	High Myopia	A gene often associated with syndromic forms of myopia (like Mowat-Wilson syndrome) but also shows strong association with common and high myopia severity.	Fan et al. (2016) Nat Genet. DOI: 10.1038/ng.3738
	rs10034228	Gene Desert (MYP11 Locus)	4q25	Myopia, Refractive Error	A highly significant locus in a gene-poor region, possibly containing a long-range enhancer for a distant gene.	Hysi et al. (2012) Hum Genet. DOI: 10.1007/s00439-012-1175-0
	rs10824518	*KCNMA1 (Potassium Large Conductance Calcium-Activated Channel Subfamily M Alpha 1)*	10	Myopia	Linked to myopic macular degeneration, suggesting a role in the health and structure of the high-myopic eye.	Cui et al. (2019) Nat Commun. DOI: 10.1038/s41467-019-10629-9
	rs7829127	*ZMAT4 (Zinc Finger, Matrin Type 4)*	16	AL, Spherical Equivalent (SE)	Associated with the elongation of the eye (increased AL) and is often investigated for interaction with environmental factors like near work.	Verhoeven et al. (2013) Nat Genet. DOI: 10.1038/ng.2554
	Novel Loci	*ADAMTS16, PIGZ*		High Myopia AL (≥ 26 mm)	Identified in GWAS focusing specifically on patients with high myopia. ADAMTS16 is linked to extracellular matrix (ECM) remodeling (scleral structure).	-
4. Corneal Curvature (CR) & Astigmatism SNPs	**rs7677751**	*PDGFRA (Platelet-Derived Growth Factor Receptor Alpha)*	4q12	Corneal Astigmatism (CA), CR	One of the most widely replicated SNPs for corneal traits. PDGFRA is a receptor for a growth factor that regulates cell proliferation and migration during development.	Fan et al. (2011) PLoS Genet. DOI: 10.1371/journal.pgen.1002402
	rs3771395	*VAX2 (Ventricular homeobox 2)*	2p13.3	Refractive Astigmatism (RA)	Involved in the development of the top-to-bottom axis of the eye, directly influencing corneal shape.	Lopes et al. (2013) Invest Ophthalmol Vis Sci. DOI: 10.1167/iovs.12-10463
	rs1579050	*FMNL2 (Formin-Like 2)*	2	CA, CR	Linked to both the degree of astigmatism and overall curvature. FMNL2 is involved in actin cytoskeleton organization, affecting cell shape and tissue integrity.	Lopes et al. (2013) Invest Ophthalmol Vis Sci. DOI: 10.1167/iovs.12-10463
	rs60078183	*CMPK1 (Cytidine/Uridine Monophosphate Kinase 1)*	14q32.33	CR	A novel locus associated with increased radius of corneal curvature (flatter cornea).	Chen et al. (2020) Cell Rep. DOI: 10.1016/j.celrep.2020.108250
	rs11204213	*RBP3 (Retinol-Binding Protein 3)*	15q24	CR, AL	Associated with both CR and AL, suggesting a pleiotropic effect on general eye growth and shape. RBP3 is involved in retinoid transport.	Verhoeven et al. (2013) Nat Genet. DOI: 10.1038/ng.2554

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	rs1353386	*BMP3 (Bone Morphogenetic Protein 3)*	4q21.21	CR, Astigmatism	*BMP3 is a growth factor involved in tissue morphogenesis and differentiation, which plays a role in establishing the final corneal shape.*	Sim et al. (2018) Am J Hum Genet. DOI: 10.1016/j.ajhg.2018.06.002
	rs17084051	*PDGFRA*	4	CR, Corneal Astigmatism	Located near the same PDGFRA gene, reinforcing the role of this signaling pathway in determining corneal geometry.	Fan et al. (2011) PLoS Genet. DOI: 10.1371/journal.pgen.1002402
	rs4896367	*NHSL1 (NHS-Like 1)*	6	Internal Astigmatism (IA), CR	While strongly associated with Internal Astigmatism (lens-related), it is also linked to CR, highlighting its role in general eye structure.	MacGregor et al. (2015) Hum Genet. DOI: 10.1007/s00439-014-1500-y
	rs12144639	*RPS6KC1 (Ribosomal Protein S6 Kinase C1)*	16	CR, Astigmatism	Identified in large meta-analyses for its influence on the mean radius of corneal curvature.	-

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Keratoconus and related ectatic disorders feature progressive stromal thinning due to dysregulated collagen assembly and crosslinking, where genetic variants in ECM pathway genes confer susceptibility and modulate central corneal thickness (CCT). Table 3 highlights key loci converging on collagen types I, IV, V, and XII, lysyl oxidase-mediated crosslinking (LOX, PLOD1), and transcription factors (ZNF469, FOXO1), positioning them as polygenic biomarkers for early risk stratification in precision ophthalmology. (Barcelo-Canton et al., 2025)

Table 3. Potential Keratoconus Biomarkers - Genes implicated in corneal thinning, primarily through their roles in extracellular matrix (ECM) regulation, collagen fibrillogenesis, and stromal biomechanics, as identified across genome-wide association studies (GWAS), familial linkage analyses, and rare variant sequencing in keratoconus cohort.

Gene	Associated trait	Proposed biological function
LOX	Corneal thinning and keratoconus; severity correlates with reduced LOX expression and activity.	Copper-dependent lysyl oxidase that crosslinks collagen and elastin, stabilizing corneal stromal ECM and maintaining biomechanical strength.
COL5A1	Central corneal thickness variation and keratoconus-related thinning.	Fibrillar collagen V alpha chain that nucleates and regulates collagen I fibrillogenesis, controlling stromal fibril diameter, spacing, and thus corneal thickness and transparency.
COL1A1	Reduced expression and rare variants reported in keratoconus and other ectasias.	Major fibrillar collagen of corneal stroma provides tensile strength; works with collagen V to form properly packed fibrils.
COL5A2	Rare variants associated with keratoconus in familial cohorts.	Collagen V alpha-2 chain partnering with COL5A1 in heterotrimeric collagen V, modulating fibril assembly and stromal architecture.
COL4A1	Novel variants linked to keratoconus pedigrees.	Basement-membrane collagen IV component contributing to Bowman's layer and epithelial–stromal interface integrity, influencing corneal curvature and thickness.
PLOD1	Familial keratoconus with ECM abnormalities.	Lysyl hydroxylase that post-translationally modifies collagen, enabling proper crosslinking and stabilizing stromal collagen networks.
TGFBI (BIGH3)	Variants reported in keratoconus and corneal dystrophies with altered corneal thickness and ECM composition.	Extracellular matrix protein induced by TGF-β that binds collagens and integrins, modulating stromal remodeling, cell adhesion, and ECM organization.
ZNF469	Strongly associated with extreme thinning (e.g., brittle cornea), CCT variation, and keratoconus in GWAS and rare variant studies.	Putative transcription factor regulating expression of collagens and other ECM components, influencing overall stromal collagen content and corneal thickness.
FOXO1	Locus associated with central corneal thickness; expressed in cornea and downstream of FOXC1.	Forkhead transcription factor implicated in stromal cell survival and metabolism, potentially regulating ECM gene expression and anterior segment development, thereby affecting corneal thickness.
COL12A1	Implicated in corneal stromal structural organization; disruption alters fibril morphology.	FACIT collagen XII that decorates collagen I fibrils and modulates TGF-β activity, organizing fibril packing and hierarchical stromal structure important for thickness and transparency.

4. Environmental Modulators and Lifestyle Factors

4.1. The Digital Environment: Near Work and Screen Time

The pervasive use of digital devices constitutes a major modern environmental shift. The mechanisms linking excessive screen time to astigmatism progression are multifactorial:

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- **Prolonged Accommodation and Ciliary Spasm**: Sustained near focusing demands can lead to accommodative spasm and altered intraocular pressure dynamics, potentially influencing globe shape [Bui et al., 2023].
- **Reduced Blink Rate and Dry Eye:** Concentrated screen use reduces blink rate by up to 60%, destabilizing the tear film, causing ocular surface inflammation, and creating an irregular optical surface that may feedback to influence corneal remodeling [Gordon-Shaag et al., 2015; Kaur et al., 2022].
- **Postural Effects**: Sustained downgaze increases eyelid pressure as described in Section 3.2.
- **Blue Light and Oxidative Stress:** While the direct role of blue light in astigmatism is debated, it can generate reactive oxygen species on the ocular surface, contributing to inflammation and tissue damage over time [Passaro et al., 2025; Zhi-Chun Zhao et al., 2018].

The 20-20-20 rule (every 20 minutes, look at something 20 feet away for 20 seconds) is a foundational ergonomic intervention to mitigate these effects. This helps the eye muscles relax and lets the cornea recover from pressure and strain caused by focusing nearby for too long (Russ Reisner, 2022).

4.2. The Protective Role of Outdoor Time and Natural Light

Time spent outdoors is the most consistently replicated protective factor against myopia onset and progression, with significant benefits for refractive error control, including astigmatism.

- **Mechanism**: Bright outdoor light (illuminance often >10,000 lux vs. <500 lux indoors) stimulates retinal dopamine release. Dopamine acts as a stop signal for excessive axial elongation, the hallmark of myopia [Thomas T. Norton et al., 2013; Higuchi,S, 2024].
- **Dose-Response**: Evidence shows a clear dose-response relationship. Each additional hour of outdoor time per week can reduce myopia risk by approximately 2%. Implementing 40+ minutes of daily outdoor time at school has been shown to reduce the incidence of new myopia cases [Biswas, Sayantan et al.; Rose KA., 2008].
- **Spectral Quality and Visual Scene**: The broader visual scenery outdoors, with ample opportunities for distance viewing and varying accommodative demands, may also play a role in healthy emmetropization.

4.3. Nutrition, Systemic Health, and Sleep

Ocular health is inextricably linked to systemic well-being.

1. **Nutrition**: A diet rich in antioxidants and anti-inflammatory compounds supports corneal integrity.
    - Lutein & Zeaxanthin: Found in leafy greens, eggs, and goji berries, these macular pigments filter blue light and protect retinal cells [Bucheli et al., 2011; Li et al., 2018].
    - Omega-3 Fatty Acids: From fish and walnuts, they support tear film quality and have anti-inflammatory properties [CG Optical, n.d.].
    - Vitamins A, C, E: Critical for photoreceptor function, collagen synthesis (corneal strength), and antioxidant defense [Jang et al., 2017; Neha & Sanwalka, 2012].
2. **lifestyle factors**:
    - Sleep: Inadequate sleep is an emerging risk factor. A study in preschoolers found children with insufficient sleep had nearly triple the odds of having astigmatism [Xixuan Zhao et al., 2025]. Sleep disruption may affect hormonal regulation of ocular growth and repair.
    - Obesity and Inflammation: Childhood obesity is independently associated with a higher prevalence and severity of astigmatism, likely mediated by chronic systemic inflammation that can affect scleral and corneal tissues [Wang et al., 2025].

Beyond general lifestyle factors, the maintenance of ocular structural integrity—particularly the collagen density of the cornea and the axial stability of the sclera—is heavily dependent on specific

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micronutrient intake. These nutrients act as essential cofactors in the biochemical pathways that regulate tissue repair and oxidative stress within the eye. The following Table 4 delineates the primary dietary sources of these key compounds and details the physiological mechanisms through which they support visual function and protect against refractive degradation.

Table 4. Key Nutrients for Ocular Health and Their Mechanisms - The table identifies six key nutrients critical for vision maintenance: lutein/zeaxanthin (antioxidant, blue light filtration), omega-3 fatty acids (anti-inflammatory, membrane structural component), vitamin A (epithelial maintenance, rhodopsin synthesis), vitamin C (collagen synthesis, aqueous antioxidant), vitamin E (lipid peroxidation prevention), and zinc (antioxidant enzyme cofactor).

Nutrient	Primary Dietary Sources	Proposed Ocular Mechanism
Lutein/Zeaxanthin	Spinach, kale, corn, eggs, goji berries	Filters high-energy blue light; protects retinal pigment epithelium; antioxidant.
Omega-3 (DHA/EPA)	Fatty fish (salmon, mackerel), flaxseeds, walnuts	Anti-inflammatory; component of photoreceptor membranes; supports tear film.
Vitamin A (Retinol/Beta-Carotene)	Liver, carrots, sweet potatoes, spinach	Essential for rhodopsin synthesis (night vision); maintains conjunctival/corneal epithelium.
Vitamin C	Amla (Indian gooseberry), citrus fruits, bell peppers	Critical for collagen synthesis (cornea, sclera); potent aqueous humor antioxidant.
Vitamin E	Almonds, sunflower seeds, wheat germ oil	Protects cell membranes from lipid peroxidation; works synergistically with Vitamin C.
Zinc	Oysters, beef, pumpkin seeds	Cofactor for antioxidant enzymes; involved in vitamin A metabolism in the retina

4.4. Integrative Ocular Dietary Protocols for Structural and Retinal Support and Health Benefits

Ocular dietary protocols (Table S1) target progressive corneal thinning and retinal degradation by syncing nutrient delivery with the body's circadian repair cycles. This approach integrates Traditional Chinese Medicine (TCM) principles, such as liver blood tonification, with modern nutritional science to bolster the extracellular matrix (ECM) and protect the macular pigment optical density.

Morning and Breakfast Structural Support: The day begins with a focus on corneal collagen stability and blue light filtration. The morning routine utilizes Amla (delivering 20x the Vitamin C of oranges) and Wheatgrass to provide the high-dose antioxidants and macular pigments (lutein/zeaxanthin) necessary to protect ocular tissues from early-morning oxidative stress. This is followed by a breakfast of soaked almonds, walnuts, and sprouts, which deliver Vitamin E and Omega-3 fatty acids to stabilize cell membranes and maintain a healthy tear film.

Daytime Maintenance and Tonification: Pre-lunch and lunch routines focus on hydration and "liver blood tonification"—a TCM principle for nourishing the eyes. Raw salads provide live enzymes and fiber to aid systemic absorption, while a lunch rich in spinach, goji berries, and bilberry provides the highest natural sources of zeaxanthin and anthocyanidins. These compounds strengthen retinal capillaries and support rhodopsin regeneration, essential for night vision.

Evening Hydration and Overnight Repair: Evening snacks like coconut water and citrus juices replenish electrolytes and Vitamin C to support ongoing collagen synthesis and iron uptake. The protocol concludes with a specialized night supplement of almond, fennel, and turmeric; this combination leverages the synergy of curcumin and piperine to reduce systemic inflammation and facilitate the repair of ocular tissues during sleep.

Inflammatory Avoidance: To preserve these gains, the diet strictly excludes pro-inflammatory triggers such as white sugar, refined flour (maida), and fried foods. Avoiding these high-glycemic items is critical to minimizing the formation of Advanced Glycation End-products (AGEs), which are known to accelerate stromal weakening and damage the delicate microvasculature of the retina.

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5. Personalized and Integrative Management Strategies

The management of pediatric ocular health is shifting from a purely reactive model to a proactive, "whole-child" approach. By combining high-tech genomic insights with standard clinical therapies and traditional wellness practices, practitioners can create a multifaceted defense against refractive progression.

5.1. Precision Medicine: Integrating Genetic Insights

The future of pediatric optometry lies in risk-stratified, personalized care that moves beyond the standard eye exam

- **Risk Stratification**: Utilizing Polygenic Risk Scores (PRS) for astigmatism and myopia enables the identification of high-risk children before significant refractive shifts occur, allowing for early, aggressive monitoring.
- **Treatment Response Prediction**: Evidence suggests that genetic variants may dictate how a child responds to specific interventions, such as orthokeratology or low-dose atropine, allowing clinicians to bypass trial-and-error and select the most effective modality initially [Ruijing Xia et al., 2025; John G Lawrenson et al., 2023].
- **Ethical Considerations**: Integrating genetic data into pediatric care necessitates robust counseling to ensure parents understand the actionable nature of the results while avoiding unnecessary anxiety or genetic discrimination [Aideen M Moore, 2022; Kelly E. Ormond, 2023].

5.2. Conventional Optical and Pharmacological Therapies

Clinical intervention remains the primary line of defense to provide a clear retinal image and prevent developmental complications like amblyopia.

- **Optical Correction**: Timely prescription of spectacles or contact lenses is the first-line treatment to provide a clear retinal image, prevent amblyopia, and reduce astigmatic defocus that may drive myopia progression (Table 5).
  - Spectacles: Modern digitally-surfaced, free-form lenses with precise cylinder and axis correction are highly effective.
  - Toric Soft Contact Lenses: Provide stable vision and are excellent for active children and those with significant anisometropia.
  - Orthokeratology (Ortho-K): Overnight wear of rigid gas-permeable lenses that temporarily reshape the cornea. Proven to slow axial elongation in myopic children by 30-60% and can correct moderate astigmatism [Vijaya Mallareddy et al., 2024].
- **Pharmacological Therapy:**
  - Low-Dose Atropine (0.01%, 0.05%): The gold-standard pharmaceutical for myopia control, shown to slow progression by 50-70%. Its mechanism involves acting on scleral fibroblasts and retinal signaling pathways. It is used concomitantly with optical correction [Fricke T, 2019; Zhang et al., 2025].

5.3. Lifestyle Prescription and Ergonomic Optimization

Clinical management must extend into the child's daily environment through specific "behavioral prescriptions" (Tables 5 and S2).

- Prescribed Outdoor Time: Recommend ≥ 90-120 minutes of cumulative outdoor activity daily.
- Structured Screen Hygiene: Enforce the 20-20-20 rule, ensure proper viewing distance (>30 cm for phones/tablets), and optimize ambient lighting to reduce glare.
- Sleep Hygiene: Advocate for age-appropriate, consistent sleep duration (9-11 hours for school-age children).
- Nutritional Guidance: Encourage a diet rich in the nutrients outlined in Table 4.

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5.4. Evidence-Based Complementary Approaches

A pilot study by Kailash Mehra under the natural vision improvement program developed by Preksha Eye Yoga centre provides preliminary evidence supporting the role of alternative, non-invasive therapies in visual health management [Mehra et al., 2020]. The study evaluated a structured protocol of eye exercises inspired from Bates Method and yogic practices (different types of eye movement, vision shifting, reading charts, Trataka, palming, blinking and accommodative drills), pranayama and dietary guidance in individuals with functional refractive errors, primarily mild to moderate myopia and astigmatism.

Results showed improvement in unaided visual acuity, accommodative stability, and reduction in eye strain and visual fatigue, indicating enhanced functional vision.

Within the context of pediatric astigmatism and myopia progression, this study supports the use of Preksha eye yoga's natural vision improvement program as an adjunctive therapy to address physiological and behavioral risk factors such as near-work stress and digital eye strain. Despite limitations related to sample size and duration, the study provides a scientific basis for integrating evidence-informed yogic eye practices into a holistic, personalized eye-care approach. [Mehra et al., 2020]

Mehra et al. supported the claim that complementary strategies offer a non-invasive means to alleviate the symptoms of digital eye strain and support long-term ocular tissue health. Detail of such complementary strategies is as follows:

- **Yogic Eye Exercises** (Trataka, Palming): While not altering corneal shape, practices like *Trataka* (steady gazing) and palming can reduce accommodative fatigue, improve convergence ability, and mitigate symptoms of digital eye strain. Studies show improvements in visual acuity parameters and accommodation flexibility [Mehra et al., 2020; Soumya et al., 2017; Alagesan, 2011].*(Table S3) (Figure S8.)*
- **Ayurvedic Interventions**:
    1. **Netra Tarpana**: This therapy, involving pooled medicated ghee over the eyes, is proposed to nourish ocular tissues, reduce dryness, and strengthen the *drishti* (vision). *Triphala* ghee is commonly used for its antioxidant and anti-inflammatory properties [Gupta et al., 2010; Peterson et al., 2017].
    2. **Triphala**: Used both internally and as an eyewash (*kashaya*), its constituents (gallic acid, ellagic acid) demonstrate potent antioxidant and anticataract activity in preclinical models. (*Table S4*)
    3. **Medicinal herbs** : The traditional medicine for ocular health, offering potential benefits through their bioactive compounds that modulate inflammation, intraocular pressure, circulation, and oxidative stress in conditions like glaucoma, cataracts, and retinal disorders *(Table S5)*
    4. **Mindfulness and Stress Reduction**: Psychological stress can manifest as visual dysfunction (e.g., Streff Syndrome). Techniques like guided meditation for vision, progressive muscle relaxation (PMR), and breathing exercises (*Pranayama* like *Anulom Vilom* and *Bhramari (Table S6*) can reduce overall sympathetic tone, potentially easing accommodative spasm and improving patient comfort [Yibo Li et al., 2022; Zulfikar S., 2022]. (*Figure S9*.)

Summary of Management Domains

The following Table 5, stratifies these interventions based on their primary goals and the current strength of evidence supporting their efficacy.

Table 5. Summary of Integrative Management Strategies for Pediatric Astigmatism - The table stratifies interventions across five domains by evidence strength: optical correction (strong, standard-of-care); myopia control modalities and low-dose atropine (strong); lifestyle modifications including outdoor time and screen hygiene (strong-moderate); nutritional support with carotenoids and omega-3 fatty acids (moderate); yogic

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exercises for symptom relief (moderate); and Ayurvedic traditional preparations and stress reduction (emerging-moderate).

Domain	Specific Intervention	Primary Goal	Level of Evidence
Optical	Spectacles / Toric Contact Lenses	Correct refractive error, prevent amblyopia	Strong (Standard of Care)
Optical (Myopia Control)	Orthokeratology, Multifocal Soft Lense	Slow axial elongation, control myopia progression	Strong
Pharmacological	Low-Dose Atropine (0.01%, 0.05%)	Slow axial elongation, control myopia progression	Strong
Lifestyle	≥90 min Daily Outdoor Time	Protective against onset/progression of myopia/astigmatism	Strong
Lifestyle	20-20-20 Rule, Screen Hygiene	Reduce accommodative strain, digital eye fatigue	Moderate-Strong
Nutritional	Diet rich in Lutein, Zeaxanthin, Omega-3, Vitamins	Support ocular tissue integrity, reduce oxidative stress	Moderate (for general eye health)
Complementary	Yogic Exercises (Trataka, Palming)	Reduce eye strain, improve accommodative facility	Moderate (for symptom relief)
Complementary	Ayurvedic Netra Tarpana / Triphala	Nourishment, antioxidant support (traditional use)	Emerging / Preclinical
Behavioral	Mindfulness, Stress Reduction Techniques	Manage stress-related visual symptoms	Moderate (for functional symptoms)

6. Future Directions and Conclusions

The landscape of pediatric eye care is undergoing a paradigm shift, moving away from reactive optical correction toward a proactive, predictive, and preventive model.

6.1. Emerging Technologies and Research Frontiers

- **Advanced Diagnostics & AI:** Integration of AI and machine learning with multimodal data (genetics, corneal topography, biomechanics, axial length, lifestyle logs) will enable predictive algorithms for individual progression risk and optimized treatment pathways.
- **Novel Therapeutics**: Research into gene therapies targeting collagen regulation, scleral cross-linking agents, and novel dopamine agonists holds promise for more targeted interventions.
- **Longitudinal Big Data**: Large-scale, longitudinal cohort studies from infancy through adolescence are needed to refine understanding of critical periods for intervention and GxE interactions.

6.2. A Proposed Clinical Pathway for the 21st Century

To effectively combat the rising prevalence of refractive errors, a standardized, evidence-based clinical pathway is required:

1. **Universal Early Screening:** Comprehensive eye exams starting at 6-12 months, including cycloplegic refraction and ocular health assessment.
2. **Risk Stratification**: For children with astigmatism ≥1.5D, family history, or other risk factors, employ advanced diagnostics (biometry, topography) and consider genetic risk profiling where available.
3. **Personalized Management Plan:**

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- Optical Correction: Immediate, precise prescription.
- Myopia Control: If myopia is present or imminent (based on risk), initiate evidence-based control (Ortho-K, low-dose atropine, specialty lenses).
- Lifestyle Prescription: Formal "prescription" for outdoor time, screen hygiene, and nutrition.
- Integrative Adjuncts: Consider evidence-based complementary therapies for symptom management and holistic care.

4. **Continuous Monitoring:** Regular 6-12 month reviews with axial length measurement to monitor efficacy and adjust treatment.

6.3. Conclusion

Pediatric astigmatism is far more than a simple optical error; it is a complex refractive disorder with deep genetic roots, significantly modulated by the modern environment. Its intimate association with myopia progression identifies it as a critical, modifiable risk factor for sight-threatening pathologies in later life. The traditional paradigm of passive correction is no longer sufficient. The future of the field lies in early detection, sophisticated etiological diagnosis, and proactive management. By seamlessly blending cutting-edge pharmacological science with structured lifestyle interventions and evidence-informed complementary care, eye care professionals can effectively disrupt the astigmatism-myopia axis. This holistic model is the key to safeguarding not only clear vision but the long-term ocular health of future generations.

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References

1. Abu-Amero. (2014). Genetics of Keratoconus: Where Do We Stand? *Journal of Ophthalmology*. https://doi.org/10.1155/2014/641708
2. Aideen M Moore. (2022). Genetic testing and screening in children. *Paediatr Child Health.*, 27(4), 243-253. 10.1093/pch/pxac028
3. Andrea Russo. (2022). Myopia: Mechanisms and Strategies to Slow Down Its Progression. *J Ophthalmol.* 10.1155/2022/1004977
4. Biswas. (2024). The influence of the environment and lifestyle on myopia. *J Physiol Anthropol*, *43*, 7. https://doi.org/10.1186/s40101-024-00354-7
5. Biswas, & Sayantan. (2025). Interaction between indoor and outdoor lighting conditions and accommodation stimuli on ocular biometry. Ophthalmic and Physiological Optics. https://publications.aston.ac.uk/id/eprint/48358/
6. Bonghyun Kim. (2018). Optimizing acupuncture treatment for dry eye syndrome: a systematic review. BMC Complement Altern Med. https://doi.org/10.1186/s12906-018-2202-0
7. Bui. (2023). Keratoconus Diagnosis and Treatment: Recent Advances and Future Directions. Clinical ophthalmology. https://doi.org/10.2147/opth.s392665
8. Chen. (2025). Association of nutritional intake with myopia and astigmatism. Sci Rep. https://doi.org/10.1038/s41598-025-13203-z
9. Cho. (2020). Analysis of tear film spatial instability for pediatric myopia under treatment. Scientific Reports, 10(1). 10.1038/s41598-020-71710-7
10. Das, S., & Roy, S. (2024). THE ROLE OF NUTRITION IN EYE HEALTH: A COMPREHENSIVE REVIEW. Journal of Population Therapeutics and Clinical Pharmacology,, 31(6), 1281-1286. https://doi.org/10.53555/jptcp.v31i6.6667
11. David P. Piñero. (2011). Vector Analysis of Evolutive Corneal Astigmatic Changes in Keratoconus. Investigative Ophthalmology & Visual Science, 52, 4054-4062. https://doi.org/10.1167/iovs.10-6856
12. Davidson. (2013). The pathogenesis of keratoconus. Eye, 28(2). https://doi.org/10.1038/eye.2013.278
13. Dibyendu Pusti. (2021). Disparity between central and peripheral refraction inheritance in twins. Scientific Reports. https://doi.org/10.1038/s41598-021-90838-8
14. Dirani M. (2008). Dominant genetic effects on corneal astigmatism: the genes in myopia (GEM) twin study. Invest Ophthalmol Vis Sci., 49(4), 1339-1344. 10.1167/iovs.07-1011
15. Dong. (2024). Impact of Astigmatism on Axial Elongation in School-Age Children: A Five-Year Population-Based Study in Tianjin, China. Investigative Ophthalmology & Visual Science, Vol.65. doi:https://doi.org/10.1167/iovs.65.13.45
16. ERICA SHING. (2025). Heritability and Genetic Factors of Astigmatism and Corneal Curvature: A Systematic Review and Meta-analysis. American Journal of Ophthalmology, 269, 161 - 171. https://www.ajo.com/article/S0002-9394(24)00380-5/abstract
17. Eye Yoga: Exercises to Reduce Eye Power, Relieve Stress, and Improve Vision. (2024, May 27). Dr. Basu eye care center, Excellence in Ayurvedic Vision Care. https://drbasueyecarecentre.com/exercises-to-reduce-eye-power-and-improve-vision/
18. Fricke T. (2019). Pharmacological interventions in myopia management. Community Eye Health., 32(105), 21-22. PMID: 31409953.
19. Gareth Lingham. (2021). Time spent outdoors in childhood is associated with reduced risk of myopia as an adult. Sci Rep. https://doi.org/10.1038/s41598-021-85825-y
20. Gordon-Shaag. (2015). The Genetic and Environmental Factors for Keratoconus. BioMed Research International. https://doi.org/10.1155/2015/795738
21. Gupta. (2025). Childhood myopia: A lifestyle disease. Indian Journal of Ophthalmology, 73(2):p, 307-308. DOI: 10.4103/IJO.IJO_1502_24
22. Han Y et al,. (2025). Association Between Maternal Pre-Pregnancy Body Mass Index and Astigmatism and Corneal Curvature in Offspring: A Cross-Sectional Study. Clin Ophthalmol, 19, 3371-3380. https://doi.org/10.2147/OPTH.S532009

 doi:10.20944/preprints202512.1806.v2

23. Hideharu Fukasaku. (2023). Association of PDGFRA polymorphisms with the risk of corneal astigmatism in a Japanese population. Sci Rep, 13. https://doi.org/10.1038/s41598-023-43333-1
24. Higuchi,S. (2024). Light at night and circadian rhythms: from the perspective of physiological anthropology research. J Physiol Anthropol, 43. https://doi.org/10.1186/s40101-024-00380-5
25. Huang Lihong. (2025). Global trends in refractive disorders from 1990 to 2021: insights from the global burden of disease study and predictive modeling. Frontiers in Public Health, Volume 13. DOI:10.3389/fpubh.2025.1449607
26. Jian Lin. (2022). Correlation between ocular residual astigmatism and anterior corneal astigmatism in children with low and moderate myopia. BMC Ophthalmology. https://doi.org/10.1186/s12886-022-02560-2
27. John G Lawrenson. (2023). Interventions for myopia control in children: a living systematic review and network meta-analysis. Cochrane Database Syst Rev. 10.1002/14651858.CD014758.pub2
28. Kaur. (n.d.). Digital Eye Strain- A Comprehensive Review. Ophthalmology and Therapy, 11(5). https://doi.org/10.1007/s40123-022-00540-9
29. Kelly E. Ormond. (2023). Ethical Aspects of Pediatric Genetic Care: Testing and Treatment. Pediatric Clinics of North America, 70(5), 1029-1046. https://doi.org/10.1016/j.pcl.2023.05.011.
30. (Keyu Chen. (2025). Association of nutritional intake with myopia and astigmatism. Sci Rep. https://doi.org/10.1038/s41598-025-13203-z
31. (Kroczek Marta. (2025). The Impact of the Position of the Upper Eyelid on the Profile of Epithelial Thickness and the Topography of the Cornea. Journal of Clinical Medicine (JCM). 10.3390/jcm14041327
32. Łabuś. (2025). A Comprehensive Analysis of the Effects of Physical Activity, Rehabilitation Methods, Environmental and Behavioral Interventions on the Development and Progression of Myopia. Quality in Sport, 39. 10.12775/qs.2025.39.56998
33. Larouche R. (2023). Determinants of Outdoor Time in Children and Youth: A Systematic Review of Longitudinal and Intervention Studies. Int J Environ Res Public Health., 20(2). 10.3390/ijerph20021328.
34. Lieberman. (2000). The Lids Influence on Corneal Shape. Cornea, 19, 336-342. 10.1097/00003226-200005000-00016
35. Lin. (2022). Correlation between ocular residual astigmatism and anterior corneal astigmatism in children with low and moderate myopia. BMC Ophthalmol, 22, 374. https://doi.org/10.1186/s12886-022-02560-2
36. Liu. (2024). Clinical effect and multi-factor analysis of "Siming Acupoints " massage in the treatment of myopia in children and adolescents. Research Square (Research Square). 10.21203/rs.3.rs-5372416/v1
37. Loukovitis. (2018). Genetic Aspects of Keratoconus: A Literature Review Exploring Potential Genetic Contributions and Possible Genetic Relationships with Comorbidities. Ophthalmology and Therapy, 7(2). https://doi.org/10.1007/s40123-018-0144-8
38. Lu Huo. (2021). Refractive errors and risk factors for myopia in infants aged 1–18 months in Tianjin, China. BMC Ophthalmology. https://doi.org/10.1186/s12886-021-02172-2
39. Margarida C Lopes. (2013). Identification of a Candidate Gene for Astigmatism. Invest Ophthalmol Vis Sci, 54(2), 1260-1267. 10.1167/iovs.12-10463
40. Matteo Pederzolli. (2025). Keratoconus: The Local Manifestation of a Systemic Disease? Journal of Clinical Medicine, 14(13), 4587. https://doi.org/10.3390/jcm14134587
41. Mehra. (2020). A pilot study on Effects of Eye Yogic Exercises & alternative Therapies on Eyesight Improvement. International Journal of Scientific and Research Publications, 10(12). 10.29322/IJSRP.10.12.2020.p10856
42. Mengru Ba, & Zhijie Li. (2024). The impact of lifestyle factors on myopia development: Insights and recommendations. AJO International, 1(1). https://doi.org/10.1016/j.ajoint.2024.100010.
43. Mutahir Shah. (2025). Association of excessive screen time exposure with ocular changes leading to astigmatism in children. PLOS One. https://doi.org/10.1371/journal.pone.0317961
44. Namba. (2020). Age-Related Changes in Astigmatism and Potential Causes. Cornea, 39(1). https://doi.org/10.1097/ico.0000000000002507
45. Namba et al. (2020). Age-Related Changes in Astigmatism and Potential Causes. Cornea, 39(1), S34-S38. 10.1097/ICO.0000000000002507

 doi:10.20944/preprints202512.1806.v2

46. Núñez MX et al,. (2019). Consensus on the management of astigmatism in cataract surgery. Clin Ophthalmol, 13, 311-324. https://doi.org/10.2147/OPTH.S178277
47. Passaro. (2025). The oxidative-stress-senescence axis in keratoconus: new insights into corneal degeneration. Frontiers in Molecular Biosciences, 12. https://doi.org/10.3389/fmolb.2025.1539542
48. Prasida Unni. (2023). Systemic Associations with Keratoconus. Life (Basel). 10.3390/life13061363
49. Prousali E. (2019). Efficacy and safety of interventions to control myopia progression in children: an overview of systematic reviews and meta-analyses. BMC Ophthalmol. 10.1186/s12886-019-1112-3.
50. R, J., MH, H., Amiri A, A., S, H., & Charati F, G. (2023). The Prevalence of Astigmatism in 7 to 13 Years Old Children: A Cross-sectional Study. Journal of Pediatrics Review, 11(4), 357-362. http://dx.doi.org/10.32598/jpr.11.4.1126.1
51. Read. (2007). The Influence of Eyelid Morphology on Normal Corneal Shape. Investigative Ophthalmology and Visual Science, 48(1), 112-119. https://eprints.qut.edu.au/10853/
52. Reza Jafari. (2023). The Prevalence of Astigmatism in 7 to 13 Years Old Children: A Cross-sectional Study. J. Pediatr. Rev, 11(4), 357-362. http://jpr.mazums.ac.ir/article-1-553-en.html
53. Richard Hobday. (2025). Myopia and daylight-A combination of factors. Front Med (Lausanne). 10.3389/fmed.2025.1481209.
54. Rose KA. (2008). Outdoor activity reduces the prevalence of myopia in children. Ophthalmology., 115(8), 1279-1285. 10.1016/j.ophtha.2007.12.019
55. Ruijing Xia. (2025). Associations between RetNet gene polymorphisms and the efficacy of orthokeratology for myopia control: a retrospective clinical study. Eye and Vis. https://doi.org/10.1186/s40662-025-00426-4
56. Russo. (2022). Myopia: Mechanisms and Strategies to Slow Down Its Progression. Journal of Ophthalmology. https://doi.org/10.1155/2022/1004977
57. Russ Reisner. (2022). 5 Vision Therapy Exercises To Reduce Astigmatism Symptoms. urban optique. https://urbanoptique.ca/5-vision-therapy-exercises-to-reduce-astigmatism-symptoms/
58. S, Y., Y, J., G, C., & Y, L. (n.d.). Age- and gender-related characteristics of astigmatism in a myopic population. Frontiers in Medicine, 9, 1011743. doi: 10.3389/fmed.2022.1011743
59. Seyed-Farzad Mohammadi, & Maryam Tahvildari. (2024). Physiology of Astigmatism. EyeWiki. https://eyewiki.org/Physiology_of_Astigmatism
60. Shah, & Guggenheim. (2018). Genome-wide association studies for corneal and refractive astigmatism in UK Biobank demonstrate a shared role for myopia susceptibility loci. Human Genetics, 137(881-896). 10.1007/s00439-018-1942-8
61. Shaw, & Alyra J. B. (2009). Eyelid pressure: Inferences from corneal topographic changes. Cornea, 181-188. https://eprints.qut.edu.au/14508/
62. Shinde. (2020). RNA sequencing of corneas from two keratoconus patient groups identifies potential biomarkers and decreased. Scientific Reports, 10(1). 10.1038/s41598-020-66735-x
63. Shinde I et al,. (2024). Comparison of Surgically-induced Astigmatism using Topography and Keratometry in Patients undergoing Phacoemulsification and Small Incision Cataract Surgery: A Prospective Interventional Study. Journal of Clinical of Diagnostic Research, 18(7), NC01-NC05. https://www.doi.org/10.7860/JCDR/2024/69674/19578
64. Shing. (2024). Heritability and Genetic Factors of Astigmatism and Corneal Curvature: A Systematic Review and Meta-analysis. American Journal of Ophthalmology, 269. https://doi.org/10.1016/j.ajo.2024.08.019
65. (Shin Takayama. (2012). Short-term effects of acupuncture on open-angle glaucoma in retrobulbar circulation: additional therapy to standard medication. Evid Based Complement Alternat Med. doi: 10.1155/2011/157090.
66. Sima. (2023). Evaluation of the efficiency and safety of TransPRK and FS-LASIK refractive procedures on patients with astigmatism and amblyopia. Rom J Ophthalmol., 67(3), 267-274. doi: 10.22336/rjo.2023.44.
67. Smita das, & Sudeshna Roy. (2024). THE ROLE OF NUTRITION IN EYE HEALTH: A COMPREHENSIVE REVIEW. Journal of Population Therapeutics and Clinical Pharmacology, 31(6), 1281-1286. https://doi.org/10.53555/jptcp.v31i6.6667

 doi:10.20944/preprints202512.1806.v2

68. Soumya. (2017). Assessment of Effectiveness of Trataka Exercise on Vision and Aesthenopia among Student Nurses with Refractive Error. International Journal of Health Sciences & Research, 7(4).
69. Thomas T. Norton. (2013). Light levels, refractive development, and myopia – A speculative review. Experimental Eye Research, 144, 48-57. https://doi.org/10.1016/j.exer.2013.05.004.
70. Vijaya Mallareddy. (2024). Innovations and Outcomes in Astigmatism Correction During Cataract Surgery: A Comprehensive Review. Cureus, 16(8). 10.7759/cureus.67828.
71. Wang. (2020). Astigmatism in school students of eastern China: prevalence, type, severity and associated risk factors. BMC Ophthalmol. https://doi.org/10.1186/s12886-020-01425-w
72. Wang. (2025). Early diagnosis of keratoconus using corneal biomechanics and OCT derived technologies. Eye and Vision, 12(1). https://doi.org/10.1186/s40662-025-00435-3
73. Wang, Z. (2021). Risk factors for astigmatic components and internal compensation:the Nanjing Eye Study. The Royal College of Ophthalmologists, 35, 499–507. https://doi.org/10.1038/s41433-020-0881-5
74. Wang et al. (2024). Prevalence and risk factors for astigmatism in 7 to 19-year-old students in Xinjiang, China: a cross-sectional study. BMC Ophthalmology, 24, 116. 10.1186/s12886-024-03382-0
75. Wei P. (2025). Biomechanics as a Causal Factor in Myopia and Astigmatism: Evidence from Mendelian Randomization. Ophthalmol Sci. 10.1016/j.xops.2025.100738
76. Wong. (2020). Digital Screen Time During the COVID-19 Pandemic: Risk for a Further Myopia Boom? American Journal of Ophthalmology, 223, 333-337. 10.1016/j.ajo.2020.07.034
77. Wong. (2022). High Prevalence of Astigmatism in Children after School Suspension during the COVID-19 Pandemic Is Associated with Axial Elongation. Children, 9(6). https://doi.org/10.3390/children9060919
78. Xiu Juan Zhang. (2025). Advances in myopia control strategies for children. British Journal of Ophthalmology, 109(2), 165-176. https://bjo.bmj.com/content/109/2/165
79. Xixuan Zhao. (2025). Association between insufficient sleep and astigmatism in preschool children. Eur J Pediatr. 10.1007/s00431-025-06004-z
80. Yangho Kim, & Ju-Hyang Lee. (2021). Association of blepharoptosis with refractive error in the Korean general population. Eye, 35, 3141–3146. https://doi.org/10.1038/s41433-021-01652-5
81. Yibo Li. (2022). Guided meditation for vision acuity training on adolescent myopia: study protocol for an open-label, prospective, multicenter, randomized controlled trial. Trials. 10.1186/s13063-021-05922-1.
82. Yoga for Your Eyes: Simple Asanas to Improve Your Vision. (2025, January 14). Yoga Journal. Retrieved November 21, 2025, from https://www.yogajournal.com/lifestyle/health/ayurveda/practices/insight-for-sore-eyes/
83. Yu M. (2023). Global risk factor analysis of myopia onset in children: A systematic review and meta-analysis. PLoS ONE 1. https://doi.org/10.1371/journal.pone.0291470
84. Zhang et al,. (2023, March). Epidemiology and Burden of Astigmatism: A Systematic Literature Review. Optometry and Vision Science., 30(3), 218-231. 10.1097/OPX.0000000000001998
85. Zhang.S. (2024). Axial Elongation Trajectories in Chinese Children and Adults With High Myopia. JAMA Ophthalmol., 142(2), 87–94. doi:10.1001/jamaophthalmol.2023.5835
86. Zhi-Chun Zhao. (2018). Research progress about the effect and prevention of blue light on eyes. Int J Ophthalmol. 10.18240/ijo.2018.12.20
87. Zulfikar S. (2022, June). The Effect of Stress on Visual Function amongst School-Going Children in Mumbai. Optometry & Visual Performance, 10(2), 91-96.
88. Adawi, H. H. H., Alharbi, H. A. M., Adam, A. M. S., Aldosery, H. M. A., Alzahrani, R. A. Y., & Albeladi, K. A. H. (2023). THE RELATIONSHIP BETWEEN APPARENT STRABISMUS AND TYPES OF REFRACTIVE ERRORS. Journal of Population and Therapeutics and Clinical Pharmacology. https://doi.org/10.53555/jptcp.v30i2.4881
89. Alagesan, J. (2011). Effect of eye exercises on myopia: A randomized controlled study. Middle East African Journal of Ophthalmology, 18(3), 225–228. https://doi.org/10.4103/0974-9233.81542
90. An, L., Hu, Q., Guan, J., Zhu, Y., Jiang, C., Zhong, X., Ma, S., Yu, D., Zhang, C., Zhuo, Y., & Qin, P. (2023). A Longitudinal Analysis about the Effect of Air Pollution on Astigmatism for Children and Young Adults (No. arXiv:2310.08843). arXiv. https://doi.org/10.48550/arXiv.2310.08843

 doi:10.20944/preprints202512.1806.v2

91. Baratta, R. O., Del Buono, B. J., Schlumpf, E., Ceresa, B. P., & Calkins, D. J. (2021). Collagen Mimetic Peptides Promote Corneal Epithelial Cell Regeneration. Frontiers in Pharmacology, 12, 705623. https://doi.org/10.3389/fphar.2021.705623
92. Birch, E. E., Stager, D. R., Wang, J., & O'Connor, A. (2010). Longitudinal changes in refractive error of children with infantile esotropia. Eye, 24(12), 1814–1821. https://doi.org/10.1038/eye.2010.129
93. Boopalan, D., Prabu Kumar, A., Vanamoorthy, M. K., Vijayakumar, V., Ravi, P., Kasi, M., & Kuppusamy, M. (2025). Yoga therapy for eye health and disease: A scoping review. European Journal of Integrative Medicine, 73, 102427. https://doi.org/10.1016/j.eujim.2024.102427
94. Bucheli, P., Vidal, K., Shen, L., Gu, Z., Zhang, C., Miller, L. E., & Wang, J. (2011). Goji Berry Effects on Macular Characteristics and Plasma Antioxidant Levels. Optometry and Vision Science, 88(2), 257–262. https://doi.org/10.1097/OPX.0b013e318205a18f
95. Çakır, B., Aksoy, N. Ö., Özmen, S., Bursalı, Ö., Çelik, E., & Horozoğlu, F. (2020). Corneal topography, anterior segment and high-order aberration assessments in children with ≥ 2 diopter astigmatism. International Ophthalmology, 40(6), 1461–1467. https://doi.org/10.1007/s10792-020-01313-8
96. CG Optical. (n.d.). How Walnuts Help Prevent Cataracts & Macular Degeneration. https://cgoptical.co.uk/walnuts-help-prevent-cataracts-macular-degeneration/
97. Chitra, J., Aghav, V., Gaonkar, A., & Rajapkar, A. (2024). Effect of Bates Method versus Tibetan Eye Chart Exercise on Digital Eye Strain among Students: A Randomized Clinical Trial. Indian Journal of Physical Therapy and Research, 6(1), 53–59. https://doi.org/10.4103/ijptr.ijptr_135_23
98. Fan, Q., Guo, X., Tideman, J. W. L., Williams, K. M., Yazar, S., Hosseini, S. M., Howe, L. D., Pourcain, B. S., Evans, D. M., Timpson, N. J., McMahon, G., Hysi, P. G., Krapohl, E., Wang, Y. X., Jonas, J. B., Baird, P. N., Wang, J. J., Cheng, C.-Y., Teo, Y.-Y., … Vatavuk, Z. (2016). Childhood gene-environment interactions and age-dependent effects of genetic variants associated with refractive error and myopia: The CREAM Consortium. Scientific Reports, 6(1), 25853. https://doi.org/10.1038/srep25853
99. Gupta, S. K., Kalaiselvan, V., Srivastava, S., Agrawal, S. S., & Saxena, R. (2010). Evaluation of anticataract potential of Triphala in selenite-induced cataract: In vitro and in vivo studies. Journal of Ayurveda and Integrative Medicine, 1(4), 280–286. https://doi.org/10.4103/0975-9476.74425
100. Gwiazda, J., Grice, K., Held, R., McLellan, J., & Thorn, F. (2000). Astigmatism and the development of myopia in children. Vision Research, 40(8), 1019–1026. https://doi.org/10.1016/S0042-6989(99)00237-0
101. Harvey, E. M., Dobson, V., Miller, J. M., & Sherrill, D. L. (2004). Treatment of astigmatism-related amblyopia in 3- to 5-year-old children. Vision Research, 44(14), 1623–1634. https://doi.org/10.1016/j.visres.2004.01.018
102. Jang, H., Srichayet, P., Park, W. J., Heo, H. J., Kim, D.-O., Tongchitpakdee, S., Kim, T.-J., Jung, S. H., & Lee, C. Y. (2017). Phyllanthus emblica L. (Indian gooseberry) extracts protect against retinal degeneration in a mouse model of amyloid beta-induced Alzheimer's disease. Journal of Functional Foods, 37, 330–338. https://doi.org/10.1016/j.jff.2017.07.056
103. Kowluru, R. A., & Kanwar, M. (2007). Effects of curcumin on retinal oxidative stress and inflammation in diabetes. Nutrition & Metabolism, 4(1), 8. https://doi.org/10.1186/1743-7075-4-8
104. Kulkarni, A., Kamath, Y., Shetty, L., & Kuzhuppilly, N. I. R. (2022). The Effect of Specific Techniques of Nasal Breathing [Pranayama] on Intra-Ocular Pressure in Normal Individuals, a Randomized Trial. Clinical Ophthalmology (Auckland, N.Z.), 16, 4047–4054. https://doi.org/10.2147/OPTH.S389495
105. Kumar, S. (2022). Yoga based Ocular Exercise (Trataka): The Scriptural and Scientific Review. Journal of Positive School Psychology, 6, 6231–6240.
106. Li, S., Liu, N., Lin, L., Sun, E.-D., Li, J.-D., & Li, P.-K. (2018). Macular pigment and serum zeaxanthin levels with Goji berry supplement in early age-related macular degeneration. International Journal of Ophthalmology, 11(6), 970–975. https://doi.org/10.18240/ijo.2018.06.12
107. Little, J.-A., Chan, V. F., Saw, S.-M., Tham, Y. C., Chew, L., Foo, L. L., Collins, M., Ebri, A. E., Han, X., Schultz, L., Gleason, D., Jacobs, L., Prakash, W. D., Morjaria, P., Robler, S. K., Emmett, S. D., MacKenzie, G., Wang, N., Khanna, R. C., … Congdon, N. (2025). Current status of school vision screening—rationale, models, impact and challenges: A review. British Journal of Ophthalmology, 109(11), 1207–1214. https://doi.org/10.1136/bjo-2024-326726

 doi:10.20944/preprints202512.1806.v2

108. Mahadik, S., Khare, S., & Diwan, V. (2023). YOGA eye exercises and Refractive Errors. Central India Journal of Medical Research, 2(02), 1–3. https://doi.org/10.58999/cijmr.v2i02.130
109. Mehra, K., Gaur, D. N., Singh, P., & Kumar, G. (2020). A pilot study on Effects of Eye Yogic Exercises & alternative Therapies on Eyesight Improvement. International Journal of Scientific and Research Publications (IJSRP), 10(12), 495–504. https://doi.org/10.29322/IJSRP.10.12.2020.p10856
110. Moringa and Its Role in Supporting Eye Health. (n.d.). [Moringa Powder]. https://moringapowder.com/blogs/benefits/moringa-and-its-role-in-supporting-eye-health
111. Morya, A. K., Shrivastava, A. K., Janti, S. S., Tejaswini, A., Gupta, R., Gurnani, B., Venkatesh, D., & Prasad, R. (2023). Effect of Asanas in Yoga on Intraocular Pressure of Practicing Healthy Individuals: A Prospective Observational Study. Maedica, 18(2), 238–245. https://doi.org/10.26574/maedica.2023.18.2.238
112. Mutti, D. O., Hayes, J. R., Mitchell, G. L., Jones, L. A., Moeschberger, M. L., Cotter, S. A., Kleinstein, R. N., Manny, R. E., Twelker, J. D., & Zadnik, K. (2007). Refractive Error, Axial Length, and Relative Peripheral Refractive Error before and after the Onset of Myopia. Investigative Ophthalmology & Visual Science, 48(6), 2510. https://doi.org/10.1167/iovs.06-0562
113. Neha, J., & Sanwalka. (2012). Role of nutrition in the prevention of age-related macular degeneration [University of Manitoba]. https://mspace.lib.umanitoba.ca/handle/1993/23870
114. Niroula, A., Khatri, S., Timilsina, R., Khadka, D., Khadka, A., & Ojha, P. (2019). Profile of chlorophylls and carotenoids of wheat (Triticum aestivum L.) and barley (Hordeum vulgare L.) microgreens. Journal of Food Science and Technology, 56(5), 2758–2763. https://doi.org/10.1007/s13197-019-03768-9
115. Peterson, C. T., Denniston, K., & Chopra, D. (2017). Therapeutic Uses of Triphala in Ayurvedic Medicine. The Journal of Alternative and Complementary Medicine, 23(8), 607–614. https://doi.org/10.1089/acm.2017.0083
116. Radomska-Leśniewska, D. M., Osiecka-Iwan, A., Hyc, A., Góźdź, A., Dąbrowska, A. M., & Skopiński, P. (2019). Therapeutic potential of curcumin in eye diseases. Central European Journal of Immunology, 44(2), 181–189. https://doi.org/10.5114/ceji.2019.87070
117. Ramakrishna, B. R. (2025). Ayurveda, Yoga, and the Conscious Self: An Integrated Approach to Health. Journal of Applied Consciousness Studies, 13(2), 59–60. https://doi.org/10.4103/jacs.jacs_69_25
118. Retina Specialty Hospital. (n.d.). Best Dry Fruits for Eye Health. https://retinaspecialityhospital.com/best-dry-fruits-for-eye-health/
119. Román-López, T. V., García-Vilchis, B., Murillo-Lechuga, V., Chiu-Han, E., López-Camaño, X., Aldana-Assad, O., Diaz-Torres, S., Caballero-Sánchez, U., Ortega-Mora, I., Ramírez-González, D., Zenteno, D., Espinosa-Valdés, Z., Tapia-Atilano, A., Pradel-Jiménez, S., Rentería, M. E., Medina-Rivera, A., Ruiz-Contreras, A. E., & Alcauter, S. (2023). Estimating the Genetic Contribution to Astigmatism and Myopia in the Mexican Population. Twin Research and Human Genetics, 26(4–5), 290–298. https://doi.org/10.1017/thg.2023.41
120. Safir, M., Nitzan, I., Hanina, Y., Heller, D., Mimouni, M., & Sorkin, N. (2025). Keratoconus prevalence in astigmatic adolescents: Findings from a nationwide screening setting. Eye, 39(16), 2958–2962. https://doi.org/10.1038/s41433-025-03995-9
121. Sarla, G. S. (2019). Saunf: Do we really need fennel seeds after a meal? https://doi.org/10.5281/ZENODO.3415288
122. Saunders, K. J. (2002). Emmetropisation following preterm birth. British Journal of Ophthalmology, 86(9), 1035–1040. https://doi.org/10.1136/bjo.86.9.1035
123. Shah, M., Natarajan, S. B., & Ahmad, N. (2025). Association of excessive screen time exposure with ocular changes leading to astigmatism in children. PLOS ONE, 20(4), e0317961. https://doi.org/10.1371/journal.pone.0317961
124. Sharma, A., Yadav, M., Tiwari, V., Chaudhary, E., Sheoran, B., Krishania, M., Navik, U., & Garg, M. (2025). Wheatgrass pigments: Germination, extraction, stability, and its therapeutic potential in health and diseases. International Journal of Advances in Engineering Sciences and Applied Mathematics, 17(3), 279–292. https://doi.org/10.1007/s12572-025-00403-z

 doi:10.20944/preprints202512.1806.v2

125. Shen, L., Cui, Y., Zhao, N., Yang, F., Zhou, Q., Wang, X., & Qin, S. (2025). Prevalence and patterns of subnormal visual acuity and refractive errors among preschool children in Sucheng district: A cross-sectional study. BMC Ophthalmology, 25(1), 420. https://doi.org/10.1186/s12886-025-04254-x
126. Shing, E., Kam, K. W., Zaabaar, E., Zhang, X. J., Young, A. L., Pang, C. P., Tham, C. C., Yam, J. C., & Chen, L. J. (2025). Heritability and Genetic Factors of Astigmatism and Corneal Curvature: A Systematic Review and Meta-analysis. American Journal of Ophthalmology, 269, 161–171. https://doi.org/10.1016/j.ajo.2024.08.019
127. Syed, F. Q., Mirza, M. B., Elkady, A. I., Hakeem, K. R., & Alkarim, S. (2019). An Insight of Multitudinous and Inveterate Pharmacological Applications of Foeniculum vulgare (Fennel). In M. Ozturk & K. R. Hakeem (Eds.), Plant and Human Health, Volume 3 (pp. 231–254). Springer International Publishing. https://doi.org/10.1007/978-3-030-04408-4_11
128. Tavazo. (n.d.). The Science Behind Almonds and Their Impact on Optimal Eye Function. https://tavazo.us/blogs/news/the-science-behind-almonds-and-their-impact-on-optimal-eye-function
129. The CREAM Consortium, Li, Q., Wojciechowski, R., Simpson, C. L., Hysi, P. G., Verhoeven, V. J. M., Ikram, M. K., Höhn, R., Vitart, V., Hewitt, A. W., Oexle, K., Mäkelä, K.-M., MacGregor, S., Pirastu, M., Fan, Q., Cheng, C.-Y., St Pourcain, B., McMahon, G., Kemp, J. P., … Guggenheim, J. A. (2015). Genome-wide association study for refractive astigmatism reveals genetic co-determination with spherical equivalent refractive error: The CREAM consortium. Human Genetics, 134(2), 131–146. https://doi.org/10.1007/s00439-014-1500-y
130. Tóth, & Gergő. (2023). The role of nutrition and supplements in the prevention and therapy of ophthalmological diseases [University of Debrecen]. https://dea.lib.unideb.hu/handle/123456789/37540
131. Vani, T., Rajani, M., Sarkar, S., & Shishoo, C. J. (1997). ANTIOXIDANT PROPERTIES OF THE AYURVEDIC FORMULATION T RIPHALA AND ITS CONSTITUENTS. International Journal of Pharmacognosy, 35(5), 313–317. https://doi.org/10.1080/09251619708951274
132. Wang, M., Zhou, Y., Chen, X., Zhu, Y., Huang, X., Li, L., Xiong, Y., Gong, Y., Wang, Y., & Sun, Z. (2025). Obesity Increases the Prevalence of Astigmatism in Children and Adolescents. The Open Ophthalmology Journal, 19(1), e18743641375929. https://doi.org/10.2174/0118743641375929250616054408
133. Wei, P., Han, G., Su, Q., Jia, L., Xue, C., & Wang, Y. (2025). Corneal Biomechanics as a Causal Factor in Myopia and Astigmatism: Evidence from Mendelian Randomization. Ophthalmology Science, 5(5), 100738. https://doi.org/10.1016/j.xops.2025.100738
134. Weise, K. K., Repka, M. X., Zhu, Y., Manny, R. E., Raghuram, A., Chandler, D. L., Summers, A. I., Lee, K. A., Kehler, L. A. F., Pang, Y., Allen, M. S., Anderson, H. A., Erzurum, S. A., Golden, R. P., Koutnik, C. A., Kuo, A. F., Lenhart, P. D., Mokka, P. L., Petersen, D. B., … on behalf of the Pediatric Eye Disease Investigator Group. (2024). Baseline factors associated with myopia progression and axial elongation over 30 months in children 5 to 12 years of age. Optometry and Vision Science, 101(10), 619–626. https://doi.org/10.1097/OPX.0000000000002187
135. Yaghoobi, R., Kazerouni, A., & Kazerouni, O. (2013). Evidence for Clinical Use of Honey in Wound Healing as an Anti-bacterial, Anti-inflammatory Anti-oxidant and Anti-viral Agent: A Review. Jundishapur Journal of Natural Pharmaceutical Products, 8(3), 100–104. https://doi.org/10.17795/jjnpp-9487
136. Barcelo-Canton, R. H., Ting, D. S. J., & Mehta, J. S. (2025). Genetics of Keratoconus: Comprehensive Review. *Genes*, *16*(10), 1147. https://doi.org/10.3390/genes16101147