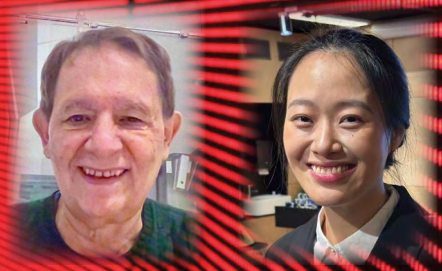
Red light therapy for myopia:

An overview of mechanisms and clinical evidence



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First submitted: April 29, 2025
Revision accepted: October 28, 2025
Revision submitted: October 26, 2025
Published: Winter 2025

Peer reviewed

Abstract

The global prevalence of myopia is rising due to increased near work and reduced outdoor activity during childhood, posing a public health challenge as high myopia increases the risk of severe ocular complications. Traditional interventions, such as spectacles and contact lenses, correct refractive errors but do not slow myopia progression. Optical devices preventing peripheral hyperopic defocus, low-dose atropine, and red light therapy (RLT) have emerged as strategies to control myopia in children. This review synthesizes evidence on RLT's mechanisms, efficacy, safety, and clinical applications. RLT, using low-intensity red light (600–700 nm), induces photobiomodulation (PBM) and is hypothesized to enhance choroidal and scleral metabolism and reduce axial elongation. Clinical trials report significant reductions in axial length (AL; pooled effect: 0.953 ± 0.294 mm) and spherical equivalent refraction (SER; 1.521 ± 0.662 D) compared to single-vision spectacles, with greater efficacy in change of AL than orthokeratology. Adverse events are rare (0.088 per 100 patient-years), and primarily consisted of transient afterimages, though reduced foveal cone density warrants long-term safety monitoring. While promising, further research is needed to confirm long-term efficacy and patient-specific responses.

Introduction

The global prevalence of myopia has surged, driven by environmental factors such as increased near work and reduced outdoor time.[1] The World Health Organization recognizes myopia as a significant public health concern due to its association with complications like myopic maculopathy, cataracts, glaucoma, retinal tears, and retinal detachment.[2] Traditional corrections (spectacles, contact lenses) improve visual acuity but do not address progression. Strategies to slow myopia include increased outdoor activity,[3] optical interventions (e.g., multizonal spectacle lenses and contact lenses with myopic peripheral defocus),[4] and low-dose atropine.[5] Recently, red light therapy (RLT) has emerged as a promising approach for controlling myopia progression in children.

Methods

This review followed PRISMA guidelines[6] to evaluate RLT's efficacy, safety, and mechanisms for myopia control in children. A literature search was conducted in PubMed, Scopus, Web of Science, and Embase until June 2025, using the terms: ("myopia" OR "nearsightedness") AND ("red light therapy" OR "repeated low-level red light" OR "low-level laser therapy" OR "photobiomodulation") AND ("axial length" OR "spherical equivalent refraction").

Inclusion criteria comprised peer-reviewed randomized controlled trials (RCTs), cohort studies, and meta-analyses evaluating RLT in children aged 4–18 years. Non-English studies, animal studies, and those lacking quantitative axial length (AL) or spherical equivalent refraction (SER) outcomes were excluded. Two reviewers independently extracted data on study design, participant demographics, RLT protocols (wavelength, duration, frequency), outcomes (AL, SER), and adverse effects. Eighteen studies involving 2,346 participants were included, providing a comprehensive evidence base .

Results

Myopia Progression and Environmental Influences

Myopia progression is driven by axial elongation, which increases myopic refraction. Natural light exposure is associated with reduced axial elongation.[7] Increased outdoor time correlates with a lower risk of myopia onset, with brighter light potentially protective.[8] These findings underpin the development of RLT interventions, such as low-level laser therapy (LLLT) and repeated low-level red light (RLRL) therapy, for myopia control in children.

Mechanisms of Red Light Therapy

RLRL, delivered via a home-use device approved in China, Australia, New Zealand, and CE-marked in Europe, emits 650 nm red light through a low-level laser (**Figure 1**). Treatment involves two 3-minute sessions daily, five days per week, with a 6-hour

Figure 1. Eyerising Myopia Management Device, Eyerising International, South Yarra, VICTORIA, Australia. The Eyerising myopia management device uses proprietary technology for administering Repeated Low-Level Red Light (RLRL) therapy that enhances blood circulation in the ocular fundus, addressing sclera hypoxia and managing the axial elongation associated with myopia. It is backed by 2-year clinical trial results showing myopia control efficacy and complies with Australian Standard IEC 60825-1:2014 for laser product safety.

interval between sessions. The device includes real-time compliance monitoring via an online portal for parents and clinicians.

Red light (600–700 nm) induces photobiomodulation (PBM), hypothesized to enhance metabolism through mitochondrial stimulation.[9] PBM is also hypothesized to improve scleral and choroidal health by reducing hypoxia and oxidative stress, key contributors to myopia.[10] In vitro studies show PBM increases cell proliferation and collagen synthesis in human fibroblasts, suggesting a potential mechanism for slowing myopia progression if scleral fibroblasts respond similarly.[11]

Clinical Efficacy of Red Light Therapy

An RCT of 74 children reported a mean AL reduction of 0.06 mm after 6 months of RLRL, compared to a 0.23 mm increase in the single-vision spectacles (SVS) group and 0.06 mm increase in the orthokeratology group.[12] A multicenter RCT showed a 69.4% reduction in AL elongation and 76.6% reduction in SER progression after 1 year of RLRL compared to controls.[13] A systematic review confirmed RLT's superiority over traditional interventions.[14] RLRL outperformed orthokeratology in comparative studies, with significant AL reduction only in the RLRL group,[15] and enhanced low-dose atropine's efficacy, suggesting synergy.[16] As shown in **Figure 2**, another RCT (50 children, aged 8–12) found RLRL reduced AL by 0.50 mm and improved cycloplegic SER by +1.25 D versus SVS after 12 months.[16] A meta-analysis of 1,714 participants reported RLRL reduced AL (pooled effect: 0.953 ± 0.294 mm) and SER (1.521 ± 0.662 D) compared to SVS.[17]

Safety and Adverse Effects

RLRL's safety profile is favorable, with an adverse event rate of 0.088 per 100 patient-years, lower than atropine or orthokeratology.[18] The primary side effect is transient afterimages. A multicenter study found no significant ocular damage or retinal function decline.[19] However, a case report noted temporary foveal structural damage and visual loss after 5 months of RLRL, with full recovery without permanent damage at follow-up.[20] A recent study using adaptive optics scanning laser ophthalmoscopy reported reduced paracentral foveal cone density in some participants after 1 year of RLRL,[21] underscoring the need for long-term safety studies.

Comparison with Other Treatment Modalities

Traditional interventions like orthokeratology and low-dose atropine (0.01%) are effective but limited by side effects and rebound myopia upon discontinuation. RLRL was significantly more effective than 0.01% atropine in slowing myopia progression over 12 months, with a lower rebound risk.[22] However, rebound myopia after RLRL cessation remains a challenge.[13]

Practical Implications for Implementation

Integrating RLRL into clinical practice requires standardized protocols for wavelength (600–700 nm), duration, and frequency. Current evidence supports two 3-minute daily sessions, five days per week, but optimization is ongoing.[23] Equipment standardization and patient compliance, facilitated by device-integrated monitoring systems, are critical for success. Clinicians must ensure proper use and regular follow-up.

Discussion

RLRL offers advantages over 1% atropine, which causes photophobia and prolonged blurred vision.[24] Optical interventions like MiSight contact lenses,[25] defocus incorporated multiple segments (DIMS) spectacle lenses,[26] and low-dose atropine[27] slow myopia progression, but only RLRL demonstrates AL reduction. No studies reported loss of corrected visual acuity, and some noted improved vision post-RLRL.[8] However, reduced foveal cone density after 1 year of RLRL[21] necessitates further risk-benefit evaluation. When compared comprehensively (**Table 1**), RLRL presents the most potent efficacy for myopia control with a low rebound risk, positioning it favorably against alternatives with more modest efficacy or less desirable safety profiles.

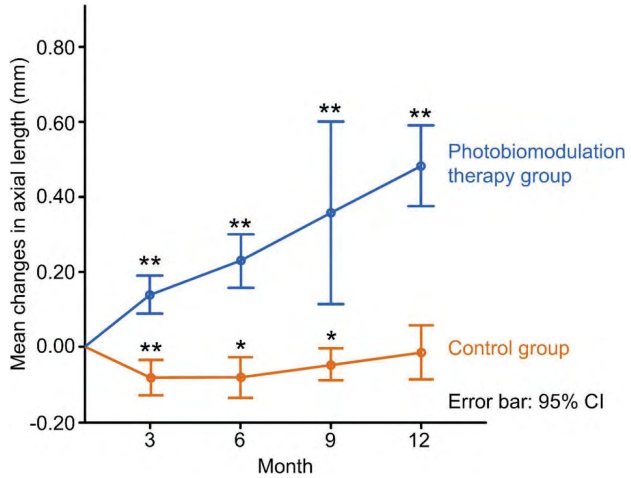

*Figure 2. Changes of axial length of two groups at 3-, 6-, 9-, and 12-month follow-up, respectively. ** and * represent P < 0.001 and P < 0.01, comparing the data of each follow-up with that of no change from baseline. Reprinted from Zhou, L., et al., Photobiomodulation therapy retarded axial length growth in children with myopia: evidence from a 12-month randomized controlled trial evidence. Sci Rep, 2023. 13(1): p. 3321, under CC-BY-NC 4.0.*

Table 1. Comparison of Myopia Control Interventions

Intervention	AL Change (mm)	SER Change (D)	Side Effects	Rebound Risk
RLRL	−0.06 to −1.03	+1.25 to +3.00	Transient afterimage, rare cone density reduction	Low to moderate
0.01% Atropine	−0.10 to +0.23	Variable	Photophobia, blurred vision	Low to moderate
Orthokeratology	−0.06	Variable	Corneal irritation, infection risk	Moderate
MiSight/DIMS Lenses	+0.10 to +0.30	Variable	Minimal	Low

AL: Axial Length; SER: spherical equivalent refraction; DIMS: Defocus Incorporated Multiple Segments; RLRL: Repeated Low-Level Red Light; Negative values in AL change indicate shortening.

Challenges and Future Directions

RLRL faces challenges, including variable individual responses, potential risks at higher intensities, and limited long-term neurobiological data.[13] Most studies focus on short-term outcomes, requiring longitudinal research to assess durability across diverse populations.[28] Future studies should optimize light exposure parameters and explore RLRL's interaction with ambient light.[7] Combining RLRL with behavioral interventions, like increased outdoor time, may enhance efficacy.[15]

Conclusion

RLRL demonstrates compelling efficacy in slowing and potentially reversing myopia progression, with evidence of AL reduction. However, limited long-term data beyond 2 years highlight the need for extended studies to confirm durability, refine protocols, and address retinal safety concerns. Ongoing research is essential to establish RLRL as a standard myopia control intervention.

Conflict of interest: none

Key points:

- **Efficacy in Myopia Control:** Red light therapy (RLT) significantly reduces progression of axial elongation and slows or reverses myopia progression in children, outperforming traditional interventions such as orthokeratology and low-dose atropine in several trials and meta-analyses.
- **Mechanistic Basis – Photobiomodulation (PBM):** RLT operates through PBM mechanisms, stimulating mitochondrial activity, improving scleral and choroidal metabolism, and reducing hypoxia and oxidative stress—factors implicated in myopia development.
- **Safety Profile:** Clinical data indicate a low adverse event rate (0.088 per 100 patient-years), with most effects being transient (afterimages). However, potential retinal structural changes (e.g., reduced cone density) require ongoing monitoring.
- **Comparative Advantage:** Unlike other myopia control strategies, RLT seems to not only slows axial elongation but may induce actual axial shortening, suggesting potential for partial reversal of structural changes in the myopic eye.

Future directions:

- **Long-Term Safety and Durability:** Extended longitudinal studies (beyond 2 years) are essential to evaluate sustained efficacy, rebound effects after discontinuation, and potential long-term retinal or photoreceptor changes.
- **Optimization of Treatment Parameters:** Future research should refine wavelength, intensity, and dosing schedules to balance efficacy and safety, and examine how RLT interacts with environmental light exposure or concurrent therapies (e.g., atropine, outdoor activity).
- **Individualized and Combined Therapies:** Investigating patient-specific responses could enable personalized treatment regimens. Integrating RLT with behavioral or optical interventions may yield synergistic benefits for broader myopia control strategies.

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