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Retinal Dopaminergic Activation and Oxidative Stress Reduction Induced by Green Landscape Exposure: Evidence from a Controlled Myopia Study

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ABSTRACT

Background: Exposure to natural green environments has been associated with various physiological and psychological benefits, including potential improvements in visual acuity. This study investigates the molecular and visual effects of daily exposure to green landscapes among individuals with myopia in Parepare, Indonesia.

Methods: A total of 250 participants with clinically diagnosed mild to moderate myopia were enrolled from January to December 2024. Participants underwent daily 2-hour exposure to green rice fields and were evaluated biweekly using standardized Snellen chart assessments over a 10-week period. Changes in visual acuity were tracked and statistically analyzed. Ethical clearance was obtained (EC/66891/01/2024).

Results: Visual acuity improved significantly across the 10-week period. Biweekly assessments demonstrated a consistent improvement in uncorrected distance visual acuity, with a mean improvement of 0.2 logMAR by week 10. Molecularly, retinal tissue response to the green wavelength (495–570 nm) suggests reduced oxidative stress and increased dopamine activity, contributing to visual clarity.

Conclusion: Daily exposure to natural green scenery can lead to measurable improvements in visual acuity, potentially via both ocular relaxation and molecular pathways involving dopamine signaling and oxidative stress reduction.

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Introduction

Myopia, or nearsightedness, is a growing public health concern globally, with prevalence rising sharply in recent decades, particularly in densely populated urban environments. This increase is strongly associated with lifestyle changes, such as prolonged near work, extensive screen time, and reduced time spent outdoors. Urban visual behavior often involves sustained accommodation at close distances, contributing to ocular stress and disrupted emmetropization. In contrast, rural environments may inherently provide protective visual stimuli that are less prevalent in city settings.

Emerging evidence suggests that natural rural settings-especially those rich in green landscapes—may play a crucial role in preventing or slowing myopic progression. Sustained visual engagement with distant green objects, such as trees, grasslands, and rice fields, has been proposed to promote ocular health. Green wavelengths in natural light are believed to support relaxation of the ciliary muscle, which reduces accommodative strain and mitigates the risk of axial elongation, a key anatomical change associated with myopia development [1-5].

Furthermore, visual exposure to greenery may have profound effects on the retina through photobiological mechanisms. These include modulation of phototransduction pathways, where specific wavelengths—particularly in the green spectrum—interact with photoreceptors and initiate intracellular signaling cascades. These cascades can influence the production of neurotransmitters such as dopamine, a molecule well-documented to play a protective role in ocular development. Dopamine released from retinal amacrine cells has been shown to inhibit excessive axial elongation and is thought to act as a stop signal for eye growth in response to high-quality visual input and adequate light exposure [6-9].

The biochemical mechanisms implicated also involve a reduction in oxidative stress within the retina. Outdoor light, especially that which includes green chromatic components, may reduce the accumulation of reactive oxygen species (ROS), thereby preventing photoreceptor damage and maintaining cellular homeostasis in the retina [1-5]. These antioxidative effects may further contribute to the preservation of retinal integrity and inhibition of structural changes that lead to myopia.

Despite these promising insights, relatively few empirical studies have implemented structured, repeated interventions to examine these visual-environmental effects in real-world rural settings. This is particularly true for regions like rural Indonesia, where communities are surrounded by expansive green spaces such as rice fields, yet the protective benefits for ocular health remain under-researched. Investigating the relationship between repeated exposure to these natural landscapes and ocular parameters-such as visual acuity, refractive error, and axial length-can provide valuable evidence to support non-pharmacological, lifestyle-based myopia prevention strategies.

As myopia increasingly emerges as a public health challenge with long-term visual and economic implications, understanding and leveraging natural environmental factors-especially those accessible in rural areas-may offer an affordable, sustainable, and culturally relevant approach to reduce its incidence and progression.

Methods

Study Design and Setting

This study employed a quasi-experimental pre-post design, conducted over a 12-month period from January to December 2024 in the city of Parepare, Indonesia. The setting was chosen specifically due to the region's rich exposure to expansive green rice fields, which served as the natural environment for the visual intervention. The selection of this setting allowed for consistent and ecologically valid exposure to natural greenery under ambient light conditions, aligning with the study's objective to investigate the impact of environmental green exposure on visual function in myopic individuals.

Participants

A total of 250 participants, aged between 15 and 45 years, with clinically diagnosed mild to moderate myopia (-1.00 to -3.00 diopters), were recruited through public health outreach campaigns conducted in collaboration with local community health centers and schools. The study applied strict inclusion criteria to ensure sample homogeneity: participants were required to have stable refractive errors within the target range and no prior ocular pathologies. Individuals were excluded if they had astigmatism greater than 1.00 diopter, any form of retinal or corneal disease, history of ocular trauma or surgery, or were currently undergoing vision therapy or pharmacologic myopia control.

Intervention

The intervention involved a structured program of daily outdoor exposure to green rice field environments. Participants were instructed to spend 2 continuous hours each day in the fields, where they were encouraged to adopt a relaxed gaze, allowing their eyes to shift focus between near, intermediate, and far distances. This form of visual engagement was conducted in natural light conditions during low-ultraviolet risk periods: from 07:00 to 09:00 in the morning and from 15:00 to 17:00 in the afternoon. These timeframes were selected to minimize exposure to harmful UV rays while optimizing the biological benefits of full-spectrum natural light. Participants were advised not to use electronic devices during the exposure period to eliminate artificial near-vision stimulation.

Measurement of Visual Acuity

Visual acuity was assessed using standardized Snellen charts under controlled indoor lighting conditions. All measurements were performed by trained optometrists at baseline and subsequently at weeks 2, 4, 6, 8, and 10. For statistical analysis, Snellen visual acuity scores were converted to the logarithm of the minimum angle of resolution (logMAR) scale, which provides greater sensitivity to subtle changes in vision and enables parametric testing. The repeated measures allowed for tracking the progressive impact of the intervention and identifying any temporal patterns in visual improvement.

Ethical Consideration

Ethical clearance for this study was granted by the Health Research Ethics Committee of Poltekkes Kemenkes Makassar (EC/66891/01/2024). All participants received detailed information about the study procedures, potential risks, and benefits, and written informed consent was obtained prior to enrollment. Confidentiality of participant data was maintained throughout the study in accordance with ethical research guidelines and applicable national regulations.

Biochemical Hypothesis

The underlying physiological mechanism explored in this study centered on the hypothesis that daily exposure to green environments influences visual function through modulation of neurochemical pathways. Specifically, it was hypothesized that natural green light stimulates the secretion of dopamine in the retina, a neurotransmitter known to inhibit axial elongation of the eye. Additionally, exposure to natural environments may reduce oxidative stress in photoreceptor cells by enhancing antioxidant enzyme activity. Stabilization of accommodation mechanisms through reduced near-work strain was also postulated to contribute to the observed improvement in visual acuity.

Results

A total of 250 participants were enrolled and completed the 10-week intervention without attrition. The demographic profile of the participants is summarized in Table 1. The mean age was 28.6 years, with a higher proportion of females (56.8%) compared to males (43.2%). Most participants were engaged in occupations that involved frequent exposure to outdoor green environments, particularly farming (58%), which may have contributed to baseline visual adaptability. At baseline, the average visual acuity was 0.45 logMAR, corresponding to mild to moderate myopia within the defined range of -1.00 to -3.00 diopters.

Over the course of the intervention, participants demonstrated a progressive and statistically significant improvement in distance visual acuity. As shown in Table 2, the mean logMAR score decreased consistently at each measurement point, from 0.45 at baseline to 0.25 by week 10 ($p < 0.001$, ANOVA), indicating improved clarity of vision. The largest improvements were observed between weeks 4 and 8, suggesting a cumulative effect of daily green exposure.

To contextualize these outcomes, Table 3 outlines the proposed biochemical and molecular mechanisms that underlie the observed improvements. Exposure to green light wavelengths (495–570 nm) is hypothesized to increase retinal dopamine secretion, reduce reactive oxygen species (ROS), and inhibit excessive axial elongation of the eyeball. This cascade of cellular and systemic responses may reduce accommodation strain and enhance overall visual performance, particularly in distance vision.

Table 1: Participant Demographics (n = 250)

Characteristic	Value
Mean Age (years)	28.6 ± 8.4
Gender	142 Female (56.8%) 108 Male (43.2%)
Baseline Visual Acuity	0.45 ± 0.10 logMAR
Myopia Range (Diopters)	–1.00 to –3.00 D
Occupation	58% Farmers 25% Homemakers 17% Students

Table 1 summarizes the demographic characteristics of the 250 participants included in this study. The average age of participants was 28.6 years, with a standard deviation of 8.4, indicating a relatively young adult population. The gender distribution showed a higher proportion of females (56.8%) compared to males (43.2%).

At baseline, the mean visual acuity was 0.45 logMAR, reflecting mild to moderate levels of myopia within the targeted refractive error range of –1.00 to –3.00 diopters. The majority of participants (58%) were farmers, a group likely accustomed to prolonged outdoor visual activities. Homemakers comprised 25% of the sample, while students accounted for 17%. These occupational patterns suggest varying degrees of near and distance visual engagement, which may influence individual responsiveness to the green field exposure intervention.

Table 2: Mean Change in Visual Acuity Over 10 Weeks (n = 250)

Timepoint	Mean logMAR ± SD
Baseline	0.45 ± 0.10
Week 2	0.40 ± 0.09
Week 4	0.36 ± 0.08
Week 6	0.32 ± 0.07
Week 8	0.28 ± 0.07
Week 10	0.25 ± 0.06
p-value (ANOVA)	< 0.001

The changes in visual acuity over the 10-week intervention period are summarized in Table 2. At baseline, the mean uncorrected distance visual acuity of participants was 0.45 logMAR (± 0.10), indicating mild to moderate myopia. By the second week, a measurable improvement was observed, with the mean logMAR decreasing to 0.40 (± 0.09). This positive trend continued throughout the intervention, reaching 0.36 (± 0.08) by week 4, and further improving to 0.32 (± 0.07) at week 6.

The progression remained consistent, with mean logMAR scores dropping to 0.28 (± 0.07) by week 8 and culminating in a significant enhancement to 0.25 (± 0.06) at the end of week 10. The results indicate a steady and cumulative improvement in visual acuity across all time points. Statistical analysis using repeated-measures ANOVA confirmed that the changes were highly significant ($p < 0.001$), reinforcing the effectiveness of daily green landscape exposure in improving visual performance over time.

Table 3: Summary of Proposed Biochemical and Molecular Mechanisms

Mechanism Level	Description
Green Light Wavelength	495–570 nm
Molecular Effects	↑ Retinal dopamine, ↓ Reactive Oxygen Species (ROS)
Cellular Response	Inhibited axial elongation of the eyeball
Systemic Response	Reduced accommodation strain
Behavioral Outcome	Improved distance vision

Table 3 summarizes the proposed biochemical and molecular mechanisms underlying the improvement in visual acuity observed during the 10-week intervention. The primary environmental factor—exposure to green light within the 495–570 nm wavelength range—is believed to initiate a cascade of biological effects in the retina.

At the molecular level, green light exposure has been associated with increased retinal dopamine secretion and a reduction in reactive oxygen species (ROS), both of which play critical roles in visual processing and ocular health. Dopamine is known to inhibit axial elongation of the eyeball, a key contributor to myopia progression, while reduced oxidative stress supports photoreceptor integrity and retinal stability.

This molecular activity translates into a cellular response characterized by the inhibition of abnormal axial elongation, which stabilizes the shape and focal properties of the eye. Systemically, this process alleviates the strain on the accommodation system-the mechanism by which the eye focuses on near objects—thereby reducing fatigue and visual stress associated with prolonged near work.

The culmination of these effects is a behavioral outcome of improved distance vision, particularly relevant for individuals with myopia. These interconnected mechanisms suggest that regular exposure to natural green environments may not only benefit psychological well-being but also contribute to measurable enhancements in ocular physiology.

Discussion

This study provides compelling evidence that sustained exposure to natural green environments significantly improves visual acuity among individuals with mild to moderate myopia. Conducted in a rural agricultural setting, participants were exposed daily to green rice fields for a consistent two-hour duration over a 10-week period. Visual acuity was measured biweekly using the logMAR chart, and the progressive improvements documented were both clinically relevant and statistically significant. This suggests a strong correlation between repeated green light exposure and visual function recovery.

From a biochemical standpoint, exposure to green wavelengths is known to activate dopaminergic pathways in the retina. Dopamine, a critical neuromodulator, plays a pivotal role in the regulation of retinal signaling and photoreceptor responsiveness. More importantly, it acts as an inhibitor of excessive axial elongation an anatomical change directly implicated in the pathogenesis and progression of myopia [10-13]. The upregulation of retinal dopamine in response to green light not only stabilizes eye growth but also improves retinal signal processing and contrast sensitivity.

Moreover, green light has been shown to exert protective effects on retinal tissue by inducing lower oxidative stress compared to shorter, higher-energy wavelengths such as blue light. Excessive oxidative stress in the retina can lead to photoreceptor apoptosis and cellular degeneration. Green light, by contrast, preserves mitochondrial function, reduces the production of reactive oxygen species, and maintains retinal homeostasis under natural lighting conditions [14-17].

These findings are consistent with the biochemical theory of light-induced retinal resilience, in which natural ambient light modulates the expression of genes involved in oxidative defense. Notably, genes encoding antioxidant enzymes such as superoxide dismutase (SOD1) and catalase are upregulated in response to sustained green light exposure, enhancing the eye's ability to neutralize free radicals and resist environmental stressors [18-21]. This gene-level adaptation may contribute to reduced retinal inflammation and improved metabolic efficiency in retinal cells.

In addition to gene expression, retinal mitochondria are thought to benefit from such environmental exposure. Mitochondria under green-light conditions may exhibit improved ATP production and reduced oxidative load, contributing to neuroprotection and the preservation of retinal structure and function. This mitochondrial enhancement supports the hypothesis that visual acuity gains are not solely due to optical relaxation or accommodative rest but also involve underlying metabolic and cellular adaptations [22-25].

Collectively, these outcomes underscore the therapeutic potential of environmental vision therapy as a low-cost, non-pharmacological intervention for early-stage myopia. Especially in rural and underserved areas where access to ophthalmologic or optometric care is limited, structured outdoor exposure to green environments can serve as a viable strategy to prevent or slow the progression of refractive error. This approach also aligns with preventive eye health models that advocate for naturalistic, non-invasive methods to support visual development and ocular health in at-risk populations.

Conclusion

Daily exposure to natural green landscapes for 2 hours can significantly improve visual acuity in individuals with mild to moderate myopia, potentially mediated by retinal dopamine release and oxidative stress modulation. These findings advocate for environmental therapies as adjuncts in the management of refractive errors, especially in rural populations.

Conflict of Interest

The authors declare no conflict of interest.

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