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Review

The Impact of Digital Device Usage on Myopia Development in Adolescents: A Narrative Review of Current Evidence

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Abstract

Myopia, or near-sightedness, is a growing global public health concern, with its prevalence increasing significantly, particularly among adolescents. While genetic predisposition plays a role, environmental and lifestyle factors, including prolonged digital device use, have been implicated in myopia development. This narrative review synthesizes current evidence on the impact of digital screen exposure on myopia progression in adolescents, examining epidemiological trends, biological mechanisms, and preventive strategies. Excessive screen time, particularly with smartphones, tablets, and computers, is associated with increased near-work demand, accommodation lag, and reduced outdoor activity, all of which contribute to axial elongation and myopia progression. The biological mechanisms underlying myopia include disruptions in emmetropization, choroidal thinning, and scleral remodeling. Additionally, dopamine release, stimulated by outdoor light exposure, plays a crucial role in inhibiting excessive ocular growth, highlighting the protective effect of spending more time outdoors. Despite emerging evidence linking digital screen use to myopia, inconsistencies in study methodologies, reliance on self-reported screen time data, and the absence of large-scale randomized controlled trials (RCTs) limit definitive conclusions. Research gaps persist in understanding device-specific risks, the role of blue light exposure, and the interaction between screen time and outdoor activities. Behavioral interventions such as limiting screen time, optimizing viewing distances, and increasing outdoor exposure remain key strategies for myopia prevention. Future studies should focus on objective measurement tools, long-term cohort studies, and personalized interventions. Addressing these gaps is essential for developing evidence-based guidelines to mitigate the impact of digital device usage on adolescent eye health.

Keywords: *Myopia, Near-sightedness, Digital device usage, Screen time, Adolescents, Eye health*

Introduction

Myopia, commonly referred to as near-sightedness, is a significant public health concern due to its increasing prevalence and associated risks of vision impairment (1). It is characterized by a refractive error in which distant objects appear blurry while close objects remain clear, primarily caused by excessive elongation of the eyeball or an increase in the refractive power of the eye's anterior segment (2). The prevalence of myopia has risen dramatically in recent decades, particularly in East and Southeast Asia, where up to 80–90% of young adults in urban areas are affected (3). Globally, projections suggest that by 2050, nearly half of the world's population will be myopic, with one in five individuals developing high myopia, a severe form of the condition associated with complications such as myopic macular degeneration, retinal detachment, cataracts, and glaucoma (3). While genetic factors play a role in myopia development, mounting evidence suggests that environmental and lifestyle factors—particularly urbanization, educational pressure, and increased near-work activities—contribute significantly to its onset and progression (4, 5).

One of the most debated lifestyle factors in recent years is the impact of digital device usage on myopia development, particularly among adolescents (6, 7). The widespread adoption of smartphones, tablets, and computers has significantly increased screen time exposure, contributing to a surge in near-work activities (6). Studies indicate that prolonged screen use may exacerbate myopia progression through mechanisms such as increased accommodation demand, reduced blink rates leading to digital eye strain, and a decrease in outdoor activity—an established protective factor against myopia (8, 9). Furthermore, the introduction of high-resolution screens with blue light emission has raised concerns regarding their potential effects on retinal health and circadian rhythms, which may indirectly influence myopia progression (10, 11). Despite these concerns, the exact relationship between digital device use and myopia remains unclear due to inconsistencies in research methodologies, variations in screen-time measurement, and confounding factors such as educational demands and genetic predisposition.

This narrative review aims to evaluate the current evidence linking digital device usage to myopia development in adolescents. By synthesizing findings from epidemiological studies, biological mechanisms, and meta-analyses, this review will explore whether excessive screen time is a significant risk factor for myopia progression. Additionally, it will assess potential preventive strategies, including behavioral modifications, outdoor exposure, and policy recommendations, to mitigate the impact of digital screen exposure on adolescent eye health. Given the increasing digitalization of education and social interactions, understanding the implications of screen time on myopia is crucial for developing effective intervention strategies and guiding future research.

Methodology

This narrative review explores the relationship between digital device usage and myopia development in adolescents. Unlike systematic reviews, which follow predefined inclusion criteria and statistical meta-analysis, this approach integrates diverse research findings to provide a broad and comprehensive understanding of the topic.

Literature search strategy

A literature search was conducted using PubMed, Web of Science, and Scopus, selecting peer-reviewed studies published up to February 2025. These databases were chosen for their extensive coverage of medical and public health research. The search employed a combination of Medical Subject Headings (MeSH) terms and keywords, including "myopia," "near-sightedness," "refractive error," "screen time," "digital screen exposure," "smartphone use," "tablet use," and "computer use." To ensure completeness, reference lists of key articles were manually reviewed for additional relevant studies.

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Selection criteria

Studies were selected based on their relevance to adolescent myopia and digital device usage rather than strict predefined inclusion criteria. Empirical research, including observational, cohort, and experimental studies, as well as systematic reviews, was prioritized. Preference was given to studies published after 2015 to reflect the most recent evidence.

Data extraction and synthesis

Relevant findings were thematically synthesized to examine epidemiological trends, biological mechanisms, device-specific risks, and prevention strategies. Conflicting evidence was analyzed to highlight research gaps and methodological limitations. A descriptive, narrative approach was used to integrate various study designs, offering a balanced discussion without applying formal quality assessment tools.

Epidemiology and trends of myopia in adolescents

Myopia, or near-sightedness, has become a significant global public health issue, with its prevalence rising rapidly, especially among adolescents. At the time of the study, approximately 23% of the world's population had myopia, with a predicted increase to 50% by the year 2050 (12). The highest prevalence rates were found in Asia-Pacific countries, with East Asia, Southeast Asia, and North America not far behind. This trend is particularly evident in East and Southeast Asia, where 80–90% of young adults in urban areas are affected (12, 13).

The age of myopia onset has been decreasing, which is concerning because earlier onset is associated with higher degrees of myopia in adulthood and a greater risk of severe ocular complications (14). Myopia typically develops during childhood and adolescence, a critical period for eye growth and emmetropization, the process by which the eye achieves optimal refractive power (15). While the eye is naturally farsighted at birth, myopia remains rare in preschool-aged children but becomes more common with increasing years of education (16). This link between myopia and education is independent of genetic factors, emphasizing the role of environmental influences such as prolonged near-work activities and reduced outdoor time (17). Regional differences in myopia prevalence are striking, with East Asian countries reporting much higher rates than Western nations. For example, up to 80% of adults in East Asia are myopic, compared to less than 10% in rural areas with limited formal education (12). In Europe, nearly 50% of young adults are myopic, while in urban East Asia, this figure rises to 80–90% (12, 13). These disparities highlight the impact of urbanization, educational pressure, and lifestyle changes on myopia development. Key risk factors for myopia include urbanization, educational demands, and digital screen exposure (5). Urban environments often limit opportunities for outdoor activities, which are protective against myopia, while educational systems that emphasize prolonged near-work activities increase the risk (4). The widespread use of digital devices, such as smartphones, tablets, and computers, has further intensified near-work demands, particularly among adolescents (7). Smartphones, with their small screens and close viewing distances, are especially concerning as they contribute to increased accommodative stress and digital eye strain (6). Although the role of prolonged near work in myopia development is still debated, many studies suggest a significant association, particularly when combined with insufficient outdoor exposure (18).

Biological mechanisms of myopia development

Myopia development is primarily driven by axial elongation of the eyeball, causing light to focus in front of the retina rather than directly on it. This structural change is influenced by genetic predisposition, environmental factors, and visual processing mechanisms that regulate ocular growth. Several biological pathways contribute to myopia progression, including ocular biometric changes, retinal signaling, accommodation lag, and the role of dopamine and light exposure **(Table 1)**.

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Table 1: Key biological mechanisms of myopia development		
Mechanism	**Description**	**Impact on myopia**
Axial length elongation	Excessive elongation shifts the focal point in front of the retina.	Primary cause of myopia; increases risk of complications like retinal detachment.
Choroidal thinning	Reduced choroidal thickness, especially in the foveal region.	It leads to faster myopia progression and degenerative changes.
Accommodation lag	Delayed focusing on near objects, common with digital screens.	Sustained hyperopic defocus promotes axial elongation.
Dopamine & light exposure	Outdoor light stimulates dopamine, inhibiting axial elongation.	Reduced outdoor time lowers dopamine, accelerating myopia.
Genetic factors	Genes like PAX6 and COL1A1 regulate eye growth.	Children with myopic parents have a higher risk.

Ocular Biometric Changes

The most significant anatomical change in myopic eyes is axial elongation, particularly in the vitreous chamber depth (19). Excessive elongation leads to a mismatch between the focal point of light and the retinal plane, resulting in blurred distance vision (19). Accompanying this is choroidal thinning, particularly at the foveal region, which is more pronounced in high myopia and is linked to myopic maculopathy and retinal degeneration (20). Additionally, scleral remodeling occurs, characterized by reduced collagen cross-linking and increased activity of matrix metalloproteinases (MMPs), making the sclera thinner and more susceptible to elongation (21).

Visual Processing and Emmetropization

Emmetropization is the eye's natural process of adjusting its growth to achieve optimal focus (22). Disruptions in this feedback mechanism—particularly prolonged hyperopic defocus—can accelerate axial elongation (22). Sustained near work, including digital screen use, has been implicated in accommodation lag, where the eye struggles to focus accurately on near objects, reinforcing the cycle of ocular elongation (8,18). Some studies suggest that higher-order optical aberrations resulting from near work may further contribute to myopia progression (22).

Genetic and Environmental Interactions

Myopia has a strong genetic component, with studies showing that children with one myopic parent have a 2.91-fold higher risk, while those with two myopic parents face a 7.79-fold greater risk (23). Several genes, including PAX6, COL1A1, and MMP-2, regulate ocular growth, scleral remodeling, and extracellular matrix stability (24, 25). However, gene-environment interactions are critical, as prolonged near-work and high educational demands can exacerbate myopia progression in genetically predisposed individuals (22, 23). Mendelian randomization studies have confirmed that longer years of education have a direct causal effect on myopia risk (26, 27).

Dopamine and Light Exposure

The dopamine hypothesis suggests that outdoor light exposure plays a protective role against myopia (28). Dopamine, a retinal neurotransmitter, inhibits excessive axial elongation by regulating retinal signaling pathways (28). High-intensity light exposure (>10,000 lux) has been shown to slow the onset of myopia, while prolonged indoor activities associated with low dopamine release contribute to uncontrolled eye growth (4). Large-scale studies indicate that spending at least two hours per day outdoors significantly reduces myopia risk in children (17, 29).

http://dx.doi.org/10.52533/JOHS.2026.60103

Accommodation and Near Work

Prolonged near work, particularly digital screen exposure, has been linked to hyperopic defocus and accommodation lag, both of which promote axial elongation (18). Some researchers propose that near work and negative lenses (used for myopia correction) have a similar impact on myopic progression by creating persistent optical defocus (23). Studies show that progressive addition lenses (PALs), designed to reduce accommodation lag, have limited success in slowing myopia, suggesting that additional factors, such as dopaminergic signaling and scleral remodeling, play a role (30).

Evidence linking digital device usage to myopia

The increasing use of digital devices, particularly among adolescents, has raised concerns about its potential role in myopia progression (31). Recent systematic reviews and meta-analyses suggest a significant association between prolonged screen exposure and myopia, though the exact causal mechanisms remain debated. This section reviews the current evidence on the relationship between digital device use and myopia, examining findings from meta-analyses, the impact of different digital devices, and limitations in the existing research.

Synthesized evidence: what meta-analyses reveal

Multiple systematic reviews and meta-analyses have investigated the correlation between screen time and myopia. A study by Foreman et al. (2021) analyzed 33 studies, with 11 included in a meta-analysis (7). The results indicated a statistically significant association between smart device usage alone (OR 1.26, 95% CI 1.00–1.60) and myopia, with an even higher association when combined with computer use (OR 1.77, 95% CI 1.28–2.45). However, the study highlighted significant limitations, including reliance on self-reported screen time, high inter-study heterogeneity, and a lack of standardized objective measurements of both myopia progression and digital screen exposure.

Another meta-analysis by Zong et al. (2024) reviewed 19 epidemiological studies, including 102,360 participants, and found a strong correlation between screen time and myopia risk (8). The study reported that each additional hour of screen use per day was associated with a 7% increase in myopia risk (OR = 1.07, 95% CI 1.01–1.13). Notably, the association was strongest for computer screen exposure (OR = 8.19, 95% CI 4.78–14.04), while smartphones showed a weaker correlation. These findings suggest that screen size, viewing distance, and duration of exposure play a crucial role in determining myopia risk.

The COVID-19 pandemic further reinforced concerns about screen time and myopia (31). Studies conducted in China during lockdowns reported a –0.3 diopter myopic shift in children, alongside a two-fold increase in screen usage due to remote learning (32). Reduced outdoor activity during this period likely exacerbated the impact of prolonged near-work exposure, supporting the hypothesis that digitalization and behavioral changes contribute to increased myopia prevalence (32).

Despite these findings, researchers emphasize that correlation does not imply causation. The existing evidence largely relies on cross-sectional and observational studies, making it difficult to determine whether digital screens directly cause myopia or merely act as an exacerbating factor in an already myopia-prone population.

Types of digital devices and myopia risk

Smartphones

Smartphones are particularly concerning due to their small screen size, high pixel density, and close viewing distance (33). Studies suggest that smartphone users engage in prolonged near-work activities, leading to increased accommodation demand and convergence strain, which may accelerate axial elongation, the primary structural change in myopia (34). A study by McCrann et al. (2020) found that myopic students used significantly more smartphone data per day (1,131 MB) compared to non-myopic students (614 MB), suggesting a potential link between increased smartphone use and myopia progression (33). However, the study noted that self-reported screen

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time did not significantly differ between groups, indicating possible inaccuracies in subjective assessments.

Tablets and Computers

Tablets and computers typically have larger screens and longer viewing distances compared to smartphones. However, these devices are often used for extended durations, particularly in educational settings. Meta-analyses suggest that prolonged computer use has a stronger correlation with myopia than smartphone use, likely due to higher screen exposure time rather than viewing distance alone (7). A longitudinal study by Wang et al. (2021) found that children who used tablets for more than four hours per day had nearly double the risk of developing myopia compared to those with limited screen time (35). Similarly, the Zong et al. (2024) study found that computer screen exposure had the highest odds ratio (OR = 8.19, 95% CI 4.78–14.04) for myopia risk, emphasizing that screen duration may be a more critical factor than device type alone (8).

Television Screens

Unlike handheld digital devices, television screens are generally viewed from a greater distance, reducing the need for sustained accommodation and convergence stress. As a result, watching television has a weaker association with myopia compared to smartphones and tablets (36). However, some studies suggest that excessive TV viewing may indirectly contribute to myopia by displacing outdoor activities, a known protective factor against myopia progression (36, 37).

Conflicting studies and limitations

Research on digital screen use and myopia progression shows conflicting results, largely due to methodological limitations. Many studies are cross-sectional, preventing causal conclusions, while confounding factors like genetics and outdoor time complicate findings (7–9, 18, 34). Self-reported screen time lacks accuracy, and the absence of large-scale randomized controlled trials (RCTs) further weakens the evidence. Some studies suggest reduced outdoor exposure, rather than screen time, may be the primary driver of myopia. The table below summarizes these key limitations **(Table 2)**.

Table 2: Conflicting evidence and limitations in myopia research

Limitations	Description	Impact on findings
Variations in study design	Many studies are cross-sectional, providing only a snapshot of myopia prevalence. Longitudinal studies are needed to confirm causality.	Cross-sectional studies cannot determine if screen time causes myopia or is merely associated with it.
Confounding factors	Factors like genetic predisposition, education levels, and outdoor activity influence myopia development.	Makes it difficult to isolate screen time as an independent risk factor for myopia.
Lack of standardized measurement tools	Many studies rely on self-reported screen time, which is prone to recall bias and inaccuracies.	Reduces the reliability of findings; objective tools (e.g., wearable trackers) are needed for accurate assessment.
Absence of Randomized Controlled Trials (RCTs)	No large-scale RCTs have directly tested screen time's impact on myopia progression due to ethical and practical challenges.	Limits the strength of evidence and prevents definitive conclusions about causation.
The role of outdoor exposure	Some studies suggest that reduced outdoor time, rather than screen time itself, is the main driver of myopia progression.	Raises the question of whether screen use is a direct cause of myopia or simply reduces time spent in protective outdoor environments.

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Behavioral and lifestyle modifications for myopia prevention

The increasing prevalence of myopia, particularly among adolescents, necessitates the implementation of effective behavioral and lifestyle modifications to mitigate its progression. While genetic predisposition plays a role in myopia development, environmental factors such as prolonged near-work activities, excessive screen time, and reduced outdoor exposure are significant contributors (4, 38, 39). Several strategies have been proposed to prevent myopia onset and slow its progression, focusing on lifestyle adjustments and environmental modifications **(Table 3)**.

Table 3: key behavioral and lifestyle modifications for myopia prevention

Strategy	Description	Supporting evidence
Increased outdoor time	At least 120 minutes per day of outdoor exposure to natural light.	Reduces myopia onset by stimulating dopamine release and slowing axial elongation (29, 37, 40, 41).
Limiting screen time	Reduce daily screen use, follow the 20-20-20 rule (break every 20 minutes, look 20 feet away, for 20 seconds).	Excessive work is linked to higher myopia risk (5, 42).
Proper lighting	Ensure well-lit environments, avoid dim lighting when reading or using screens.	Poor indoor lighting increases accommodation stress (43).
Reading distance & posture	Maintain a distance of at least 30 cm from books and screens, sit upright with proper back support.	Close working distances increase accommodation demand, contributing to myopia (38).
Visual breaks & blinking	Encourage regular breaks from near work and blinking exercises.	Helps reduce digital eye strain and dry eye symptoms (44).

Increased outdoor exposure

Spending more time outdoors has been widely recognized as one of the most effective preventive measures against myopia (41). Studies have demonstrated that children who engage in outdoor activities for at least 120 minutes per day exhibit a lower risk of developing myopia (38). The protective effect of outdoor exposure is attributed to increased exposure to natural light, which stimulates dopamine release in the retina, inhibiting excessive axial elongation of the eyeball. A school-based cluster randomized trial in China found that incorporating additional outdoor time into school curriculums significantly reduced myopia incidence (40). Similarly, a meta-analysis revealed that each additional hour spent outdoors per day reduces myopia progression by approximately 2% (41).

Reduction of screen time and near-work activities

Studies suggest that individuals who spend more than three hours per day on near-work activities are at a higher risk of developing myopia compared to those with limited exposure. The 20-20-20 rule, which recommends taking a 20-second break every 20 minutes while focusing on something 20 feet away, has been proposed as an effective strategy to reduce visual strain (42). Additionally, maintaining a reading distance of at least 30 cm and ensuring adequate room lighting can help alleviate accommodative stress and minimize myopia progression (38).

Implementation of proper lighting conditions

Lighting plays a crucial role in visual health, particularly in reducing the risk of myopia progression (43). Insufficient indoor lighting can lead to increased accommodative demand and

http://dx.doi.org/10.52533/JOHS.2026.60103

prolonged near-work stress (43). Studies suggest that maintaining bright ambient lighting, optimizing desk lamp positioning, and maximizing exposure to natural daylight can significantly lower myopia risk (38, 39). Implementing blue light filters on screens and adjusting screen brightness can further mitigate digital eye strain and reduce visual fatigue (44).

Regular visual breaks and postural adjustments

Maintaining proper posture and incorporating regular visual breaks are essential in reducing eye strain associated with near-work activities (44). Ergonomic recommendations include maintaining an upright sitting posture, ensuring screens are positioned at eye level, and using chairs with adequate back support (38). Moreover, encouraging children to engage in alternative activities that do not require sustained near focus, such as outdoor play and sports, can further reduce myopia risk (38).

Future directions and research gaps

Despite increasing evidence linking digital device use to myopia progression, significant research gaps remain. Future studies should focus on establishing a clear causal relationship through well-designed longitudinal studies and randomized controlled trials (RCTs). Current research largely relies on self-reported screen time, which is prone to recall bias; therefore, standardized, objective measurement tools such as wearable trackers and screen-time monitoring apps should be integrated into studies. Additionally, the interaction between screen use, accommodation stress, and axial elongation requires further investigation to determine the specific mechanisms contributing to myopia progression. Understanding the role of different types of digital devices, screen distances, and lighting conditions will also help refine preventive strategies tailored to adolescents' digital habits.

Another crucial area for future research is the interplay between screen time and outdoor exposure. While outdoor activity is widely recognized as protective against myopia, the extent to which screen use displaces time spent outdoors remains unclear. More research is needed to explore whether specific interventions, such as school-based policies that encourage outdoor recess or digital device usage guidelines, can effectively balance screen exposure and outdoor activity. Additionally, investigating personalized myopia prevention strategies, incorporating genetic predisposition and lifestyle factors, could lead to more targeted interventions. As digital education and screen reliance continue to grow, interdisciplinary collaboration between ophthalmologists, educators, and technology developers will be essential in designing evidence-based policies to protect adolescent eye health.

Conclusion

The rising prevalence of myopia, particularly among adolescents, highlights the urgent need to understand the impact of digital device usage on eye health. While evidence suggests that prolonged screen time may contribute to myopia progression through increased accommodation stress and reduced outdoor exposure, inconsistencies in research findings prevent definitive conclusions. Behavioral modifications, including limiting screen time, maintaining proper viewing distances, and increasing outdoor activity, remain key preventive strategies. However, further research is needed to establish causality and refine intervention strategies. As digital reliance grows, a multidisciplinary approach integrating ophthalmology, education, and technology is essential to develop evidence-based guidelines. Addressing these research gaps will be crucial in mitigating the long-term public health impact of myopia

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Author contribution

All authors contributed to conceptualizing, data drafting, collection and final writing of the manuscript.

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