Nearsightedness: A Comprehensive Review of Myopia and its Impact on Vision

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ABSTRACT

Introduction:

Myopia is a common ocular disorder that affects nearly 140 million people in the US. It causes difficulty in focusing on objects located at a far distance. The cause of myopia is multifactorial and only partially understood. There are several medical and surgical management options for myopia in adults, and only some of these apply to adolescents, even though the average onset of myopia is reported to range from 6-14 years old. In this literature review, we will review the current understanding of the causes, challenges, management options, and preventative measures of myopia in adults and adolescents and identify gaps for future research.

Research Question: What does the current literature describe about the causes, management options, and preventative measures of myopia in adults and adolescents, and what are areas for possible future research?

Methods:

We searched PubMed, Embase, Web of Science, and Cochrane Library from the database origin through January 3, 2024. We included manuscripts describing the causes, challenges, management options, and preventative measures of myopia in adults and adolescents. We restricted our review to full-length articles published in English.

Discussion:

The causes and management options for myopia for adults and children are well-researched, though gaps remain. The cause of myopia is multifactorial, with genetic and environmental components, though a thorough understanding of all causes has not been achieved. There are several challenges associated with living with myopia, including financial, social, and management-related challenges. Additionally, while non-surgical treatments such as orthokeratology (Ortho-K), contact lenses, glasses, and atropine eye drops are effective, they can be very costly and translate to a life-long financial burden. The same applies to surgical treatments such as refractive lens exchange (RLE), photorefractive keratectomy (PRK), and laser-assisted in situ keratomileusis (LASIK). Furthermore, there are currently no safe surgical treatments for adolescents due to their eyes being underdeveloped. More research is needed to thoroughly understand the causes of myopia and possible additional management options for adolescents. This work should include expert-conducted studies, studies on how to alleviate the effect of refractive surgery on growing eyes, and more studies on how to effectively reduce the acute repercussions of refractive surgery.

Conclusion:

In this review, we summarized the current understanding of the causes, challenges, management options, and preventative measures of myopia in adults and adolescents and

identified gaps for future research. It is clear that myopia has far-ranging impacts on patients, and more research can change how we improve the quality of life of millions of Americans.

Introduction

Myopia, or nearsightedness, is a refractive error that makes far-off objects appear unclear while closer objects appear distinct. Myopia affects nearly 140 million people in the U.S.[1] It is essential to catch and treat myopia early because, after its onset in adolescents and teenagers, it typically worsens every few months until the late teenage or early adulthood years. This ultimately causes a greater burden on families compared to if it was caught and treated early.[2] The current body of literature regarding the effects and treatments for myopia is well-developed. Many treatments have been identified, and their safety and efficacy have been compared. In this literature review, we will summarize the literature on the effects of and treatments for myopia in adults and adolescents, discuss preventative measures for myopia in adolescents, and identify several gaps for future research.

Research Question: What does the current literature describe about the causes, management options, and preventative measures of myopia in adults and adolescents, and what are areas for possible future research?

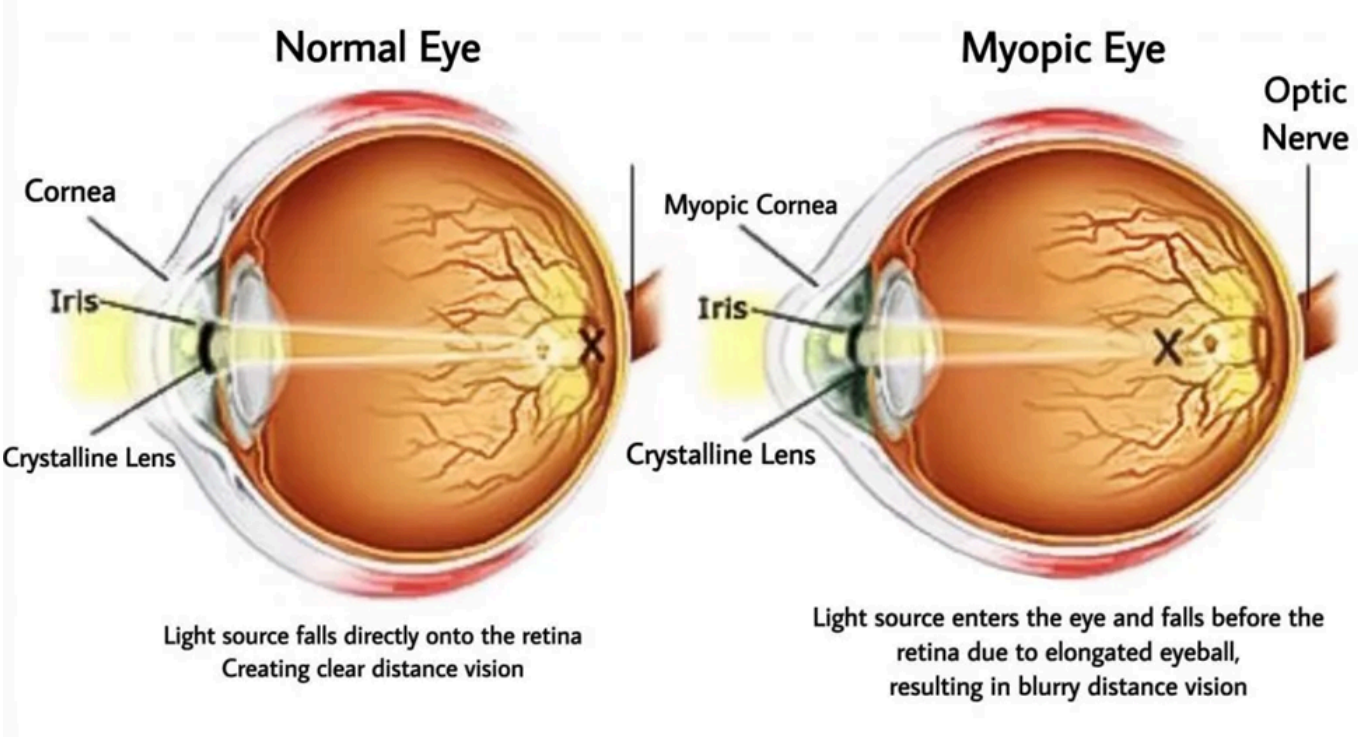
Methods

Our search strategy involved several steps: (1) simultaneous searches of MEDLINE via PubMed, Embase, Web of Science, and Cochrane Library electronic databases, and (2) manual searches of reference lists from included articles to capture studies that did not register in the electronic search. Database searches focused on causes, challenges, management options, and preventative measures of myopia in adults and adolescents. We used publicly available data and Institutional Review Board approval was not required. We excluded opinion and perspective pieces. We restricted our review to full-length articles published in English.

A Closer Look at Myopia

The eye has 2 parts that focus images: the cornea and the lens. The cornea is the clear dome-shaped front portion of the eye, and the lens is a clear structure with a curved surface. In order for a person to see, light must pass through the cornea and the lens. They refract the light so that the light is focused directly on the nerve tissues, or the retina, at the back of the eye. The retina translates light into signals sent to the brain, enabling us to see images.[3] Myopia is a refractive error, meaning that the problem occurs when the shape or condition of the cornea

results in an incorrect focus of light entering the eye. Myopia often results from the shape of the eye being too long from front to back or oval-shaped. It could also occur from the curve of the cornea being too steep. As a result of these changes in the shape of the eye, light rays come to a point in front of the retina. The messages that the retina sends to the brain are discerned as blurry.[4] When looking at nearby objects, the light rays don't have to converge as much because the objects are closer. This allows the myopic eye to focus the light onto the retina more accurately, resulting in clearer vision for nearby objects compared to distant ones.[5]



Causes of Myopia

The cause of myopia is multifactorial, complex, and poorly understood. Myopia is a trait that can be inherited. If one or both of a person's parents have myopia, they have an increased chance of developing the condition. Myopia is neither a dominant nor a recessive trait, but multifactorial, meaning that it is caused by numerous factors.[6–8] More research is needed to better characterize the heritability and genetic component of myopia. In doing so, we could better predict vision needs for adolescents and address them earlier through screening. This will also help save costs by minimizing unnecessary screening. Environmental factors can also contribute to myopia. Some of these factors include more education, near work, and lack of

outdoor exposure. Past studies have shown that people who go earn advanced degrees are at twice the risk of nearsightedness as people who do not.[9] Near work refers to any work that requires focusing on an object close-up and is associated with an increased rate of myopia. Since more people nowadays use computers and spend more time on devices, the rate of myopia has increased.[9] Additionally, when people spend long periods indoors, their eyes don't have to focus on faraway objects, which may increase the risk of myopia.[4,8] The current literature suggests a strong correlation between reduced time spent outdoors, increased near-work activities, and a higher risk of developing myopia. However, a significant weakness lies in the complexity of interactions between genetic predispositions and environmental influences, making it challenging to isolate specific factors responsible for myopia development. Additionally, the varying methodologies and populations across studies contribute to the difficulty in drawing universally applicable conclusions.[10–12]

Financial Challenges

Myopia comes with various challenges, with one of the most apparent being its financial burden. Treatments such as contact lenses, glasses, and surgery can be very costly, and, unlike other conditions that may result in a one-time or short-term cost, the chronic nature of myopia translates to a life-long burden.[13,14] Several studies conducted in various countries have demonstrated the great financial burden that myopia has.[15–17] In fact, some have estimated the annual cost and treatment of myopia to be as great as 10.1 billion USD in the U.S.[17] Moreover, a recent study showed that annual direct costs of myopia in the U.S. exceeded $670 billion in 2018 and are projected to rise to 1.7 trillion in 2050.[18] Costs of glasses and lenses are set to double, and costs of myopic retinopathy, a consequence of severe myopia, are estimated to quadruple.[19] Myopia poses a significant financial burden due to the high costs of treatments and its long-term nature, with estimates reaching billions of dollars globally and projected to continue rising in the future.

Social Challenges

Glasses are the most popular treatment option for myopia, but their use can contribute to social stigma. This can be a significant challenge, especially for young adolescents who are experiencing critical periods of socialization in their early life. Stigma of glasses can cause poor social interactions and bullying especially since most adolescents get glasses from elementary to middle school.[20] In fact, one study found that adolescents who wear glasses are 35-37% more likely to be victims of bullying.[21] The consequences of bullying at this age are grave and have been well researched, as adolescents may experience social withdrawal, have underdeveloped social skills, higher levels of depression and anxiety, and even have long-term consequences into young and middle adulthood, such as suicidality, drug abuse, lower wealth status, and increased susceptibility to chronic disease.[22–26] This may explain why another study found that 48.9% of the participants did not wear their eyeglasses due to teasing and bullying by their peers. Students without poorer presenting visual acuity and lesser correction of visual acuity were more likely to not be wearing their eyeglasses.[27]

Common Management Challenges

Contact lenses are an excellent choice for anyone who needs vision correction and wants to avoid wearing glasses full-time. However, contact lenses have their difficulties and risks. If not used correctly, these treatments can do more harm than help, which is why many adolescents prefer glasses over contact lenses, as they are not ready for the responsibility involved in using contacts.[28] The main reason why contact lenses can be difficult to use is because of the discipline and adherence to hygiene and care routines that are needed. Some people might find this more challenging than others, especially in the initial stages.[29] Several studies have demonstrated the risk of infection that contacts have.[30–34] In fact, some have concluded that the users of daily-wear lenses who wore them overnight had a risk of ulcerative keratitis 9 times as great as the users of daily-wear lenses who did not, suggesting the high risk that comes with improper care of contact lenses.[33] Thus, while contact lenses may be excellent for vision correction and avoiding issues such as childhood bullying, there are still risks involved.

Complications of Untreated Myopia

Untreated myopia by itself is not without complications. Common symptoms of myopia include eyestrain and headaches, which may not always be a cause for concern but can be bothersome and intrusive.[35,36] One of the most feared consequences is retinal detachment, which is a medical emergency and requires prompt treatment.[37] Evidence shows that the risk of developing a retinal detachment is five or six times greater in people with severe myopia compared to those with mild myopia.[38] Additionally, another study found that an increased prevalence of myopia directly correlated with an increased rate of retinal detachment incidence, further asserting the theory that myopia is associated with an increased risk of retinal detachment.[39]

Management Options

Currently, there are many treatments for myopia, and most patients elect non-surgical approaches. Non-surgical treatments include atropine eye drops, orthokeratology, prescription contact lenses, and prescriptive glasses.

Atropine Eye Drops

Certain non-surgical treatments for myopia have been shown in many cases to slow the progression of myopia. Atropine is an acetylcholine receptor inhibitor that is widely used outside ophthalmology for indications such as slow heart rate or antidote for nerve agent poisoning. A 2023 randomized clinical trial found that 0.01% atropine eye drops did not slow myopia progression or axial elongation.[40] A 2023 meta-analysis of 12 randomized controlled trials also found that 0.01% atropine eye drops did not significantly slow the progression of myopia, but did

find evidence that 0.05% atropine eye drops slowed the progression of myopia.[41] Another study supports this finding by concluding that 0.05% atropine was more effective in slowing myopia progression than 0.01% atropine was.[42] Thus, there is strong evidence to suggest that atropine eye drops, in higher doses, may slow the progression of myopia. The majority of prescribed atropine eye drop treatments involve using sufficient doses, and unintentional under-dosing may occur only due to various reasons such as improper administration or inconsistent use.[41,42] Side effects of atropine eye drops include blurred eyesight, stinging, and eye irritation.[43] Further research is needed to determine the most effective dosage and frequency of atropine eye drops to slow myopia progression. Additionally, long-term studies are needed to determine the long-term effects of atropine eye drops on myopia progression. The use of these studies will help incorporate the use of atropine eye drops more frequently in myopia treatment prescriptions.

Orthokeratology (Ortho-K)

One of the newest forms of non-surgical myopia treatment is orthokeratology (Ortho-K). [BL8] Ortho-K is the use of specially designed contact lenses that temporarily reshape the cornea to improve vision.[44] Two studies involving a total of 674 eyes of 337 adolescents found evidence that Ortho-K use significantly slowed myopia progression both after short (1-year) and long-term (12-year) usage.[45,46] Interestingly, there is evidence that Ortho-K lenses are similarly effective to low-dose atropine in the slowing of myopia progression.[41] Additionally, a 3-year study found that while all modalities of treatment showed some efficacy in myopia management, for 184 out of the 342 adolescents in the study (55%), Ortho-K was the most prescribed modality.[46] The body of literature on Ortho-K is nascent, and more research is needed on long-term efficacy and safety as its adoption continues to become more popular amongst school-aged adolescents.

Glasses and Prescriptive Contact Lenses

Several studies have concluded that prescription contact lenses also slow the progression of myopia.[41,47–49] Single-vision prescriptive glasses were not shown to have contributed to controlling myopia progression.[41,50] However, several studies have shown that certain special types of myopia control or myopia management glasses, such as defocus incorporated multiple segments (DIMS) spectacle lenses and spectacle lenses with aspherical lenses, have contributed to slowing the rate of myopia progression.[50–54] These non-surgical treatments temporarily improve vision, but do not provide permanent vision correction.

Photorefractive Keratectomy (PRK)

One of the most popular myopia surgical options is photorefractive keratectomy (PRK). During PRK, an eye surgeon uses a laser to reshape the cornea.[55] Studies have found that 41%-85% of eyes achieve perfect visual acuity and 91-99% of eyes achieve near-perfect visual acuity after

PRK.[56,57] PRK is also considered a very successful procedure for long-term visual outcomes, with studies reporting 59-74% of patients maintaining near-perfect visual acuity as far as 15-16 years out.[58,59]

Side effects and complications of PRK are quite rare; however, some more common complications are corneal ectasia, corneal haze, glare, and vision regression.[60,61] Out of these complications, one of the most rare is corneal ectasia. Corneal ectasia is a rare complication from vision disorders that causes the cornea to thin and bulge out.[62] A study conducted in 2007 asserted that corneal ectasia only occurred in 0.04%-0.6% of PRK procedures.[63] Another rare complication of these is corneal haze. Corneal haze is a cloudy layer in the eye that most commonly appears after trauma, infection, or surgery.[56] Among 266 post-PRK eyes, corneal haze incidence was 5% in blue irises.[64] Additionally, one study demonstrated that glare increased from 27% preoperatively to 42% in the post-PRK patients.[65] One quite common complication of PRK is vision regression, with one 3-year study concluding that myopic regression occurred in 78% of eyes in the first 12 months after PRK.[66] All of these complications occur postoperatively and may require retreatment.[60] Overall, though, patients are highly satisfied with PRK, reporting 80-98% satisfaction rate.[67–69]

Laser-assisted in situ keratomileusis (LASIK)

Another widely-used myopia surgical treatment option is laser-assisted in situ keratomileusis (LASIK) surgery. During the LASIK procedure, a special type of cutting laser or mechanical blade is used to precisely change the shape of the dome-shaped clear tissue at the front of the cornea to improve vision.[70] LASIK has proven to be very effective, with several large studies showing greater than 99% achieving near-perfect visual acuity and 70% - 95% achieving perfect vision.[71,72] In addition, LASIK has a 95% patient satisfaction rate.[73,74] LASIK surgery is also considered a very successful and popular elective procedure, with approximately 16.3 million procedures performed worldwide since the inception of LASIK in 1989.[75]

One of the most common complications after LASIK is dry eye. Several studies have shown that immediately after LASIK, 95% of patients reported dry eye symptoms. Dry eye symptoms were reported in as high as 60% of patients 1 month after LASIK.[76–79] In fact, dry eye was more common following LASIK than PRK surgeries.[80] Additionally, the risk of epithelial ingrowth (EI) is significantly increased in various clinical circumstances of LASIK, especially when the flap is lifted for retreatment.[81–83] Other complications of LASIK surgery include corneal flap abnormalities, corneal ectasia, unexpected refractive outcomes, irregular astigmatism, decentration, visual aberrations, and loss of vision. Along with dry eye, common temporary side effects of LASIK include infectious keratitis and diffuse lamellar keratitis.[23–26] One advantage of LASIK is that patients are also typically able to see full results after just a few hours of having undergone the procedure, whereas PRK patients tend to start seeing a difference after a few days.[84] One study also demonstrated that LASIK provided better visual outcomes than PRK in patients who have undergone cataract extraction and intraocular lens placement.[85]

Phakic intraocular lens surgery

Another type of surgical treatment for myopia is intraocular surgery. Intraocular surgery is performed inside the eye rather than on the cornea. There are 2 types of intraocular surgery: phakic intraocular lens surgery and refractive lens exchange surgery.[86] Phakic intraocular lens surgery involves the placement of an artificial lens inside the eye without disturbing the eye's natural lens. The eye is numbed with eye drops or local anesthetic. Microscopic holes are created in the peripheral iris either with a laser or with scissors to encourage normal eye pressure after phakic intraocular lens placement.[87] Phakic intraocular lens surgery is considered a generally safe and effective procedure. An 8-year follow-up study comprised of 67 eyes with toric phakic intraocular lens surgery found that the mean corrected distance visual acuity (CDVA) and uncorrected distance visual acuity (UDVA) significantly improved from preoperative to 1 year after implantation, and remained stable over the 8-year follow-up. Additionally, the spherical equivalent (SE) significantly improved after surgery.[88]

Refractive lens exchange (RLE)

Refractive lens exchange (RLE) is a type of eye surgery where the natural lens in the eye is removed, and a clear artificial lens is put in its place. This option corrects the refractive error as well as eliminates the formation of cataracts in the future and can be a good alternative for people who are not candidates for LASIK or PRK.[89] This includes those whose vision is not stable, those who have corneal scars or disease, and those who have a history of certain eye infections.[81,82] RLE is known to be quite a successful procedure. A study comprised of 39 patients with refractive lens exchange found that 99% and 100% of patients achieved perfect and near-perfect monocular corrected distance visual acuity (CDVA), respectively. Binocularly, 100% of patients achieved a perfect binocular corrected distance visual acuity (CDVA).[90] A study comprised of 608 patients with monovision LASIK (which is receiving LASIK in only one eye) and 590 patients with RLE concluded that 84.7% and 90.7% of patients with moderate to high myopia achieved a perfect binocular uncorrected distance visual acuity (UDVA) for monovision LASIK and RLE, respectively.[91] However, along with its high visual acuity results, RLE surgery has many postoperative complications. Studies have demonstrated that complications such as posterior capsular opacification, retinal detachment, and cystoid macular edema can occur after RLE.[92,93]

Myopia in adolescents

Surgical treatments for myopia are preferable to non-surgical treatments because many non-surgical treatments only slow the progression of myopia, while surgical treatments actually fix nearsightedness and usually result in perfect or near-perfect vision.[94] Unfortunately, adolescents cannot be subject to any form of surgical treatment for myopia, since their eyes are still undergoing development. If adolescents receive surgical treatment while their eyes are still developing, the shape of their cornea will continue to change after the treatment as well, leading

to unexpected results.[95] It is important to wait for refractive stability before undergoing laser vision correction.

Management Options in Adolescents

There are several medical and surgical management options for myopia in adults, but none of these are safe for adolescents, even though the average onset of myopia is reported to range from 6-14 years old.[96–98] The U.S. Food and Drug Administration (FDA) has only approved LASIK and PRK surgery for individuals over the age of 18 years old.[99,100] Fortunately, there are current ways to prevent the progression of myopia with non-surgical treatments such as contact lenses, glasses, and low-dose atropine eye drops. All of these treatments can be used to slow the growth of myopia in adolescents. Additionally, there are methods to help prevent the diagnosis of myopia altogether. Some of these methods include spending more time outside, using electronic devices for shorter periods, and protecting your eyes from the sun.[101,102] Spending increased time outdoors can help control myopia. A study conducted in Taiwan showed that when sunlight comes in contact with the retina, it releases dopamine into the eye.[103] This may prevent the eye from elongating and becoming more myopic. In addition, decreased use of electronic devices has been shown to protect eye health in adolescents.[104] Vision develops throughout early and middle childhood. If many of these years are spent staring at a screen, a child is training their eyes to focus on a near-field object.[101,105] Over time, they will lose part of their ability to stop focusing on near-field objects, leaving them with permanently near-focused eyes, or myopia. Furthermore, wearing sunglasses will protect adolescents' eyes from harmful ultraviolet rays and help slow the progression of myopia if they spend a lot of time outdoors.[106] It is important to consider these methods of prevention and implement them thoroughly so adolescents can ensure better eyesight.

Conclusion

In this review, we summarized the current understanding of the causes, challenges, management options, and preventative measures of myopia in adults and adolescents and identified gaps for future research. The current literature regarding the effects and treatments for myopia is well-researched though areas remain for future research, especially in understanding the causes of myopia and possible future management options for adolescents. It is clear that myopia has far-ranging impacts on patients, and more research can change how we improve the quality of life of millions of Americans.

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