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The effectiveness of pinhole glasses for minimizing the impact of computer vision syndrome

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ABSTRACT

Background: Computer Vision Syndrome (CVS) is a visual impairment due to using digital devices, such as computer monitors, gadgets, tablets, and others, for a long intensity. Research has shown that precision spectral filters effectively reduce CVS symptoms by blocking blue light. Some studies also state that this lens cannot improve accommodative accuracy or reduce visual stress due to reduced light entering. Pinhole glasses can be a promising intervention in minimizing the impact of CVS, especially in increasing eye acuity and eye accommodative amplitude.

Methods: We searched for articles in PubMed, Science Direct, Google Scholar, and other related journal databases using specific keywords and Boolean logic. We screened all articles using inclusion criteria. The data obtained was then structured based on the problems discussed.

Result: A study showed that visual acuity in Multiple-Pinhole (MPH) glasses and visual acuity in Single-Pinhole (SPH) glasses increased significantly compared to baseline. All participants had the same or better visual acuity when wearing one type of pinhole glasses than when not using them. In addition, participants' depth of focus and accommodative amplitude showed an increase when using MPH and SPH glasses compared to baseline. All participants experienced increased accommodation when wearing both types of pinhole glasses.

Conclusion: Based on SPH and MPH, pinhole glasses have the potential to minimize the impact of CVS.

Keywords: Computer Vision Syndrome, visual impairment, pinhole glasses.

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INTRODUCTION

In this all-digital era, the need for electronic communication devices such as mobile phones, computers, and laptops tends to increase. This is also supported by the Work from Home (WFH) policy and the implementation of distance learning as a result of the Covid-19 pandemic. According to a survey conducted by Ericsson, smartphone users from 2016 to 2020 tend to increase.[1] Changes in work habits and online study require people to stare at cellphones or computer screens longer or even more than eight hours a day. Increased intensity of staring at digital screens can be directly related to increased eye health risks. Symptoms can include tension in the eye muscles, blurred vision, red eyes, and much more.[2] These various symptoms can be categorized as Computer Vision Syndrome (CVS). The global prevalence of CVS includes 60 million people, which will increase yearly.[3] Symptoms of CVS that are not treated immediately will reduce productivity and eye performance, increasing the risk of accidents at work.[4]

Long and continuous use of computers, smartphones, tablets, and other digital devices can put a strain on vision, triggering CVS.[5] CVS is a visual disturbance complaint caused by using a Visual Display Terminal (VDT) such as computer monitors, gadgets, tablets, and other digital devices for too long.[6] Some main mechanisms that cause CVS include accommodative, extraocular, and ocular surface mechanisms. Briefly, it is the result of uncorrected or undercorrected refractive errors as well as binocular and/or accommodative disturbances.[7]

CVS can cause eye fatigue, causing several problems in the organs of vision, such as decreased visual acuity, convergence ability, and eye accommodation. Visual acuity is a quantification that determines the threshold of vision. The better a person's visual acuity at detecting the given stimulus, the lower the visual threshold. Visual acuity is determined by the size of the smallest object, which is visible at a certain distance.[8] Accommodation is the process of changing focus by the eye to maintain the clarity of the image received by the retina.[9] Meanwhile, the accommodation amplitude is a measure of the closest point at which the eye can focus, i.e., the range from the far point to the near point in diopters.[10] So far, several studies have been carried out to minimize CVS symptoms that arise in VDT users, such as precision spectral filters. However, the efficacy of this intervention has not

been sufficiently demonstrated.[5]

Research has shown that precision spectral filters are effective in reducing the symptoms of CVS. However, some studies have also stated that this lens cannot improve accommodative accuracy and cannot reduce visual stress that may be due to reduced light entering.[9] To help accommodation the eyes, pinhole glasses can be used as a therapy in minimizing eye fatigue due to CVS. Pinhole glasses have a significant impact in helping the accommodation of the eye. However, the use of pinhole eyewear has not been sufficiently promoted to minimize the incidence of CVS. Until now, no one has used pinhole glasses as a CVS intervention.

A study showed that visual acuity in pinhole glasses increased significantly compared to baseline (study with target measurements in natural conditions before being given the intervention).[11] In addition, pinhole glasses can increase the depth of focus and amplitude of accommodation.[12] Given this potential, pinhole glasses can be used as a solution to minimize eye fatigue based on the approach of the eye accommodation mechanism to CVS. Therefore, further discussion of this modality is needed. However, studies discussing pinhole glass with CVS are still limited. Therefore, we aim to provide a comprehensive overview of the current state of knowledge regarding the effectiveness of pinhole glasses for minimizing the impact of CVS. We also identify areas for future research and potential implications for practice.

METHODS

In this literature review, we used Boolean "OR" and "AND" logic with the keywords "Computer Vision Syndrome," "CVS," "pinhole glasses," "lens filters," "accommodation amplitude," and "visual acuity" to obtain specific articles. The search was carried out through journal databases, such as PubMed, Science Direct, Google Scholar, and other related journal databases using specific keywords. We screened 33 articles from PubMed, 5 from Science Direct, 17 from Google Scholar, and 8 from other databases. We screened all 63 articles using inclusion criteria: (1) the article is not a case report or case series; (2) the article was published in the last 10 years. No language restriction was used in this literature review. In the end, we included 30 articles that met our inclusion criteria. The data that has been obtained is then structured based on the problems discussed.

Computer Vision Syndrome (CVS)

CVS is a complaint of visual impairment caused by prolonged use of VDTs such as computer monitors, gadgets, tablets, and other digital devices. CVS occurs when there is a disturbance in the focus of vision. This happens more often when staring at a screen on a smartphone than when reading a physical book because the contrast produced by the device is worse than the contrast in a physical book.[6] In addition, exposure of the eyes to very bright screens for a long time can also cause CVS symptoms to appear because the eyes experience visual stress. Even more, poor posture while staring at a computer screen and other environmental factors, such as ambient light, can exacerbate the symptoms of CVS.[13,14]

The main mechanisms that cause CVS include accommodative mechanisms, extraocular mechanisms, and ocular surface mechanisms. This accommodative mechanism causes double vision, blurred vision, myopia, presbyopia, and slowed shifting of focus. Most people with accommodation or binocular problems don't cause symptoms when they perform normal, less strenuous visual tasks. However, this problem can worsen if the computer is used for a long time.[15] The extraocular mechanism occurs due to an inappropriate sitting position when facing a digital screen, so muscle contractions can occur in the long term. Complaints usually arise after using VDT for more

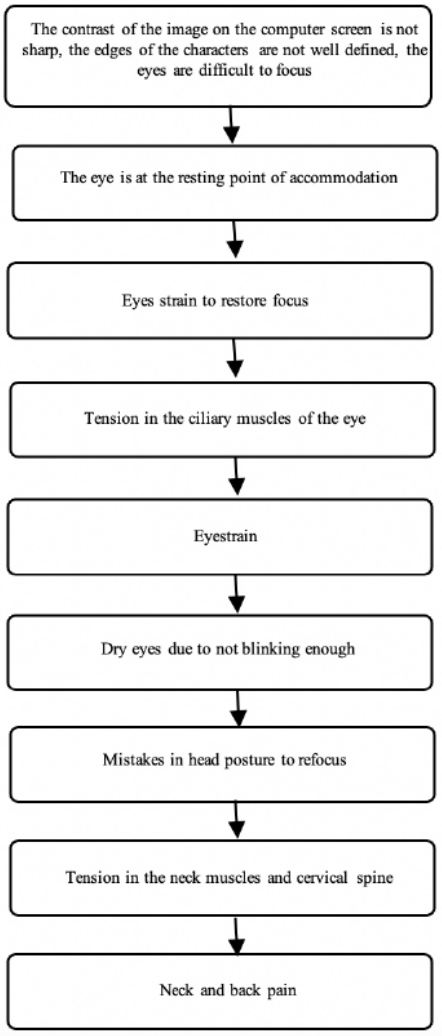

Figure 1. Pathophysiology of Computer Vision Syndrome.[13,14]

Table 1. Symptoms of Computer Vision Syndrome[18]

Category Symptoms	Symptoms	Possible Cause
Asthenopia	Eye strain	Binocular vision
	Tired eyes	Accommodation
	Sore eyes	
Ocular surfaces associated	Dry eyes	-
	Watery eyes	
	Eye irritation	
	Contact lens problems	
Vision	Blurred vision	Refractive error
	Slow change of focus	Accommodation
	Double vision	Binocular vision
	Presbyopia	Correction of presbyopia
Extraocular	Neck pain	Location of a computer screen
	Back pain	
	Shoulder pain	

than three hours.[16]

Meanwhile, the mechanism of the ocular surface is determined by the width of the palpebral fissure (eyelid gap). Ocular surface exposure during VDT use (2.3 cm^2) was almost the same as the relaxed state (2.2 cm^2) and decreased during reading (1.2 cm^2). The increase in ocular surface area exposure is directly proportional to the increase in tear evaporation. An increase in the area of exposure accompanied by a decrease in blink frequency affects the viability of the tear film in VDT users so that VDT users experience worse vision problems than when reading.[17] The pathophysiology of CVS is briefly explained in Figure 1. Symptoms of CVS can be grouped into four: related ocular surface, visual, extraocular, and asthenopia. Asthenopia is a major component of CVS, as stated in Table 2.[14]

When looking at the screen at close range, the eyes require accommodation, convergence, and miosis. When this happens continuously, it can cause eye strain. Research also states that text on a computer is made up of tiny pixels. Meanwhile, the smaller the pixels that the eye sees, the lower the resolution captured, so the visual system will work harder.[14] This can cause eye strain and fatigue.

In addition to these factors, other factors stress, thus affecting CVS. These factors consist of brightness, contrast, screen glare, and screen refresh rate. As explained earlier, inadequate screen brightness and poor contrast can interfere with eye focus, making eyes work harder and tire more easily. While the screen refresh rate affects the rate of eyelid blink.[14] Blinking aims to maintain the state of the eye as it affects the maintenance of the ocular surface environment and tear ducts.[19] Thus, the degree of blinking affects CVS symptoms. The difference in blink rate during computer leaks and breaks is very significant. When leaking a computer, we sometimes encounter small fonts and poor contrast. This can reduce a person's blink rate.[14]

Computer users with myopia and hypermetropia may develop complaints of blurred vision, diplopia, and transient myopia after work. This disorder is temporary in some workers and even persists.[14] A comprehensive eye exam is performed to diagnose CVS. The test, with particular emphasis on the visual requirements of working distance digital devices, includes a patient history to determine the patient's symptoms and the presence of general health problems, medications being taken, or environmental factors that may be contributing to symptoms associated with computer use, measurement of visual acuity for assess the extent to which vision may be affected, refraction to determine the appropriate lens power needed to compensate for refractive errors (farsightedness or astigmatism) and test how the eye focuses.[5]

To get a single, clear picture of what is being seen, the eye must effectively shift focus, move, and work in unison. This test will look for problems that prevent the eye from focusing effectively. This test can be done without using eye drops to determine how the eye responds under normal vision conditions. Armed with information from this test and from the results of other tests, your doctor can diagnose CVS and recommend treatment options.[5]

CVS is treated with a blue light filter lens.[9] Additionally, the American Academy of Ophthalmologists factors ergonomic tips that include the 20–20–20 rule: every 20 minutes, turn your eyes to look at an object at least 20 feet away for at least 20 seconds. Next, sit about 25 inches from the computer screen and keep the digital light from being brighter than the surrounding light. Taking more frequent breaks from the computer screen has been shown to not only reduce the incidence of CVS but also maintain one's productivity.[14]

Figure 2. (A) Multiple-Pinhole Glasses (MPH) and (B) Single-Pinhole Glasses (SPH).[11]

Table 2. Advantages and Disadvantages of Precision Spectral Filters and Pinhole Glasses[9,11,12,23–25]

Aspect	Precision	Pinhole Glasses
Excess	Reducing subjective and objective measures of eye fatigue	Reduce circles of confusion
	Helps reduce symptoms of eye strain	Blocking peripheral deviation
	Reduces the symptoms of Computer Vision Syndrome by reducing the transmission of blue light	Increase the depth of focus.
	Reduces photochemical damage to the eye	Encourages eye muscles to exercise and relax
Deficiency	Does not increase the accuracy of eye accommodation	Reduce eye strain
	Unable to reduce visual stress	Correcting near and far vision
		Improve retinal clarity
		Improve visual acuity
		Accommodative amplitude increase
		Not functional enough for daily use
		Blocking part of the vision
		Increase eye fatigue, especially when reading.
		Causes headaches and increases eye strain if used while working

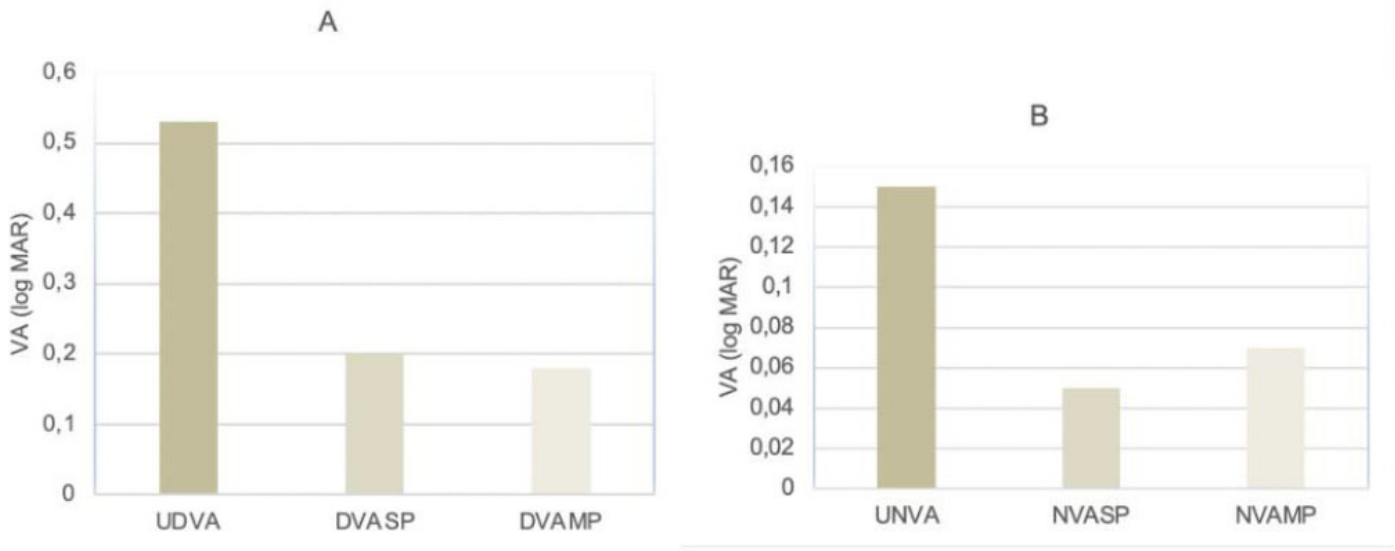

Figure 3. Effect of SPH and MP Glasses on Visual Acuity.[11]
UDVA: Uncorrected Distance Visual Acuity; DVASP: Distance Visual Acuity with Single-Pinhole Glasses; DVAMP: Distance Visual Acuity with Multiple-Pinhole Glasses; UNVA: Uncorrected Near Visual Acuity; NVASP: Near Visual Acuity with Single-Pinhole Glasses; NVAMP: Near Visual Acuity with Multiple-Pinhole Glasses.

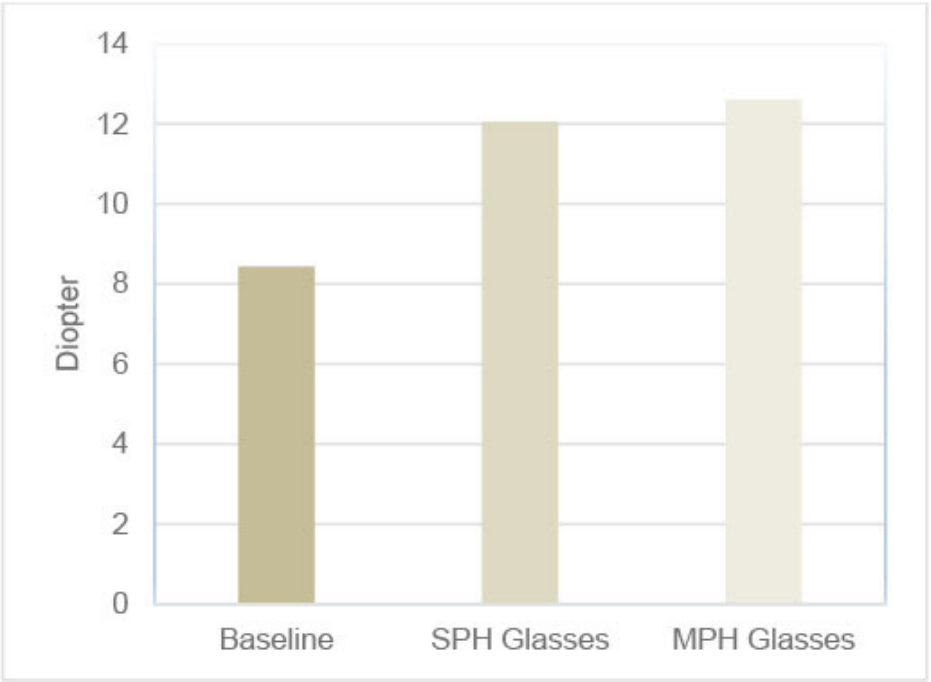

Figure 4. Effect of Pinhole Glasses on Accommodative Amplitude.[11]

Computer Vision Syndrome (CVS) Intervention

Increased disturbance of ocular accommodation, particularly at high frequencies (the eye experiences a moderately intense loss of focus), appears to be associated with digital eye strain. Several studies have reported that precision spectral filters can reduce and control accommodative interference and minimize symptoms due to CVS. This lens works by blocking the blue light emitted from digital devices for two hours. One study also showed that over twelve months, multiple lens designs overall provided a better user satisfaction rating than single-vision glasses. However, other studies have shown that precision spectral filters do not improve the accommodation accuracy of the eye.[9]

However, precision spectral filters, including blue light filter lenses, can help to reduce the symptoms of eye strain from digital devices. Blue light from digital devices can increase symptoms of visual fatigue because blue light spreads across the eye and can impact the eye's efforts to improve and maintain visual focus. Nowadays, many people are using precision spectral filters, considering their very fast promotion. One study found that blue light filter lenses significantly reduced subjective and objective measures of eye fatigue from two hours of computer use.[9]

In a 2017 review, Lawrenson JG et al.,[20] identified 3 of 118 randomized control studies that analyzed the effects of blue light filter lenses. In a clinical study, Ide T et al. found that eye fatigue, as measured by the critical blink fusion frequency (a visual measure of executive function and a proxy for eye fatigue), was significantly reduced by blue light filter lenses.[21] In addition, similar studies have also shown that the intensity of using blue light filter lenses can reduce CVS symptoms.[22]

Basically, the more blue light is filtered, the lower the occurrence of CVS symptoms and sequelae. However, although blue light is relatively strong, research suggests that blue light is not strong enough to

cause damage to the retina. Laboratory studies have confirmed that reducing the transmission of blue light (430 nm) through blue light filter lenses by 50% can reduce about 80% of photochemical damage to the retina.[23] Some studies also state that this lens cannot improve accommodative accuracy and cannot reduce visual stress that may be due to reduced light entering. CVS treatment intervention to increase the accommodative amplitude and visual acuity of the most effective replacement of light filter lenses, namely pinhole glasses.

Pinhole Glasses

Pinhole glasses are glasses with a series of double pinholes, the same size, and arranged regularly. Pinhole glasses have been marketed in many countries to improve vision by reducing circle of confusion (optical point caused by the cone of light rays from the lens not achieving perfect focus when imaging a point source) and blocking peripheral aberrations, increasing depth of focus, encouraging eye muscles to exercise and relax and reduce eye strain and discomfort.[11]

Pinhole glasses haven't come to the attention of the ophthalmic department. A study conducted by Kim WS et al. showed that MPH increased uncorrected near and far visual acuity, depth of focus, and accommodative amplitude.[12] Unlike the SPH, more than a hundred pinholes are arranged in each lens of MPH glasses. Therefore, MPH glasses should allow sufficient light to enter to enhance the illumination behind the glasses so that MPH eyewear users can easily identify the aperture perpendicular to their visual axis. An aperture is an opening that allows light to enter. The only difference between MPH and SPH glasses is the number of pinholes. However, the difference in functional changes between MPH and SPH glasses has not been studied.[11]

Pinhole Glasses Working Mechanism

Pinhole glasses, especially MPH glasses, can be used to correct presbyopia, such as near and far vision, regardless of the individual's refractive status. These glasses also don't require a prescription.[26]

The mechanism of action of pinhole glasses is to reduce the circle of blur and block the incident light that deviates from the cornea and lens because the holes in pinhole glasses are smaller in diameter than the diameter that the pupil of the eye can handle.[11] A small hole in pinhole glasses can narrow the incident light, block the stray light from reaching the retina, and improve retinal clarity.[24]

This pinhole effect can increase the depth of focus and the amplitude of accommodation.[26] Therefore, pinhole glasses can improve visual acuity in individuals with presbyopia. A study conducted by Kim WS et al. showed that visual acuity (VA) in MPH glasses and visual acuity in SPH glasses increased significantly compared to baseline. All participants had the same or better VA when wearing either type of pinhole glasses than not wearing them. No significant difference was observed between VA when wearing MPH and SPH glasses.[11] Unlike filter lenses, which are used all the time, pinhole glasses are used for a certain period of time. This is because wearing pinhole glasses intensely can result in eye fatigue.[11]

Figure 3A shows that the mean distance visual acuity with single-pinhole glasses (DVASP) is significantly better than the average uncorrected distance visual acuity (UDVA). The difference between DVASP and distance visual acuity with multiple-pinhole glasses (DVAMP) was not significant. Figure 3B shows that the average near visual acuity with single-pinhole glasses (NVASP) is significantly better than the average uncorrected near visual acuity (UNVA). The difference between NVASP and near visual acuity with multiple-pinhole glasses (NVAMP) is not significant.[11]

In addition, participants' depth of focus and accommodative amplitude showed an increase when using MPH and SPH glasses compared to baseline. No significant difference was seen in the use of MPH and SPH glasses. All participants experienced increased accommodation when wearing both types of pinhole glasses. However, the accommodative amplitude changes in MPH and SPH glasses were not significantly different.[11]

Figure 4 shows a significant difference when not wearing pinhole glasses and using pinhole glasses.[11] Glare and reflections from the monitor due to the use of digital devices make it difficult for the eyes to focus, causing fatigue in the organs of vision.[27] Eye fatigue causes several problems with the organs of vision, such as irritation, double vision, red eyelids, headaches, decreased eye acuity, and decreased ability of eye convergence and accommodation. Based on this, pinhole glasses can overcome the decline in eye acuity due to CVS. However, pinhole glasses are not functional enough for everyday use if a person is indicated to be nearsighted. Although pinhole glasses focus on objects in front of us, they also block parts of our vision. A study conducted in 2017 found that pinhole glasses actually increased eye fatigue, especially when used while reading. Working with pinhole glasses can cause headaches due to increased eye strain.[11] Therefore, the use of pinhole glasses should be worn at certain times. In addition, pinhole glasses also increase the accommodative amplitude of the eye which is the maximum accommodation amount of the effect that is produced when a person sees at close range.[25,28]

For users of digital devices, there is a decrease in the amplitude of accommodation. By using pinhole glasses, the decreased accommodative amplitude of the eye due to CVS can be increased again. However, for better improvement, the author suggests using glasses that block blue light when using digital devices and afterward using pinhole glasses as a therapy to increase eye sharpness and reduce accommodative amplitude due to Computer Vision Syndrome.

CONCLUSION

Computer Vision Syndrome (CVS) is characterized by symptoms such as tension in the eye muscles, blurred vision, red eyes, and many more. This happens because the use of VDT in a long intensity and carried out continuously will have an impact on impaired eye accommodation and eye acuity. Disruption of eye accommodation and sharpness will certainly be a serious problem if not treated immediately. The preventive measure currently used by the public is to use precision spectral filters. The mechanism of action of precision spectral filters by blocking the blue light produced by digital devices is said to

reduce eye muscle tension. However, precision spectral filters have proven to be ineffective in increasing accommodation and eye acuity, so an alternative is needed. Recent interventions based on several studies show that pinhole glasses are the right choice to overcome this.

A small hole in pinhole glasses can narrow the incident light, block the stray light from reaching the retina, and ultimately improve retinal clarity. This pinhole effect can increase the depth of focus and the amplitude of accommodation. Based on this, by using pinhole glasses, the decline in eye acuity due to CVS can be overcome.

In addition, pinhole glasses also increase the accommodative amplitude of the eye, where the accommodative amplitude is the maximum accommodation amount of the effect that is produced when a person sees at close range. In users of digital devices, there is a decrease in the amplitude of accommodation. By using pinhole glasses, the decreased accommodative amplitude of the eye due to CVS can be increased again. While limitation of this study is the exact mechanism for wearing pinhole glasses has not been discussed much in this study. Apart from that, the functional differences between SPH and FSH are also unclear. The author hopes that future research can discuss this matter in more depth.

CONFLICT OF INTEREST

The author consciously declares that there is no conflict of interest in all aspects of the study.

ETHICAL CONSIDERATION

This literature study does not conflict with ethics. However, this study has following the COPE and ICMJE guidelines.

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AUTHOR CONTRIBUTION

The first, second, and third authors screened and entirely wrote the literature review. Meanwhile, the fourth and fifth authors supervise writing, make corrections, and inform related data or library sources. All authors read and give final approval to the manuscript to be printed. Any disagreement was discussed with all authors.

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