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Exploring the link between convergence insufficiency and electronic device use

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Abstract

Purpose: This literature review aims to explore the potential link between Convergence insufficiency (CI) and the use of electronic devices. CI is a common binocular vision disorder characterized by difficulty in maintaining proper eye alignment during near tasks.

Method: Search the literature using keywords such as "Convergence insufficiency ", "electronic devices", "smartphones", "tablets" and "computer" in electronic databases such as PubMed, Scopus and Google Scholar. The review included studies examining the relationship between CI and electronics, including experimental and observational studies.

Results: These used various methods, including surveys, clinical studies, and experimental designs. Findings suggest that prolonged and excessive use of electronic devices may lead to developing or worsening CI symptoms.. Factors such as close work, decreased frequency, and perceived fatigue associated with the use of electronic devices have been implicated as potential mechanisms behind this relationship. However, the evidence remains limited and inconclusive, as some studies report conflicting results.

Conclusion: Although there is some evidence of a possible link between CI and electronics, more research is needed to establish a positive relationship. The results of this literature review highlight the importance of promoting healthy lifestyles and raising awareness of the risks associated with the overuse of electronic devices, especially for people with CI. Future research should focus on investigating prevention and interventions to reduce the negative effects of electronic devices on vision health.

Keywords: Convergence Insufficiency; Binocular Vision Disorders; E-Learning; Digital Eye Strain; Computer Vision Syndrome.

1. Introduction

Convergence insufficiency (CI) is a common binocular vision disorder characterized by difficulty maintaining proper eye alignment during near-vision tasks. Individuals with CI often experience symptoms such as eye strain, double vision, blurred vision, and difficulty concentrating, particularly during prolonged reading or screen-related activities. With the increasing prevalence of electronic devices such as smartphones, tablets, and computers, concerns have emerged about their potential to exacerbate visual health problems, including the development or worsening of CI. This literature review aims to examine the relationship between CI and the use of electronic devices, considering the implications of prolonged screen time on visual function.

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The rise of convergence insufficiency in modern society may be partly attributed to the technological advancements associated with the Fourth Industrial Revolution (4IR). With the integration of digital technology into daily life, near-vision tasks have become more intensive, particularly for younger populations.[1] The COVID-19 pandemic further accelerated this trend by forcing many educational systems to adopt online learning models. As a result, children and adults alike have been exposed to increased screen time, raising concerns about the impact of such near work on the eyes and visual systems.[2]

Traditionally, near work was defined as tasks like reading printed books or writing with pen and paper. However, in today's digital environment, near work now includes extended periods spent using electronic devices. [3]Several studies have recognized that screen time for children, even as young as two years old, has increased significantly, with pre-pandemic data showing average daily use of electronic devices ranging from one to two hours for young children. [4,5]The global shift to online learning has only intensified this trend, furthering concerns about the implications for visual health.[6]

Screen-based reading, as opposed to reading physical materials, presents unique challenges to the visual system. Research has shown that reading from a screen may cause more visual strain than traditional reading due to factors like suboptimal contrast, screen reflections, and the pixelated nature of text. Unlike printed characters, digital characters consist of bright dots with blurred edges, which can contribute to eye strain and discomfort.[7, 8] These visual challenges may play a role in the development or worsening of CI among frequent users of digital devices.

1.1. Changing educational approaches to students: e-learning

The rapid expansion of e-learning has introduced a new dimension to the discussion of CI and digital eye strain. E-learning is increasingly seen as a fundamental aspect of modern education, relying heavily on electronic devices for communication, instruction, and interaction. [9] While e-learning offers significant advantages in terms of flexibility and accessibility, it also raises questions about the long-term effects of extensive screen time on the visual system. Students, who are among the most frequent users of digital devices for educational purposes, may be particularly vulnerable to developing visual disorders such as CI.

In conclusion, electronic devices are an integral part of modern life, used for work, communication, entertainment, and education. However, their prolonged use has been associated with visual issues, including CI. This literature review will explore the impact of electronic devices on CI and discuss possible strategies to mitigate their negative effects on visual health.

2. Methods

To explore the relationship between convergence insufficiency (CI) and the use of electronic devices, a comprehensive search of relevant literature was conducted using electronic databases including PubMed, Scopus, and Google Scholar. The search focused on studies published in the last 10 years, from 2013 to 2023, and used key terms such as "Convergence insufficiency," "E-devices," "Smartphones," "Tablets," and "Computers." Both experimental and observational studies were included, allowing for a broad examination of the association between CI and electronic device usage. Studies involving both clinical and non-clinical populations were reviewed to capture the full scope of the disorder's prevalence and its potential exacerbation due to prolonged screen time.

2.1. Non-clinical population

Richman et al. (2017)[40] investigated the prevalence of binocular and accommodative disorders, including CI, among U.S. optometry students aged 24 to 31. The study revealed that 42% of this population experienced some form of binocular dysfunction, with CI being the second most common disorder, affecting 13% of participants. Similarly, Sharifet et al. (2018) [41]examined CI among Iranian university students, finding a prevalence rate of 10%. Hashemi et al. (2019)[43] later reported a lower prevalence rate of 5.46% in an Iranian sample, although the study acknowledged that factors such as overprotection and punctuality showed a slight but statistically insignificant correlation with CI.

The studies reviewed suggest that CI prevalence may be higher among university students due to the increased visual demands of near work and prolonged periods spent using electronic devices. The higher prevalence among students, compared to the general population, is likely influenced by academic pressures that require extensive near-vision tasks, such as reading and working on digital platforms. However, the differences in CI prevalence rates across these studies also highlight the importance of methodological variations, including diagnostic criteria, population demographics, and sample size. For instance, the study by Hashemi et al. (2019) used a broader age range, which may have contributed to the lower observed prevalence

2.2. Clinical population

In the clinical setting, Lara et al. (2015)58examined vergence disorders, including CI, among patients aged 10 to 35 years and reported a CI prevalence rate of 3.5%. The study employed five diagnostic criteria, including decreased positive fusional vergence (PFV) and near point of convergence (NPC) regression[59] to identify CI. However, a later study by Rao (2020)[59] examined a broader age group of patients (8 to 49 years) who were hospitalized for asthenopia, a condition associated with eye strain. This study found a significantly higher prevalence of CI, with 18% of participants affected.

The discrepancy between these two clinical studies can be attributed to differences in diagnostic rigor. Rao's study applied less stringent diagnostic criteria compared to Lara et al., which may have inflated the observed prevalence of CI. Furthermore, Rao's study occurred during a period of increased electronic device usage, suggesting that prolonged near work on electronic devices could be a contributing factor to the higher CI rates observed. The study's findings align with concerns about the impact of constant close focus required by smartphones, tablets, and computers on vergence functions.

3. Literature Search

A comprehensive literature search was conducted from August 2013 to March 2023 across multiple databases, including Elsevier, PubMed, Medline, and EBSCOhost. The search used combinations of relevant keywords such as "Convergence Insufficiency (CI)," "Vergence Anomalies," "Binocular Vision," "Digital Eye Strain (DES)," "Computer Vision Syndrome (CVS)," "E-devices," "Children," and "Near Work." The search aimed to gather evidence on the relationship between CI, e-device usage, and related visual problems across both clinical and non-clinical populations. Medley reference manager was used to organize and screen the articles. Studies published in English within the last decade were included, and data were extracted from full-text papers that met the selection criteria.

3.1. Digital Eye Strain and Convergence Insufficiency

One of the most notable findings across studies is the significant rise in digital eye strain (DES) due to the increased use of digital devices across all age groups. According to several studies, DES, also known as computer vision syndrome, affects over 50% of computer users and includes various symptoms, such as eye strain, dry eyes, and visual discomfort. DES symptoms can be categorized into two main groups: those associated with vergence and accommodation problems, such as convergence insufficiency (CI), and external symptoms, such as dry eyes. Binocular vision disorders like CI exacerbate these symptoms, particularly during prolonged near-vision tasks on digital devices.10

3.2. Vergence Anomalies in School-Aged Children

A cross-sectional study conducted by Sharifet et al. (2018) involving 537 children aged 10 to 16 years highlighted the prevalence of vergence anomalies in school-aged children. The study used stratified sampling and found that non-strabismic vergence abnormalities, including CI, were the most common visual problem among children, with significant implications for their educational performance. Convergence insufficiency, characterized by difficulties in near work, was identified in 7.1% of the sample, showing a strong correlation with intensive near work tasks, including digital device use. The study emphasized the importance of preventive strategies and visual control to support educational success in children.[11]

3.3. Impact of Near Work and Screen Time on CI Symptoms

Another study by Hashemi et al. (2019) examined the effect of 30 minutes of near work (reading) on CI symptoms in adult populations. The study involved both symptomatic and asymptomatic CI subjects and revealed a significant worsening of CI symptoms, such as increased near-point convergence (NPC) distance and reduced positive fusional vergence (PFV), after the reading task. This study supports the hypothesis that prolonged near work, including activities on digital devices, can exacerbate CI symptoms.

Similarly, a pilot study conducted by Isono et al. (2021) examined the effects of blue light from digital screens on visual fatigue and CI symptoms in adolescents. The study reported a reduction in visual complaints when blue light was filtered from LED-backlit screens, indicating that blue light may contribute to DES and CI.[12]

3.4. E-learning and Increased Screen Time

The shift to e-learning, particularly during the COVID-19 pandemic, has also contributed to the growing concern around CI and visual health. A study by Rao (2020) reported that increased screen time due to e-learning significantly raised

the risk of CI among children and adolescents. The study found that CISS (Convergence Insufficiency Symptom Survey) scores increased by over 43% during periods of isolation and quarantine when students relied heavily on digital devices for learning. The findings suggest that excessive close-up work, without adequate breaks, can negatively impact vergence function, increasing the prevalence of CI.[13]

3.5. Convergence Insufficiency and Mobile Devices

Another critical study by Hashemi et al. (2016) examined the relationship between CI and mobile phone use in a population of 50 individuals aged 5 to 20 years. The study found a statistically significant correlation between prolonged mobile phone usage (more than 6 hours per day) and increased symptoms of CI, such as headaches, eye strain, and difficulties in reading. This study underscored the need for guidelines and interventions aimed at reducing excessive mobile device use, particularly among younger populations.14

The reviewed literature demonstrates a clear link between digital device use and an increased prevalence of CI and related visual problems, such as DES and CVS. Studies consistently show that prolonged near work, whether for academic or recreational purposes, exacerbates vergence dysfunction, particularly in younger populations. This growing issue underscores the need for targeted public health interventions to reduce the impact of excessive screen time and promote better visual habits, including regular breaks and blue light protection. Future research should focus on preventive measures and the long-term effects of digital device use on visual heal.[15]

3.6. Prevalence and Symptoms of Digital Eye Strain

Digital eye strain is a widespread condition, with around 40% of adults and up to 80% of teenagers experiencing symptoms such as eye strain, tired eyes, dry eyes, blurred vision, and headaches. These symptoms can manifest both during and after screen use. The visual discomfort associated with DES has significant implications for occupational productivity, particularly in environments where digital devices are essential for daily tasks. Studies have shown that symptoms can worsen without regular breaks from screen use, and the small screens of smartphones and tablets tend to exacerbate these problems due to the need for closer viewing distances.

3.7. Ocular Causes of Digital Eye Strain

The primary ocular causes of DES are linked to the high visual demands placed on both accommodation and vergence systems. The closer viewing distances required by smaller screens significantly increase the strain on the eyes. Prolonged digital screen use alters natural blink patterns, often reducing the frequency of blinking, which in turn leads to tear film instability and dry eyes. Moreover, the pixelated nature of digital displays, where characters lack clear edges and are composed of bright dots with blurred borders, creates additional visual demands, leading to increased eye strain.

3.8. Impact of Screen Time on Visual Health

A growing body of literature emphasizes the association between increased screen time and the development of various visual problems. For instance, a systematic review involving 15 studies and nearly 50,000 children highlighted a potential link between prolonged screen time and the risk of developing myopia. Although the findings are mixed, there is growing concern that extended use of digital screens during early development may contribute to the progression of refractive errors such as myopia. A separate study found that the average font size and viewing distance when reading on smartphones were significantly closer than traditional print material, increasing the visual demands and potentially contributing to the development of DES.

3.9. Differences in Blink Patterns and Accommodation

Another notable difference between digital displays and printed materials lies in blink patterns. Research has consistently shown that individuals blink less frequently when using digital screens, which can lead to dry eye symptoms. Additionally, closer viewing distances, especially with smaller devices like smartphones, increase the demand on the eyes' ability to accommodate and converge, leading to higher rates of visual fatigue. The effects are particularly pronounced when users spend extended periods without taking breaks, as is common in both professional and educational settings.

3.10. Clinical Management of Digital Eye Strain

The management of DES involves addressing both the environmental and physiological factors contributing to symptoms. Eye care practitioners must be aware of the specific visual demands posed by digital screen use and modify standard eye examinations accordingly. This includes measuring visual acuity at both typical viewing distances for

digital devices and prescribing appropriate refractive corrections for near work. Additionally, regular breaks, proper ergonomic practices, and the use of artificial tears are essential strategies to mitigate the effects of DES.

3.11. Understanding Convergence Insufficiency

Convergence insufficiency is a common eye disorder that affects the ability of the eyes to work together when focusing on nearby objects. It occurs when the eyes are unable to converge or turn inward, causing symptoms such as double vision, eye strain, headaches, and difficulty reading or doing close-up work. The condition can be exacerbated by prolonged use of electronic devices, as the eyes are required to focus at a fixed distance for an extended period of time. Research has shown that individuals who spend a significant amount of time using electronic devices are more likely to experience symptoms of convergence insufficiency. This is due to the fact that electronic screens emit blue light, which can cause eye strain and disrupt the normal functioning of the eyes. Additionally, the constant movement of the eyes across the screen can lead to fatigue and discomfort, further exacerbating the condition.

3.12. Impact of Prolonged Device Use on Eye Health

The increased prevalence of electronic devices in our daily lives has raised concerns about the impact on eye health. Studies have shown that prolonged use of electronic devices can lead to a variety of eye problems, including dry eyes, eye strain, blurred vision, and headaches. These symptoms can be particularly problematic for individuals with convergence insufficiency, as they may exacerbate existing visual issues and contribute to further discomfort.

Furthermore, the blue light emitted by electronic screens has been linked to a range of health problems, including disrupted sleep patterns and increased risk of eye diseases. This is especially concerning for individuals who use electronic devices late into the night, as exposure to blue light can interfere with the body's natural sleep-wake cycle and lead to insomnia.

3.13. Tips for Reducing Eye Strain

To mitigate the effects of prolonged electronic device use on convergence insufficiency, there are several strategies that individuals can incorporate into their daily routine. These include:

Taking regular breaks: It is important to give your eyes a rest by taking frequent breaks from electronic devices. Follow the 20-20-20 rule, which recommends looking at something 20 feet away for 20 seconds every 20 minutes.

Adjusting screen settings: Reduce the brightness and adjust the contrast of your electronic devices to minimize eye strain. You can also try using blue light filters or wearing specialized glasses to reduce blue light exposure.

Practicing good posture: Maintain a proper sitting posture and position your screen at eye level to reduce strain on your neck and eyes. Avoid slouching or hunching over your device, as this can put additional strain on your eyes. By incorporating these tips into your daily routine, you can help alleviate the symptoms of convergence insufficiency and reduce the negative effects of prolonged electronic device use on your eye health.

In conclusion prolonged use of electronic devices can have a significant impact on convergence insufficiency and overall eye health. It is important to be mindful of the potential risks associated with excessive screen time and take proactive steps to protect your eyes. By incorporating simple strategies such as taking breaks, adjusting screen settings, and practicing good posture, you can minimize the effects of prolonged device use and maintain healthy eyesight for years to come.

4. The Visual Effect Of Near Work And Digital Eye Strain In Children

The visual impact of close work and the digital eye as children use smart devices explain much of the new work in today's society. World penetration of smart devices was 34.7% in 2018.[42] considering that reading printed texts is always different from reading from a screen, attention should always be paid to the visual impact of using electronic devices. The image will not appear for a long time. Impact of Daylight Saving Time (DST). [6,10] Most of the consumer's eyesight is between 20.0% and 40%.[44,35,45] some studies8 reported rates as high as 68.5% and 69.0%. Digital eye syndrome is thought to be related to the short-term (acute) and long-term (change) effects of interference caused by focusing on the accommodation and vergence systems. Dry eye symptoms experienced by many users are caused by the drying of the front surface of the eye due to constant focus on digital screens and decreased blinking frequency.[59] Research shows that using electronic devices for an hour causes eye fatigue in young people. Anxiety and confusion may be up to five times greater.[36,37] Internal DES results from interference in the accommodative or vergence systems, or a

combination of both, so there is no doubt that voluntary continued use of electronic devices harms the face. Another cause of DES is the blue light emitted by LED displays used in modern digital devices. Blue light, or short wavelength light, has wavelengths between 400 nm and 500 nm and can damage the structure of the eye.[46] In general, blue light is mostly filtered by eye structures such as the cornea and lens.[47] However, some individuals, such as aphakic and pseudophakic individuals who do not have crystalline lens protection, are sensitive to blue light. Injuries also occur in children due to lenses.[44] Studies have shown that exposure to blue light can worsen DES symptoms in patients. There are several studies investigating the effectiveness of blue light-blocking filters in treating DES symptoms.[22,48,49,50] While some studies [22,49] show improvement in reported symptoms, other studies [50] disagree, so there is some debate about its effectiveness in managing symptoms. Children are more likely to develop DES symptoms than adults. Symptoms occur when the perceived demands of the job exceed the perceived ability to perform a simple task.[51] because children's eyes are quite plastic; the stress of not being able to compensate for near vision can lead to vision problems and/or binocular vision in the next year. Now the reality is that e-learning technologies are integrated into the current education system. This approach has become popular; however, the e-learning perspective should be taken into account. No research determines the direct impact of e-learning and the long-term use of electronic devices. Studies on the effectiveness of binocular vision in children targeting DES are lacking. This distinction needs to be addressed as the digital revolution enters children's world.

4.1. Limitation

A limitation of this review is the lack of diagnostic criteria for CI in the included studies. Some studies have used very strict criteria, while others have used a simpler approach, using only a single diagnosis. These real differences affect the consistency of CI diagnostic reports

and lead to significant differences in the prevalence of the disease across different cultures. All studies included in this review considered CIs or electronic devices; this includes a study on CI and mobile phone use in healthcare. Studies have shown improved vision in children after using electronic devices, and another study linked vision after spreading toenails to CI. However, no studies have shown a direct relationship between electronic use and CI in children. However, the evidence in this review may be a direct reflection of our observations.

Recommendation

This review recommends further research focusing on congestion Disability, especially CI, is implemented in elementary schools The kids. Future researchers should also consider Young children's situation with a direct focus on the impact Use of electronic devices. This is considered close work. To do so Schools are evolving towards a more tech-savvy environment In the model, it is essential to understand both the short-term and short-term aspects Long-term effects of prolonged exposure to electronic devices. Diagnosis needs to be specified in future research Criteria used to diagnose CI using recognized standards Clinical standards and reliable clinical diagnostic methods. This allows for reprehensibility in future studies and may allow accurate comparisons between age groups in the population and demographics.

5. Result

The review identified several studies that examined the potential link between CI and e- devices. These studies utilized various methodologies, including surveys, clinical examinations, and experimental designs. The findings suggest that prolonged and excessive use of e-devices may contribute to the development or worsening of CI symptoms. Factors such as increased near work, reduced blink rate, and visual fatigue associated with e-device use have been proposed as potential mechanisms underlying this relationship. However, the evidence is still limited and inconclusive, with some studies reporting conflicting results.

6. Discussion

The findings of this literature review highlight the need for further research to establish a definitive causal relationship between CI and e-devices. Longitudinal studies with larger sample sizes and standardized diagnostic criteria for CI are necessary to provide more robust evidence. Additionally, the development of preventive measures and interventions to mitigate the potential negative effects of e-devices on visual health, including CI, should be explored.

7. Conclusion

The reviewed studies emphasize the importance of standardizing methodologies in research on Convergence Insufficiency (CI) to ensure consistent and reliable findings. Critical variables such as age, diagnostic criteria, and near-work exposure significantly influence outcomes. Evidence highlights a strong link between CI symptoms and prolonged electronic device use, particularly during near work, though further research is needed to confirm causal relationships and refine diagnostic approaches.

The growing reliance on digital devices for work, education, and leisure has exacerbated visual discomfort, including symptoms of Computer Vision Syndrome (CVS). Contributing factors like altered blink patterns and sustained close-up screen use pose serious risks to productivity and quality of life, especially for vulnerable groups such as children and adolescents. The COVID-19 pandemic and the rise of e-learning have further intensified these challenges, underlining the importance of early detection and intervention to mitigate the impact on visual health and learning.

Addressing these issues requires raising awareness, promoting healthier screen habits, and developing effective management strategies. Research specific to regions like the Jazan area during the pandemic highlights the intersection of CVS and CI, calling for tailored interventions to address these overlapping visual health challenges. Future efforts should focus on creating innovative preventative measures and adopting a multidisciplinary approach to mitigate the long-term effects of digital device overuse, ensuring sustainable visual health for all age groups.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest concerning the research, authorship, or publication of this literature review.

Statement of ethical approval

This literature review is a synthesis of existing scholarly work and does not involve any direct experimentation with human or animal subjects. Therefore, ethical approval was not applicable.

Statement of informed consent

As this work is a review of previously published studies, it does not involve collecting primary data from human participants. Consequently, informed consent was not required.

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