OULUN AMMATTIKORKEAKOULU

Riikka Torvela

# DIGITAL EYE STRAIN IN THE NEW ERA OF DIGITALIZATION AFTER THE OUTBREAK OF COVID-19

Scoping Review

# DIGITAL EYE STRAIN IN THE NEW ERA OF DIGITALIZATION AFTER THE OUTBREAK OF COVID-19

Scoping Review

Riikka Torvela
Master´s Thesis
Fall term 2022
Master of Health Care,
Clinical Optometry
Oulu University of Applied Sciences

**ABSTRACT**

Oulu University of Applied Sciences
Master of Health Care, Clinical Optometry

---

Author: Riikka Torvela
Title of thesis: Digital Eye Strain in the New Era of Digitalization after the Outbreak of COVID-19 – Scoping Review
Supervisors: Dr. Robert Andersson and Tuomas Juustila
Term and year of thesis completion: Fall term 2022
Pages: 74 + 1 appendix

---

**Introduction:** The outbreak of COVID-19 led the world to a new era of digitalization, as the mandatory worldwide social isolation in the first quarter of the year 2020 changed the communication between people to happen mainly through digital platforms. It is to be expected that due to time and money-saving aspects, remote working and studying will continue after the worse days of the pandemic, and hours of digital device usage will also remain massive in the future.

**Purpose:** This scoping review aimed to identify existing research results and possible information deficiencies in the existing studies and compare empirical evidence of how the outbreak of COVID-19 has impacted the use of digital devices and, thereby, digital eye strain in adults.

**Methods:** This scoping review consisted of eight qualitative descriptive survey studies. The main literature search was conducted on the 21st of March 2022 from three different databases, PubMed, CINAHL, and Academic search premier, using key search terms ("computer vision syndrome" OR "digital eye strain") AND ("covid-19" OR "sars-cov-2"). Only studies regarding adults (age limit 18 years), available in full text and published in English, were included.

**Results:** The reported average increase in screen time after the outbreak of COVID-19 ranged between 2.1h – 4.8h ± 2.8h, raising the total screen time to 8.65h ± 3,74h - 11.1h ± 4.5h. The prevalence of digital eye strain ranged between 66.6% to 94.3%. The increase in screen time was the most reported risk factor for DES. Young adults were found to be more symptomatic than relatively older people. Even though the prevalence of DES remained quite the same compared to pre-covid time, the frequency and intensity of symptoms became more severe while total screen time increased in all age groups. Additionally, the median DES scores were higher for those whose screen time jumped more during the pandemic. The most common symptoms were headache, dryness of the eyes, eye strain, and eye fatigue.

**Conclusions:** The results give an alarming sign of how this new era of digitalization may lead to epidemic worsening or even chronic state of digital eye strain in the future, especially among young adults, all students, and remote workers, if total screen time remains as high as reported in recent studies, adequate breaks are not taken care of, and proper ergonomics are neglected.

---

Keywords: digital eye strain, computer vision syndrome, digital vision syndrome, COVID-19, digital technology, computer work

# TABLE OF CONTENTS

# 1 INTRODUCTION

The COVID-19 pandemic led the world to a new era of digitalization where almost all remaining paper documents were turned into digital form, and nearly all activities started to function via digital devices and the internet. After the outbreak of the pandemic, digitalization increased significantly across the globe in all age groups requiring drastic lifestyle changes, one being an increased exposure to digital devices (Ganne et al. 2021). Already before the pandemic, people spent a significant time during the day in front of a computer or other digital devices. However, the pandemic-induced turbulence raised digitalization to a new level moving both professional and social activities into a web-based platform and forcing people to work and study more from home offices. Social distancing became mandatory, and online working and studying became unavoidable. (Wangsan et al. 2022.) It has been noted that COVID-19 has revolutionized how we interact outside the pandemic and has enabled people to communicate over large geographical areas. On the other side, the increasing use of electronic devices can have far-reaching consequences on the body, including musculoskeletal and visual systems. (Chetty et al. 2020.)

Before the outbreak of COVID-19, many studies had observed that increased use of digital devices correlated with increased symptoms of digital eye strain, and the prevalence of symptoms due to digital eye strain was estimated to range between 25% to 93%. It was also noted that the incidence and severity of digital eye strain were expected to increase unless digital eye strain management was improved. (Coles-Brennan, Sulley and Young 2019.) The outbreak of the COVID-19 pandemic led the world unfortunately into a de facto global remote working experiment as approximately 3.9 billion people worldwide were under lockdown by early April 2020 (Wang, Wei and Deng 2021; Napoli, Nioi and Fossarello 2021).

According to global estimates, nearly 60 million people are affected by computer vision syndrome (CVS), e.g., digital eye strain (Alghamdi and Alrasheed 2020). As the use of digital devices, remote working, and studying online has increased dramatically during the COVID-19 pandemic, there is an ongoing concern about the effects of increased use of digital devices and poor ergonomics on vision and digital eye strain and the increasing visual symptoms associated with the use of digital devices in terms of work ergonomics, inadequate breaks, lighting, air conditioning, and inadequate working distances for vision correction.

In the internet age, people have witnessed an information overload at an individual level and a so-called information explosion with increasing numbers of articles and studies being published with open access. The overwhelming volume of information we encounter has made it almost impossible to navigate and retrieve the information we need. (Booth, Sutton and Papaioannou, 2016, p.13.)

This scoping review aimed to identify existing research results and possible information deficiencies in the existing studies and compare empirical evidence of how the outbreak of COVID-19 has impacted the use of digital devices and, thereby, digital eye strain in adults. Additionally, the aim was to explore the most prevalent symptoms and risk factors of digital eye strain after the outbreak of COVID-19.

The main literature search was conducted on 21 March 2022 from three different databases, PubMed, CINAHL, and Academic search premier, using key search terms ("computer vision syndrome" OR "digital eye strain") AND ("covid-19" OR "sars-cov-2"). The search was done separately on two platforms, PubMed and EBSCOhost. EBSCOhost included both CINAHL and Academic search premier. Date limitation was set in PubMed until 21 March 2022 and in EBSCOhost until March 2022, as a more precise delineation was not possible. There was no need for setting a retrospective time limit as the outbreak of COVID-19 limited the studies to begin from 2020. No methodology or language limits were applied, nor was a full-text filter added in the search itself, but only studies of full text in English from 2020 to 2022 were included.

This scoping review consisted of eight descriptive survey studies from six countries: India, Saudi Arabia, China, Spain, Nepal, and Chile. The study selection part included a critical appraisal of the studies using the Centre for Evidence-Based Medicine - Oxford University Assessment Form of critical appraisal for qualitative studies. The data-driven content analysis aimed to draw clear and reliable conclusions about the phenomenon under study and organize the material in a clear and compact format without losing the information it contains.

# 2 THEORETICAL BACKGROUND

The theoretical background of this scoping review consists of three parts: the COVID-19 pandemic, the use of digital devices, and digital eye strain.

## 2.1 The COVID-19 Pandemic

The coronavirus disease (COVID-19) is an infectious disease caused by the SARS-CoV-2 virus. Cases of an unknown form of viral pneumonia were first reported in the city of Wuhan, China, in December 2019. From there, they spread gradually around the world in the following weeks. On January 7, 2020, the Chinese Institute of Scientific Research announced that viral pneumonia is a new coronavirus (SARS-COV-2), later called COVID-19, by World Health Organization (WHO). (Alsharif and Qurashi 2021.) According to the COVID-19 weekly epidemiological update by World Health Organization (2022), by July 3, 2022, more than 546 million confirmed cases and more than 6.3 million deaths had been reported worldwide.

The most common symptoms of COVID-19 listed by the World Health Organization are fever, cough, tiredness, and loss of taste or smell. Symptoms can also include sore throat, headache, aches and pains, diarrhea, discoloration of fingers or toes, a rash on the skin, and red or irritated eyes. Severe symptoms include breathing difficulties or shortness of breath, loss of speech or mobility, confusion, and chest pain. In more severe cases, a person can become seriously ill; in worse cases, COVID-19 can also be fatal. People with underlying medical conditions such as cardiovascular disease, chronic respiratory disease, diabetes, or cancer are more likely to develop severe illnesses and require medical attention, as well as the older population. However, the majority of those infected with the virus experience mild to moderate respiratory illness and recover without special treatment or hospitalization. (World Health Organization 2022.)

Some people may experience long-term effects, known as post-COVID conditions (PCC) or prolonged COVID, that can cause many ongoing health problems lasting weeks, months, or even years. Post-COVID conditions are often found in people with severe illness or who have not been vaccinated, but anyone infected with the virus can experience PCC. People with post-COVID illness may have a wide range of symptoms, including fatigue or exhaustion that interferes with daily life, symptoms that worsen after physical or mental exertion (also known as "post-exercise malaise"), fever, cough, chest pain, fast-beating or bounding heart, the difficulty of thinking or concentrating, e.g., “brain fog”, headache, sleeping problems, dizziness when standing up, depression or anxiety. (CDC – Centers for Disease Control and Prevention 2022a.)

Viruses constantly change through mutations, and sometimes these mutations lead to a new virus variant. Some variants arise and disappear, while others persist. Since the outbreak of COVID-19, various variants have been detected, and new variants are still expected to occur. Omicron is currently the dominant variant circulating globally, accounting for over 98% of viral sequences after February 2022, informed by GISAID (Global Initiative on Sharing Avian Influenza Data). It causes more infections and spreads faster than other variants, although data suggest that Omicron is less severe in general. All in all, more information is needed to fully understand the severity of disease and death associated with Omicron and other variants. (World Health Organization, 2022c; CDC - Centers for Disease Control and Prevention 2022b.)

As SARS-CoV-2 is highly contagious, it is challenging to determine which measures might be more effective and durable for continued prevention. Measures such as lockdowns and restrictions, quarantines, physical distancing, mandatory use of face masks, and hand hygiene have been implemented as primary preventive strategies to contain the COVID-19 pandemic. While global lockdowns and restrictions have shown a protective effect in reducing covid-19, SARS-CoV-2 infection, and covid-19 mortality, these measures can also disrupt the psychosocial and mental health of children and adolescents, global economies, and societies. (Talic et al. 2021)

One way to slow the spread of SARS-CoV-2, the virus that causes COVID-19, is vaccination, which is highly effective in preventing serious diseases, hospitalizations, and death. (World Health Organization 2022a). Globally, vaccination programs have proven safe and effective and saved lives. However, most vaccines do not provide 100% protection, and it is unknown how well vaccines will prevent future SARS-CoV-2 infections as new variants emerge. (Talic et al. 2021). The World Health Organization continues to support countries to reach 70% vaccination coverage as soon as possible. As of 22 May 2022, nearly a billion people in lower-income countries are still unvaccinated. Only 57 countries, almost all of them being high-income countries, have vaccinated 70% of their population. (World Health Organization, 2022a.)

According to Talic et al. (2021), further research is needed to assess the effectiveness of public health interventions after adequate vaccination coverage has been achieved. Continued control of the covid-19 pandemic will likely depend not only on high vaccination coverage and its effectiveness but also on continuous adherence to effective and sustainable public health measures. Until herd immunity to COVID-19 is achieved, despite already proven high vaccination rates, public health prevention strategies are likely to remain the primary measures for disease prevention, especially in places with low availability of COVID-19 vaccines. (Talic et al. 2021.)

## 2.2 The Use of Digital Devices

Already before the pandemic, many people spent a significant amount of time during their day at the computer or other digital devices like tablets and smartphones. According to The European Working Condition Survey (EWCS2010), at that time, about 30% of workers used computers full time during their working day, and 25% used them between ¼ and ¾ of the time (Seguí et al. 2015). The use of digital devices in almost every aspect of vocational and non-vocational activities increases every year. In 2016, for example, adult Americans viewed digital media for an average of 5,6h per day, and, in 2018, recent reports showed an amount of 60 hours per week accessing content (Coles-Brennan, Sulley and Young 2019.) In comparison, in 2016, in the UK, it was estimated that adults spend 4h45min per day using digital media, and a multination European study reported that by three years of age, 68% of children regularly use a computer. Also, social media and multitasking are particularly prominent, and 87% of younger adults aged 20-29 reported using two or more digital devices simultaneously. In early 2020, just before the pandemic, adults in the UK spent 25h per week online based on Ofcom research. As the pandemic continues, estimates suggest that typical adults in the UK spend around 40% of their waking hours viewing digital devices (Moore, Wolffsohn and Sheppard 2021.)

According to the Digital 2022 July Global Statshot Report, in July 2022, there were approximately 5.03 billion internet users globally, around 63.1% of the world´s population. Internet users have increased by 3.7% (+178 million) over the past 12 months. 92.1% of internet users accessed the internet via mobile phones, 28.2% via a tablet device, 60.3% via personal laptop or desktop, and 28.7% via work laptop or desktop. The average daily internet usage time among the 16 to 64 years old was 6h 49min. The highest average internet usage time was among 16 to 24 years old (7.19h-7.54h). The usage time decreased steadily as 25 to 34 years old had the second highest time

(7.02h-7.13h), 35 to 44 years old the third highest 6.32-6.38h), 45 to 54 years old the second lowest (6.03h-6.07h) and 55 to 64 years old the lowest usage time (5.26h-5.45h). (Datareportal 2022.)

The COVID-19 pandemic led the world in 2020 into a de facto global remote working experiment as approximately 3.9 billion people worldwide were under lockdown by early April 2020 (Wang, Wei and Deng 2021; Napoli, Nioi and Fossarello 2021). The pandemic caused an accelerated change to full-time remote work and changed traditional office work. Some firms are likely to switch to a hybrid work model, employees splitting their time between remote and office work instead of fully returning to their pre-COVID-19 work arrangements after the pandemic. (Yang et al. 2022.) For students, the change after the outbreak of COVID-19 was as dramatic as for the working population as virtual models replaced almost all face-to-face classrooms, and many digital innovations, including online platforms and teleconference systems, were generated. (Wangsan et al. 2022).

Before the pandemic, it was not very common to work from home. According to Wang, Wei and Deng (2021), the American Community Survey (2017) showed that only 2.9 percent of the US workforce worked remotely. In comparison, in 2015, only 2 percent of the Europeans worked mainly from home. After the outbreak of COVID-19, it was estimated that by April 2020, 37% of Americans were working from home full-time. (Yang et al. 2022.) From this point of view, it is understandable that before COVID-19, most workers had little remote working experience, and neither were they nor their organizations prepared to support this practice (Wang, Wei and Deng 2021).

## 2.3 Digital Eye Strain

Digital eye strain (DES), in other words, computer vision syndrome (CVS), is a condition of ocular discomfort or visual disturbance related to the prolonged use of digital devices like computers, tablets, e-readers, and cell phones and has been detected as an emerging public health issue resulting from a range of stresses on the ocular environment (American Optometric Association 2022; Coles-Brennan, Sulley and Young 2019). Computer vision syndrome has been a recognized health problem for over 20 years. As the variety of digital devices linked to potential problems has increased over the years, the terms digital eye strain (DES) and visual fatigue (VS) has become, in some sense, more appropriate terms to use as patients may not consider devices such as tablets and smartphones to be computers (Sheppard and Wolffsohn 2018). Also, the terms digital device syndrome (DVS) and smartphone vision syndrome (SVS) have been used in studies, for example, by Hundekari, Sisodiya and Kot (2021).

There is a high commonness of visual complaints related to the visual stress associated with intensive near-visual work among computer workers, and all in all, as many as 90 percent of digital device users periodically experience symptoms of digital eye strain (Lawrenson, Hull and Downie 2017; Mork et al. 2018; Rosenfield 2011). According to Seguí et al. (2015), it has been estimated that 90% of the 70 million workers in the United States who use a computer more than 3 hours per day experience eye-related symptoms, and those symptoms have been considered one of the most common health-related complaints among video display terminal (VDT) workers. Because of the massive increase in the use of digital devices in recent years, many millions of people are at risk of DES. Even though symptoms are usually transient, the condition can cause significant, frequent discomfort for sufferers. Even though DES affects a massive number of individuals worldwide, its physiological basis and exact mechanism remain unclear (Coles-Brennan, Sulley and Young 2019; Sheppard and Wolffsohn 2018.)

Digital eye strain involves a group of ocular symptoms, including eye strain, headache, tired eyes, tearing, general fatigue, blurred vision, burning sensation, red eyes, irritation, dry eye, foreign body sensation, double vision, and pain behind the eye (Coles-Brennan, Sulley and Young 2019; Usgaonkar, Shet Parkar and Shetty 2021). The formal term for eye strain is asthenopia, a term generally used to describe symptoms related to prolonged use of the eyes (Heus, Verbeek and Tikka 2018). Literally, asthenopia refers to the weakness or impairment of the eyes or vision and is, therefore, appropriate to describe symptoms caused by a visual or ocular disorder rather than purely extrinsic environmental factors (Evans 2007, p.16).

DES symptoms can be divided into internal and external symptoms. Internal symptoms are more associated with accommodation and binocular vision anomalies, such as blurred vision at near, blurred distance vision after use of the computer, difficulty refocusing from one distance to another, headache, and ache behind the eyes. External symptoms, in turn, are more related to dry eye symptoms like burning eyes, irritation, tearing, eye strain, headache, tired eyes, sensitivity to bright lights, and eye discomfort (Sheppard and Wolffsohn 2018; Rosenfield 2011). These symptoms make up the umbrella diagnosis of computer vision syndrome or digital eye strain caused by the manifestation of an evaporative dry eye leading to ocular surface compromise and asthenopic symptoms caused by a constant state of accommodation and convergence (Bahkir and Grandee 2020).

Internal symptoms of computer vision syndrome associated with accommodation and vergence disorders seem to be, in most cases, a result of looking at a visually demanding near target for a long time and not specifically at the electronic monitor. On the contrary, dry eye symptoms seem to be directly related to computer use due to gaze position, reduced blinking rate, incomplete blinking, and other environmental factors. (Rosenfield 2011.)

Increased visual stress during near-vision work, such as insufficient lighting, glare, uncorrected refractive errors, and accommodative and binocular disorders, may aggravate eye symptoms (Coles-Brennan, Sulley and Young 2019; Mork et al. 2018). Age-related loss of accommodation may cause additional visual stress for presbyopic subjects, especially since intermediate vision, needed for viewing digital devices, is often uncorrected (Coles-Brennan, Sulley and Young 2019).

Many gaps in knowledge related to DES exist due to a lack of validated instruments to measure the matter. Primarily, DES is measured with questionnaires based on self-evaluation, though the diagnosis is based on patient-reported outcomes. As there is no golden standard in measuring DES, questionnaires do not follow a standard pattern in different studies, and results vary depending on how the questionnaire was produced. Some aspects related to DES can be measured objectively, for example, tear osmolarity, blinking rate, and accommodation facility. Still, even if the results of these tests could indicate DES, they cannot be linked to the condition so closely that they could be used to estimate DES solely. (Seguí et al. 2015.)

One questionnaire that has already been translated into different languages and used in several studies is made by Seguí et al. (2015). They developed a valid questionnaire to measure computer vision syndrome in the workplace. Their CVS-Q questionnaire evaluates the frequency and intensity of 16 CVS-related symptoms and overall symptom severity (CVS score). Scores can be compared between different individuals or in the same individual at different times or conditions. There are 16 symptoms used in the questionnaire. Some of these symptoms are more related to external symptoms, like dryness, feeling of a foreign body, itching, burning, tearing, eye redness, excessive blinking, heavy eyelids, increased sensitivity to light, and colored halos around objects. Other symptoms are more internal like eye pain, difficulty focusing for near vision, blurred vision, double vision, and feeling that sight is worsening. Headache can be related to both internal and external symptoms. In answering, the frequency is divided into three different options: never (0), occasionally (1), and often or always (2). The intensity is divided into moderate (1) or intense (2). The total score is calculated using a formula, and the worker is considered suffering from CVS if the total score is ≥ 6. This test is validated with the Rasch model but also has its limitations. (Seguí et al. 2015.)

The only way to diagnose CVS or DES properly is through a comprehensive eye examination, including patient history, visual acuity measurements, refraction, examining the eye's surface by a microscope, and examining binocular vision, e.g., testing how eyes focus, move, and work together. Based on the overall information due to these examinations, the eye care professional can determine the presence of DES. (American Optometric Association 2022.)

## 2.4 Internal Symptoms of Digital Eye Strain

Blurred vision is a common symptom resulting from a long computer work session causing visual and other additional stress. It may be a result of an uncorrected refractive error, an accommodative infacility, or an inaccurate accommodative response during screen viewing. Also, ocular muscle fatigue and vergence anomalies play a role in causing both blurred vision as well as diplopia (Coles-Brennan, Sulley and Young 2019; Rosenfield 2011.)

According to studies, all refractive errors, including astigmatism and presbyopia, should be appropriately corrected, and the correction of refractive errors is an essential intervention for DES sufferers. (Sheppard and Wolffsohn 2018). According to Coles-Brennan, Sulley and Young (2019), in various studies, uncorrected refractive error, especially astigmatism, is also shown to be a significant cause of eye strain, causing especially symptoms like headache and tired eyes.

### 2.4.1 Refractive Errors

Optical correction of refractive error can both relieve or remove accommodative strain and improve visual capacity to reduce or prevent eye symptoms when working with digital devices, especially during prolonged use of devices or multitasking. (Heus, Verbeek and Tikka 2018). The retinal image must be focused appropriately to maintain a clear vision of small targets throughout the work on a digital device. Spherical hyperopia, myopia, and astigmatism should be corrected to minimize blur and reduce the visual stimulus to accommodation (Rosenfield 2011.) In visual accommodation, the eye changes focus on maintaining a clear image, and it requires both changes in optical lens power and alignment of the eyes, vergence. Accommodation is driven by visual blur, which stimulates the oculomotor system to alter refractive power to focus the retinal image (Coles-Brennan, Sulley and Young 2019.) Ophthalmic practitioners should also examine the visual function at the distances the digital devices use to ensure clear vision at an intermediate distance (Sheppard and Wolffsohn 2018).

The presence of uncorrected oblique astigmatism is shown to reduce visual acuity significantly. An increased target blur makes performing a task more difficult, leading to increased symptoms like eyestrain and headache (Rosenfield 2011). According to studies, already 0.50-1.00D of uncorrected simulated astigmatism has been established to cause a negative impact on subjective visual comfort, and 1.00-2.00D of astigmatic error may increase task errors by up to 370% and reduce the productivity of digital device workers to a considerable extent (Sheppard and Wolffsohn 2018).

### 2.4.2 Accommodation and Vergence Anomalies

When using digital devices like computers, laptops, and smartphones, the devices are held at an intermediate distance between near and distance vision. Focusing on the intermediate distance causes strain on the visual system, which is mainly designed for comfortable near and distant vision (Bahkir and Grandee 2020.) Office work tasks like typing, writing, and reading require intense visual efforts like focusing on different distances, mainly from intermediate to near, requiring different accommodation and convergence demands. Also, good coordination of eye movements is needed to observe various objects when looking from screen to paper and keyboard, so that fusion images of both eyes occur and adequate binocular vision is obtained (Seguí et al. 2015.) The convergence and accommodation work together during near work and combined with miosis, they form the triad response, constituting three synkinetic actions that play together during near vision (Evans 2007, p.28).

As switching fixation from screen to other material or into distance occurs frequently, accommodative facility, the ability to make rapid changes in accommodative response, is essential to computer use (Sheppard and Wolffsohn 2018). An accommodative facility is the flexibility to focus on a variety of viewing, and its testing is a standard clinical test that stimulates rapid changes in the accommodative stimulus (Jaiswal et al. 2019; Rosenfield 2011). The closer an object is located to the eyes, the more eyes must work to accommodate and converge. The constant near work demands the eyes to always be in a state of accommodation, and the required convergence tires the extraocular muscles. When this state is maintained for extended periods, visual demands exceed the capacity of visual accommodation, which can increase symptoms like eye strain and headache. (Bahkir and Grandee 2020; Heus, Verbeek and Tikka 2018.)

People that work with computers must be able to accommodate smoothly and rapidly and maintain an accurate response to perform near tasks comfortably (Sheppard and Wolffsohn 2018). Lag in accommodation, i.e., under accommodation, means the amount by which the accommodative response is less than the accommodative stimulus in diopter and is related to the accuracy of accommodation. When this difference exceeds the depth of focus, symptoms like blurred near vision and sore and tired eyes may occur. (Coles-Brennan, Sulley and Young 2019; Jaiswal et al. 2019.) Both, small degrees of lag, meaning under- accommodation as well as lead, meaning over accommodation, can go unnoticed due to depth of focus, but in frequent demand of near work, both are noted as a common cause of asthenopia (Coles-Brennan, Sulley and Young 2019; Rosenfield 2011).

Several studies of smartphone users under the age of 35 have shown a more significant lag in the accommodation after smartphone use than before use, and reading from smartphones or tablets at 35-40cm has resulted in a statistically significant greater lag than reading printed text at the same distance. Although reading from a distance of 50cm, no significant lag of accommodation was found between a handheld e-reader and printed text, which could be due to extended viewing distance. (Jaiswal et al. 2019.)

There is still a shortfall in understanding how computers affect the accommodative facility. Some studies show a decrease in accommodative facility aligning with asthenopic symptoms, but on the other hand, some studies show no difference or even an improvement after computer use. It is possible that the differing working distances, and detail within the task, including font size and contrast, may create different demands on the accommodation and vergence systems affecting differently to the accommodative facility (Jaiswal et al. 2019; Sheppard and Wolffsohn 2018.)

Vergence dysfunctions consist of various motor disorders, such as convergence insufficiency, poor vergence facility, and decompensated heterophoria (Sheppard and Wolffsohn 2018). The vision test should mimic the circumstances under everyday conditions when testing binocular vision to detect what is happening with the visual system. For example, if there is a need to know if the symptoms reported by the patient while working on the computer are due to binocular vision anomaly, the most relevant tests are to be made at the appropriate distance, e.g., the same viewing conditions as when the patient works on the computer. (Evans 2007, pp. 13-14.)

There are mixed results in the studies about vergence features concerning computer use, but people with binocular vision problems experience more significant visual symptoms with long-term use of the eyes (Sheppard and Wolffsohn 2018). Headache is a common symptom associated with decompensated heterophoria after prolonged use of the eyes, often in unfavorable visual conditions. Generally, headache caused by binocular vision problems is milder or absent in the morning after a night´s sleep and worsens during the day. Blurred vision, often noticed by the person when working near, is also a common symptom in heterophoria which can be associated with accommodative difficulties such as undercorrected hypermetropia or presbyopia, also causing general fatigue or tenderness of the eyes or eyelids. (Evans 2007, p. 15.)

Jaiswal et al. (2019) point out that convergence insufficiency, characterized by a near-exophoria, is the most common vergence disorder with symptoms occurring near work. However, still, no studies were found investigating vergence facility after computer or handheld device use. Also, limited evidence is available on the impact on phoria with digital devices. Still, it seems that there is a more significant movement for phoria to shift towards greater exophoria after using a computer during the working day (Jaiswal et al. 2019; Sheppard and Wolffsohn 2018). For now, there is no evidence for any long-term changes occurring with long-duration use, and it appears that deviation changes will recover to normal levels in a relatively short time. (Jaiswal et al. 2019).

Any vergence anomaly that causes difficulty in maintaining clear and single vision at near, for example, uncompensated heterophoria, vergence infacility, or excessive or insufficient convergence, is likely to cause symptoms when an electronic display is viewed continuously at near. Thus, it is essential to test these parameters at the same distance where the screens are placed. (Rosenfield 2011.)

## 2.5 External Symptoms of Digital Eye Strain

External symptoms of digital eye strain are mostly ocular surface related and highly associated with dry eye consisting of symptoms like dryness, itchiness, irritation, redness, burning sensation, foreign body sensation, tearing of eyes, sore eyes, and blurred vision. Some of the symptoms can be due to both factors, for example, blurred vision, as well as caused by internal factors can also be caused by external factors like abnormal tear physiology and unstable tear film due to dry eye disease (DED). (Coles-Brennan, Sulley and Young 2019.) Prolonged use of digital devices can predispose to DED, and although DED is one of the most common eye diseases worldwide, its impact on a patient's overall health is often underestimated. (Napoli, Nioi and Fossarello 2021).

Dry eye is considered a major etiology of DES, with factors like altered or incomplete blinking rate, wider gaze angle, environmental influences like decreased humidity, ventilation fans, air conditioning, and airborne dust particles causing and exacerbating evaporative dry eye. (Bahkir and Grandee 2020; Rosenfield 2011; Sheppard and Wolffsohn 2018.) According to studies, the severity of dry eye is affected by the duration of computer use, and digital device users commonly encounter symptoms associated with dryness in otherwise healthy eyes. (Coles-Brennan, Sulley and Young 2019.)

A study by Portello, Rosenfield and Chu (2013) points out that although computer vision syndrome symptoms are associated with decreased blink rate, the completeness of the blink of an eye can be just as significant. The use of digital devices causes a substantial fall in the blink rate, resulting in meibomian glands not being mechanically stimulated as often to release a proper lipid layer, causing a slowing of the rate of tear film regeneration (Bahkir and Grandee 2020). Incomplete blinking, on the other hand, disturbs the balance of replenishment and evaporation of tear film as the eyelids are not spreading the tear film evenly over the ocular surface, causing an unstable tear film, disruption of tear structure, and thus homeostasis of the ocular surface causing ocular discomfort. Incomplete blinking paired with inadequate lipid layer presents as a foreign body sensation, grittiness, burning, and itching of the eyes (Bahkir and Grandee 2020; Jaiswal et al. 2019.)

While working with desktop computers, screens are often viewed in a horizontal gaze that tends to be higher so that the palpebral aperture is wider than in conventional near work, laptop, or tablet use, usually performed gazing down. A vertically larger palpebral aperture leads to faster tear film evaporation and incomplete blinking (Bahkir and Grandee 2020; Sheppard and Wolffsohn 2018.)

The prevalence of dry eye disease is more common in women than in men, and the prevalence of dry eye increases with age. The female gender is one of the most widely studied and consistently identified significant risk factors for dry eye disease (DED) worldwide. Generally, gender, sex, and hormones play an important role in the regulation of ocular surface and adnexal tissues and differences in the incidence of DED between women and men. According to research so far, the higher rate of DED in women compared to men only becomes significant with age. It is stated in TFOS DEWS II that in the future, there is a need to include a detailed assessment of the prevalence of DED of varying severity, prevalence in youth, incidence studies in different populations, and the impact of the use of current technologies such as mobile devices. The need to increase clinical signs of dry eye data is still high in populations under 40 years of age. (Nelson et al. 2017; Stapleton et al. 2017; Sullivan et al. 2017.)

The prevalence of DED is largely due to the effects of sex steroids (e.g., androgens, estrogens), glucocorticoids, hypothalamic-pituitary hormones, insulin, insulin-like growth factor 1, and thyroid hormones (Sullivan et al. 2017). Dry eye incidence has been reported to be higher in people with autoimmune diseases like arthritis, thyroid disease (not treated with hormones), allergy, and with people taking antihistamines, anti-anxiety medications, antidepressants, oral steroids, or vitamins (Rosenfield 2011).

## 2.6 Risk Factors, Control and Prevention of Digital Eye Strain

Increased remote working with digital devices during COVID-19 has increased visual stress and musculoskeletal impairments such as back, neck, shoulder, and wrist pain among workers. Risk factors of DES include continuous on-job and overtime working, neglecting adequate breaks, lack of suitable ergonomics at the workstation, poor postures, and simultaneous use of multiple devices (Chetty et al. 2020).

As the expansion of information technologies has resulted in the increased use of digital devices, many studies have attempted to address computer workers' safety and health issues (Seguí et al. 2015). International regulations have been issued regarding health and safety requirements for workers using digital devices in their work to minimize the symptoms of computer vision syndrome. Also, according to studies, the economic impact of computer vision syndrome is exceptionally high, and minimizing digital eye strain symptoms that reduce occupational efficiency will result in a significant financial benefit (Rosenfield 2011.) Given the high prevalence of computer vision syndrome, optometrists will be examining and guiding multiple patients with DES weakly, and affected patients will reasonably expect advice from a specialist managing both visual and ocular symptoms of DES. (Moore, Wolffsohn and Sheppard 2021).

According to Coles-Brennan, Sulley and Young (2019), many authors have suggested breaks as a management strategy for DES, but breaks alone were not associated with reduced symptoms, whereas viewing distant subjects during breaks was. The 20-20-20 rule is nowadays a commonly found strategy on the websites of optometric associations. It is a simple way to take frequent breaks from viewing the screen to look at the distance, as is generally recommended. The rule is to take a break every 20 minutes to focus your eyes for 20 seconds to at least 20 feet (6 meters) away (Alghamdi and Alrasheed 2020; Moore, Wolffsohn and Sheppard 2021).

In a round table discussion by Gallagher et al. (2021), Jayme Vaccaro reminds people that built-in breaks or stretch reminders can also be used on digital devices. Also, screen time tracking on devices is available to remind the user how much screen time has been used during the day. (Gallagher et al. 2021.) It would be essential to reduce the total screen time as much as possible. Still, although lessened screen time might lower the prevalence and symptoms of CVS, achieving measurable changes in total hours might be challenging due to the current way of working. Modification of other factors may be more realizable. (Wangsan et al. 2022.)

Computer glasses, designed to optimize vision in the intermediate and near regions, have been found to reduce symptoms of digital eye strain by providing suitable correction for the viewing distances and angles needed at the workstation (Coles-Brennan, Sulley and Young 2019; Sheppard and Wolffsohn 2018). An accurate vision correction may reduce symptoms in presbyopic computer users to a greater extent than ergonomic intervention. A single near add may not provide adequate vision across the range of demand levels, and for that reason, occupational lens correction is required. (Sheppard and Wolffsohn 2018.)

There are also several lens designs for pre-presbyopes with a progressive power profile of +0.50D to +1.25D, aiming to ease the accommodative demand when using digital devices. In the study by

Yammouni and Evans (2020), most pre-presbyopics suffering from DES preferred low adds over a control (plano) lens with distance refractive error corrected. The most often preferred add was +0.75D. They concluded that low add +0.75D lenses might be beneficial for people from 20 to 40 years suffering from symptoms of DES, but the finding is not universal, and more studies are needed to confirm this. (Yammouni and Evans 2020)

Also, management of vergence anomalies, blinking exercise to maintain the regular blinking pattern, use of eye drops, and prescription of color filters in all vision correction options, especially blue light-absorbing filters, have been suggested as management strategies (Coles-Brennan, Sulley and Young 2019). Although blue-blocking (BB) spectacle lenses are being marketed to relieve eye strain and discomfort while using digital devices, improve sleeping quality and even give protection from retinal phototoxicity, high-quality evidence is still lacking to support using blue-blocking lenses to improve visual performance, sleep quality, relieve eye fatigue or conserve macular health (Lawrenson, Hull and Downie 2017).

Optimizing workstation installation and device placement, as well as checking environmental factors like room humidity, can also reduce symptoms of DES. (Moore, Wolffsohn and Sheppard 2021). Natural ventilation is a better option than artificial ventilation. It is recommended to adjust the distance from eyes to screens to at least ~45-60cm and place the screen in a down gaze position. The screen's brightness ought to be adjusted to match the room's lighting level, and the contrast is recommended to be increased as much as possible to reduce eye strain. A matte screen filter can also be used to reduce glare. (Napoli, Nioi and Fossarello 2021.) Laptops are typically placed at different distances and gaze angles compared to desktop models. In laptops, the keyboard is attached to the monitor, which means there is less flexibility in adjusting the workstation so that the keyboard remains within comfortable reach (Rosenfield 2011).

Appropriate workplace and computer ergonomic setup are also necessary. Increased digital device usage has impacted both the visual and musculoskeletal systems. The prolonged duration of visually demanding work and other factors such as uncorrected refractive error and accommodation/vergence needs might also exacerbate the impact on the neck/shoulder region. This impact can cause musculoskeletal disorder (MSD) symptoms like pain and discomfort in the neck area, shoulder, elbow/wrist/hand, upper back, and lower back when using digital devices. (Regmi, Suresh and Asokan 2022; Zetterberg, Forsman and Richter 2017.) Prolonged use of mobile phones or other digital devices can also cause text neck syndrome describing repetitive stress injury (RSI), occurring when the neck is hung or flexed in a forward position when bending down to look at a digital device (Regmi, Suresh and Asokan 2022).

During the COVID-19 pandemic, it has been brought up that dry eyes may also occur due to prolonged mask-wearing contributing to CVS. (Gallagher et al. 2021). Moshirfar, West and Marx (2020) noted that healthcare providers should be aware of the mask-associated ocular dryness and irritation in all mask wearers and its threats to eye health. Additional care and screening are especially important for people who work with masks for long periods and have a history of dry eye disease, recent eye surgery, or another surface inflammatory disease such as Sjogren's syndrome. (Moshirfar, West and Marx 2020.) Lubricant eye drops and eye protection like eyeglasses can ease the irritation when used with facial masks. Although wearing a mask or eyewear that is not centered well might fog the lenses and cause difficulty focusing, contributing to slips, trips, and falls. Masks can also cause other visual barriers, like blocking the lower peripheral vision field. A tight fit reduces visual obstruction and minimizes fogging of glasses. (Gallagher et al. 2021; Kal, Young and Ellmers 2020.)

# 3 PURPOSE AND OBJECTIVES OF THE THESIS

**Purpose:** This scoping review aimed to identify existing research results and possible information deficiencies in the existing studies and compare empirical evidence of how the outbreak of COVID-19 has impacted the use of digital devices and, thereby, digital eye strain in adults.

**Objectives**: This scoping review had two study objectives. The first study objective was to create a detailed description of how the outbreak of COVID-19 has impacted the use of digital devices and, thereby, digital eye strain in adults and to add information value by creating clarity to the data without losing the information it contains. The second study objective was to explore the most prevalent symptoms and risk factors related to digital eye strain after the outbreak of COVID-19. By data-driven content analysis of the selected studies, the aim was to organize the fragmented data in a clear and compact format and to draw clear and reliable conclusions.

The purpose and objectives of the development section were to create up-to-date information for the work field about the effects of the outbreak of COVID-19 on the use of digital devices and, thereby, digital eye strain in adults and its impact on vision and eye health.

# 4 IMPLEMENTATION OF THE THESIS

The implementation of the thesis included forming a research question, defining the selection criteria for the studies, data search process, selection and quality assessment of the studies, and analysis of the data.

## 4.1 Scoping Review as a Research Method

Scoping review has become an increasingly popular way of synthesizing research evidence of the potentially large and diverse literature on a broad topic. In scoping reviews, a systematic approach is followed to identify key concepts and synthesize the results of previous and current studies. Scoping review also aims to indicate where possible information gaps exist or evidence is lacking and reveal limitations in the existing studies. (Pham et al. 2014; Tricco et al. 2018.)

This scoping review consisted of eight qualitative descriptive survey studies. The main literature search was conducted on 21 March 2022 from three different databases, PubMed, CINAHL, and Academic search premier, using key search terms ("computer vision syndrome" OR "digital eye strain") AND ("covid-19" OR "sars-cov-2"). Only studies regarding adults (age limit 18 years), available in full text and published in English, were included.

## 4.2 Research Question

The research question for this scoping review was based on a PICO table standing for Population/problem, Intervention, Comparator, and Outcome consisting of the following pieces:

**P** (population and problem) = adults and digital eye strain
**I** (intervention) = the outbreak of COVID-19
**C** (comparator) = the use of digital devices
**O** (outcome) = any positive or adverse health-based objective or subjective clinical outcome when comparing P and C after the outbreak of COVID-19

**Research question**: How has the outbreak of COVID-19 impacted the use of digital devices and, thereby, digital eye strain in adults?

### 4.3 Criteria for the Selection of Studies

The PICO table developed for the research question was fulfilled with the study design and settings, complementing PICO into PICOSS, and was used as a base for inclusion and exclusion criteria.

Inclusion criteria, also known as eligibility criteria, describe the specific attributes a study must obtain to be included in this review. In reverse, exclusion criteria define the attributes that disqualify a study from being included in this review.

**Inclusion criteria:**

Only studies regarding adults (age limit of 18 years) were set to be included in this review. The studies had to be made after the outbreak of COVID-19 and investigate digital eye strain in relation to the use of digital devices during the pandemic. To be included in this scoping review, the title and content of the study had to correspond, the study had to be available in full text and published in English. As for the study design, only scientific studies, or articles about original studies, published in a scientific publication, were included.

*Table 1. Inclusion criteria for the scoping review defined with the PICOSS table*

| | |
|---|---|
| **P** (POPULATION AND PROBLEM) | studies that investigate digital eye strain regarding adults, age limit of 18 years |
| **I** (INTERVENTION) | studies that are made after the outbreak of COVID-19 and investigate the phenomenon during the pandemic |
| **C** (COMPARATOR) | digital eye strain is being studied in relation to the use of digital devices |
| **O** (OUTCOME) | the title and content of the study correspond, and the study is available in full text, published in English |
| **S** (STUDY DESIGN) | scientific studies or articles about original studies that have been published in a scientific publication |
| **S** (SETTING) | all |

**Exclusion criteria:**

The exclusion criteria for this scoping review complemented the inclusion criteria oppositely. Studies regarding children or adolescents were set to be excluded, also studies not answering the review question, e.g., studies that did not investigate digital eye strain in relation to the use of digital devices during COVID-19 and studies that were not available in full version. Also, non-scientific studies like discussions, commentaries, letters to the editors, or other non-professional studies were set to be excluded. There was no need for setting a retrospective time limit in years for inclusion-exclusion criteria as the outbreak of COVID-19 limited the studies starting from 2020, when the phenomenon began.

*Table 2. Exclusion criteria defined for the scoping review*

| |
|---|
| Studies regarding children or adolescents, age limit of 18 years |
| Studies not answering the review question: studies that do not investigate digital eye strain in relation to the use of digital devices during COVID-19 |
| The title and the content of the study do not correspond, the study is not available in full text, or the study is published only in another language than English |
| Non-scientific studies like discussions, commentaries, letters to the editors, or other non-professional studies |

## 4.4 Data Search Process, Selection, and Quality Assessment

### 4.4.1 Data Search Process

Scoping search for this review was made at the beginning of March 2022 in PubMed to determine the direction of the evaluation, estimate how many studies are likely to be found, and finalize the review question. After the scoping search, the data search process was conducted in three stages. The first stage included the initial search and meeting with Oulu University of Applied Sciences´ information specialist to ensure and determine the optimal key search terms and databases included for the main search. In the second stage, the main search was implicated, and duplicates were removed. In the third stage, verification was made to check that the search strategy had not missed any relevant studies. The whole search was documented along with the process and is also illustrated in figure 1.

The initial literature search was made on 15 March 2022 in PubMed using search terms (“computer vision syndrome” OR “digital eye strain”) AND (“COVID-19”). The date limitation was set until 15 March 2022. There was no need for setting a retrospective time limit as the outbreak of COVID-19 limited the studies to begin from 2020. No methodology or language limits were applied, nor was a full-text filter added. The search gave 28 results, including 6 results from the year 2020, 16 from the year 2021, and 7 from the year 2022. 6 cross-sectional studies, 4 desk studies, 9 survey studies, 4 letters to editors, one randomized controlled trial, one round table discussion, two commentaries, and one validation of questionnaire were found.

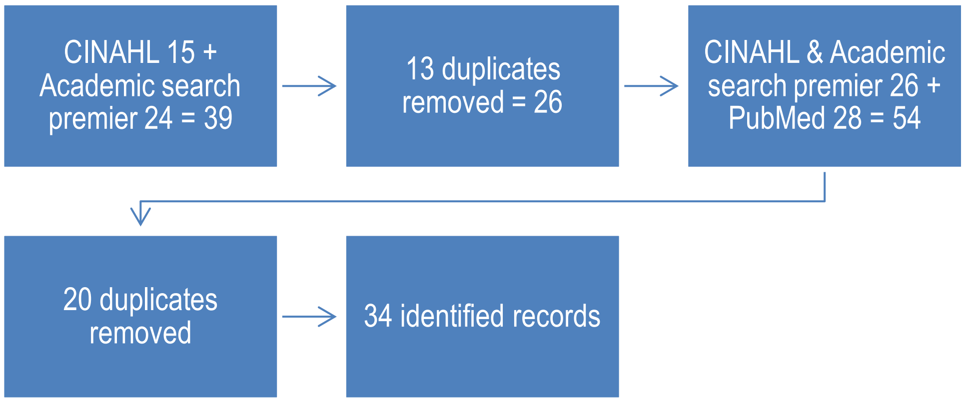
After the initial search, an information specialist in the library of Oulu University of Applied Sciences was consulted to ensure the relevance and comprehensiveness of key search terms based on the research question and to determine which databases are to be included in the main search. An additional key search term, “sars-cov-2” was included to complement the search terms used in the initial search, and three databases were selected: PubMed, CINAHL, and Academic search premier.

The main literature search was conducted on 21 March 2022 from three different databases, PubMed, CINAHL, and Academic search premier, using key search terms ("computer vision syndrome" OR "digital eye strain") AND ("covid-19" OR "sars-cov-2"). The search was done separately on two platforms, PubMed and EBSCOhost. EBSCOhost included both CINAHL and Academic search premier. Date limitation was set in PubMed until 21 March 2022 and in EBSCOhost until March 2022, as a more precise delineation was not possible. There was no need for setting a retrospective time limit as the outbreak of COVID-19 limited the studies to begin from 2020. No methodology or language limits were applied, nor full-text filter added. Only studies in English appeared in the search results.

For PubMed, the added search term “sars-cov-2” gave no additional results compared to the initial search and the result remained as 28 identified records. Using the EBSCOhost, the search gave the overall result of 39 identified records, 15 from CINAHL and 24 from Academic search premier, of which EBSCOhost automatically removed 13 exact duplicates. 26 identified records remained.

After the individual searches, the 26 identified records from the EBSCOhost search were compounded with 28 PubMed records, of which 20 were found to be duplicates. After the removal of duplicates, six identified records remained: one review, two commentaries, two cross-sectional studies, and one survey study, all from the year 2021. Those six results were added to the 28 results from PubMed, making the final amount of 34 results. Searches from all three databases gave a total amount of 67 identified records, of which, after removing 33 duplicates, 34 remained. No registers or grey literature were searched.

*Figure 1. The data search process*




The PRISMA Extension for Scoping Reviews (PRISMA-ScR) checklist (Tricco et al. 2018) was used to ensure explicit documentation of all the details of search strategies was implemented.

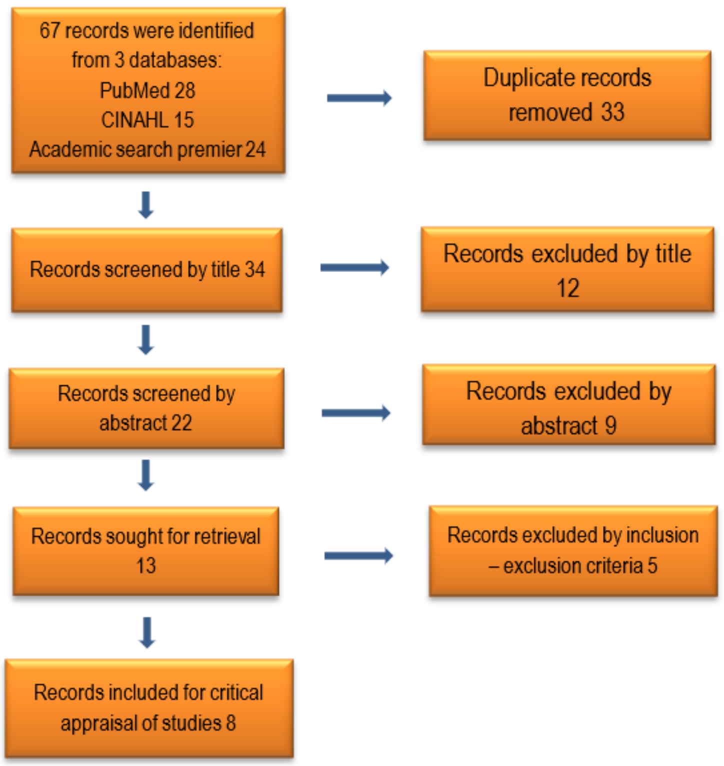
### 4.4.2 Selection of the Studies

The titles, abstracts, and relevance to the review question of each study were assessed according to the inclusion-exclusion criteria. Studies that did not fill out the inclusion criteria were excluded and are listed in appendix 1 with reasons for the exclusion.

The first stage of selecting the studies consisted of title and abstract screening within the inclusion-exclusion criteria. Of 34 identified records, 21 were excluded during the first stage. 12 studies were excluded by title: 10 studies were excluded for not meeting the inclusion criteria of studies regarding adults, and two were excluded for being non-scientific studies. Nine studies were excluded by abstract: five studies for not meeting the inclusion criteria of studies regarding adults, and 4 studies were excluded for not answering the research question. 13 identified records remained for the opening of the full text.

In the second stage, full versions of the 13 studies were obtained. Nine studies out of 13 had direct open access. From revising full versions of these nine studies, four studies were letters to the editor and therefore excluded for being non-scientific studies. The information specialist and supervisor of the study were consulted to obtain a full version of four studies without open access. Full versions of three studies were obtained through extended rights, one thru an information specialist with the access rights of the University of Oulu and two thru the supervisor of the study. The full version of one study remained out of reach and was asked directly from the author thru ResearchGate, but no response was received. Eventually, the full version of that study was obtained thru long-distance service from the University of Oulu. After reading full versions of nine studies, one was excluded for not meeting the inclusion criteria of studies regarding adults. The study included research subjects between 16 and 25 years of age. All identified records were in English, and there was no need for translation.

*Figure 2. The selection process of the studies*



### 4.4.3 Quality Assessment of the Studies

Eight studies were selected by inclusion-exclusion criteria for quality assessment of this scoping review and are presented in table 3. All studies were qualitative descriptive survey studies. Studies were fully read and thoroughly revised, including a critical appraisal of the content of the studies through the Centre for Evidence-Based Medicine - Oxford University Assessment Form of critical appraisal for qualitative studies (Centre for Evidence-Based Medicine (CEBM) 2022).

*Table 3. Studies selected for the quality assessment*

| No. | Title | Publication | Year | Authors |
|---|---|---|---|---|
| 1 | Impact of the COVID-19 lockdown on digital device-related ocular health | Indian Journal of Ophthalmology | 2020 | Fayiqa Ahamed Bahkir, Srinivasan Subramanian Grandee |
| 2 | Effect of digital device use during COVID-19 on digital eye strain | Clinical & Experimental Optometry | 2021 | Balsam Alabdulkader |
| 3 | Digital Eye Strain Epidemic amid COVID-19 Pandemic - A Cross-sectional Survey | Ophthalmic Epidemiology | 2021 | Pratyusha Ganne, Shaista Najeeb, Ganne Chaitanya, Aditya Sharma, Nagesha C Krishnappa |
| 4 | Computer Vision Syndrome During SARS-CoV-2 Outbreak in University Students: A Comparison Between Online Courses and Classroom Lectures | Frontiers in Public Health | 2021 | Lixiang Wang, Xin Wei, Yingping Deng |
| 5 | Computer Vision Syndrome in the Spanish Population during the COVID-19 Lockdown | Optometry and Vision Science | 2021 | Caridad Galindo-Romero, Alberto Ruiz-Porras 1, Diego García-Ayuso, Johnny Di Pierdomenico, Paloma Sobrado-Calvo, Francisco J Valiente-Soriano |
| 6 | Digital Eye Strain among Adults Presenting to Tertiary Care Hospital in the Era of COVID-19 Pandemic: A Descriptive Cross-sectional Study | JNMA; Journal of the Nepal Medical Association | 2022 | Anjila Basnet, Samyam Bickram Pathak, Anurag Marasini, Rohit Pandit, Amita Pradhan |
| 7 | Smartphone Vision Syndrome Associated with Prolonged Use of Digital Screen for Attending Online Classes during COVID-19 Pandemic among Medical Students: A Cross-sectional Study. | Journal of Clinical & Diagnostic Research | 2021 | Hundekari Jagdish, Sisodiya Rishendra, Kot Lokendra |
| 8 | High frequency of digital eye strain and dry eye disease in teleworkers during the coronavirus disease (2019) pandemic | International Journal of Occupational Safety and Ergonomics | 2021 | Daniela Salinas-Toro, Cristian Cartes, Christian Segovia, Maria Jesus Alonso, Begoña Soberon, Maritza Sepulveda, Claudia Zapata, Patricio Yañez, Leonidas Traipe, Claudia Goya, Patricia Flores, Daniela Lopez, Remigio Lopez |

In this section, selected studies are numbered from 1-8 to facilitate the presentation of the critical appraisal.

All eight studies were published in pre-review journals and written in English. A qualitative approach was appropriate in all studies, seeking a deeper understanding of people´s views or experiences concerning specific circumstances. In studies no. 1-3, 5, 7, and 8, the sampling strategy was ranged at the maximum variation of experiences by including participants from different demographics and settings. The sampling strategy was limited to selected settings in studies no. 4, 6, and 7, although the participants were randomly chosen inside these limited settings, and the reliability was not critically weakened. In studies no. 4 and 7, participants were included only from a single institute. In study no. 6, participants included in the study were patients of the Ophthalmology Outpatient Department of a tertiary hospital. There was no information on whether, in this study, the participants were diagnosed with an eye disease or had symptoms related to eye disease when coming to the tertiary hospital or if they were regular patients with refractive errors coming to basic eye examinations. No information was given about possible ocular examinations, but information about the type of refractive error was registered.

Regarding eye health, in study no. 1, participants were excluded if they were contact lens wearers, on treatment for glaucoma, or had undergone ocular surgery. In study no. 4, participants with a history of ocular surgery or active ocular disease were excluded. In study no. 7 students who had any eye disorder or were using eye drops frequently were excluded. In other studies, exclusion criteria did not contain eye health. In studies no. 1-5,7, and 8, it was stated that the study did not include ocular examinations. In study no. 6, no information regarding ocular examinations was given. In all the studies sample size was sufficient, ranging from 137 to 1939.

In six studies out of eight (no. 1-5 and 7), data collection methods were described in sufficient detail. In studies no. 1 and 7, the questionnaires used in the study were added to the appendix, and in study no. 2, it was written to be included in the study's appendix, although it was not counted in the article to be seen. In study, no. 5 questionnaire was available online. In studies no. 3 and 4 CVS-Q questionnaire designed by Seguí et al. (2015) was used, and in study no. 4, supplementary material was available online. In the studies, no. 6 and 8 questionnaires were not available.

In studies no. 1-4 data were analyzed using SPSS software, in study no. 5 by PSPP software (free replacement of SPSS software), and in study no. 8 using Stata. In all those studies P-value $< .05$ was considered significant. In study no. 7 results were compared using Exploratory Factor Analysis (EFA). In the study, no. 6 data entry was done in Microsoft Excel. Only in study no. 4 researchers' positions were described as part of the research process. In none of the studies researchers' positions in relation to the research question were mentioned, for example, existing knowledge of the topic to be searched. In all eight studies, results answered the research question, and conclusions were drawn justified by the results. Also, in all studies, results were presented and explained in detail and compared to previous studies, although in study no. 6, the results were presented and explained narrowly.

After a critical appraisal of the studies, all eight studies were included in the review to meet the reliability and credibility criteria. All studies have flaws and weaknesses, but in selected studies, the weaknesses were considered non-critical, and there were no flaws that would critically impact the findings of an individual study and the results of the review. All specifications of the aspects of quality assessment are assembled in Table 4.

*Table 4. Quality assessment table*

| Study no. | Qualitative approach appropriate | Sampling strategy appropriate | Data collection described in sufficient detail | The data analysis approach is appropriate for the methodology used | The researcher's position described | Results answer the question | Inclusion drawn justified by the results |
|---|---|---|---|---|---|---|---|
| 1 | v | v | v | v | NS | v | v |
| 2 | v | v | v | v | NS | v | v |
| 3 | v | v | v | v | NS | v | v |
| 4 | v | vx | v | v | vx | v | v |
| 5 | v | v | v | v | NS | v | v |
| 6 | v | vx | vx | vx | NS | v | vx |
| 7 | v | vx | v | v | NS | v | v |
| 8 | v | v | vx | v | NS | v | v |

**Item adequately addressed: v = Yes; x = No; vx = partially/unclear; NS = not stated**

## 4.5 Analysis of the Data

### 4.5.1 Results

This scoping review consists of eight studies, presented in Table 5. All selected studies are qualitative descriptive survey studies from six countries: India, Saudi Arabia, China, Spain, Nepal, and Chile. Sample sizes vary from 137 to 1939, and in all studies, data were collected by questionnaires. The results are summarized in Table 6.

*Table 5. Studies selected for the scoping review*

| No. | Title, publication, and year | Authors | The aim of the study | Research method | Sample size | Country of implementation and protocol approval |
|---|---|---|---|---|---|---|
| 1 | Impact of the COVID-19 lockdown on digital device-related ocular health<br><br>Indian Journal of Ophthalmology, 2020. | Fayiqa Ahamed Bahkir, Srinivasan Subramanian Grandee. | To assess the impact of the lockdown on digital device usage and, consequently, the ocular surface health implications and circadian rhythm abnormalities related to digital eye strain. | An open online survey made with Google Forms aimed at individuals over 18 who use digital devices. An online survey was sent through various social media platforms (WhatsApp, Facebook, Instagram). | A total of 407 usable responses were obtained; the average age of respondents was 27.4 years. 44.5% female, 55.5% male. | India. The study was approved by the Institutional Human Ethics Committee. |
| 2 | Effect of digital device use during COVID-19 on digital eye strain<br><br>Clinical & Experimental Optometry, 2021. | Balsam Alabdulkader | To evaluate the COVID-19 isolation's impact on digital device use by comparing hours spent on digital devices before and during the 24-hour curfew in Saudi Arabia while assessing the symptoms associated with digital eye strain. | Observational cross-sectional study for Saudi Arabian residents, age >18 years, recruited via snowball sampling using social media. An online questionnaire made with Google forms was used to collect the data. | A total of 1939 valid responses, mean age of 33 +- 12.2 (range 18-81) years. 72% females, 28% males. | Saudi Arabia. The study was approved by the ethics committee of King Saud University and conducted under the standards described in the 1964 declaration of Helsinki. |
| 3 | Digital Eye Strain Epidemic amid COVID-19 Pandemic - A Cross-sectional Survey<br><br>Ophthalmic Epidemiology, 2021. | Pratyusha Ganne, Shaista Najeeb, Ganne Chaitanya, Aditya Sharma, Nagesha C Krishnappa | To estimate the prevalence of digital eye strain (DES), describe the pattern of gadget usage, and analyze the risk factors for DES during the COVID-19 pandemic. | A cross-sectional, questionnaire-based study. An online survey using Google Forms for students and members of the general population aged 18 and over. | 941 responses from students of online classes (688), teachers of online classes (45), and the general population (208). Mean age 23.4 +- 8.2 years (range 18-79 years). Female 48.9%, male 51.1%. | India. Approved by the Institutional ethics committee of All India Institute of Medical Sciences (AIIMS) and conducted in accordance with the declaration of Helsinki. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | Computer Vision Syndrome During SARS-CoV-2 Outbreak in University Students: A Comparison Between Online Courses and Classroom Lectures<br><br>Frontiers in Public Health, 2021. | Lixiang Wang, Xin Wei, Yingping Deng | To compare the prevalence of CVS in university students of different teaching modes during the SARS-CoV-2 outbreak period. | A cross-sectional, observational, web-based survey study using the validated Computer Vision Syndrome Questionnaire (CVS-Q). | 137 responses; 63 from Chinese students who took classroom lectures and 74 from international students (MBBS) who took online lectures. 33.33% of Chinese and 47.30% of MBBS were female. | China. Approved by the Ethics Committee of West China Hospital of Sichuan University and performed in accordance with the declaration of Helsinki. |
| 5 | Computer Vision Syndrome in the Spanish Population during the COVID-19 Lockdown<br><br>Optometry and Vision Science, 2021. | Caridad Galindo-Romero, Alberto Ruiz-Porras 1, Diego García-Ayuso, Johnny Di Pierdomenico, Paloma Sobrado-Calvo, Francisco J Valiente-Soriano. | To assess computer vision syndrome-related eye symptoms due to the use of electronic devices during the COVID-19 lockdown in Spain in 2020. | A descriptive study through an online questionnaire hosted on Google Forms and filled in by participants older than 18 years. | 730 results. The respondent's average age was 36+-14 years (range 18-73 years). 65.3% female and 34.7% male. | Spain. Approved by the Ethics Committee of the University of Murcia and conforms with the principles and applicable guidelines for the protection of human subjects in biomedical research. |
| 6 | Digital Eye Strain among Adults Presenting to Tertiary Care Hospital in the Era of COVID-19 Pandemic: A Descriptive Cross-sectional Study<br><br>JNMA; Journal of the Nepal Medical Association, 2022. | Anjila Basnet, Samyam Bickram Pathak, Anurag Marasini, Rohit Pandit, Amita Pradhan. | To find out the prevalence of digital eye strain among the adult population in a tertiary care hospital in the era of the COVID-19 pandemic. | A descriptive cross-sectional study. Data was collected by filling semi-structured research questionnaire. | A sample size of 318 participants attending the Ophthalmology Outpatient Department of a tertiary hospital, patients >20 years. 54.4% female and 45.6% male. | Nepal. Approval from the Institutional Review Committee of KIST Medical College and Teaching Hospital. |
| 7 | Smartphone Vision Syndrome Associated with Prolonged Use of Digital Screen for Attending Online Classes during COVID-19 Pandemic among Medical Students: A Cross-sectional Study | Hundekari Jagdish, Sisodiya Rishendra, Kot Lokendra | To investigate the impact of online cl on the development of Digital Vision Syndrome (DVS) among undergraduate medical students. | A cross-sectional study through a pre-tested Google Form questionnaire related to digital vision syndrome (DVS). | 280 medical students, with a mean age of 20.36 +-1.30, between 18-25 years. 135 female, 145 male. | India. Approval obtained from the Institutional Ethics committee (Reg. No. ECR/1192/inst/MP/2019). |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Journal of Clinical & Diagnostic Research, 2021. | | | | | |
| 8 | High frequency of digital eye strain and dry eye disease in teleworkers during the coronavirus disease (2019) pandemic<br><br>International Journal of Occupational Safety and Ergonomics, 2021. | Daniela Salinas-Toro, Cristian Cartes, Christian Segovia, Maria Jesus Alonso, Begoña Soberon, Maritza Sepulveda, Claudia Zapata, Patricio Yañez, Leonidas Traipe, Claudia Goya, Patricia Flores, Daniela Lopez, Remigio Lopez | To evaluate visual display terminal (VDT)- related digital eye strain (ES) and dry eye disease (DED) symptoms in subjects whose work was changed to teleworking (TW) during the coronavirus pandemic. | A cross-sectional study. A digital self-reported survey was answered. | A sample of 1797 participants. Mean age 40.5 (SD 11.1) years. 69.9% female, 30.1% male. | Chile. Approved by Centro de la Vision ethics committee and followed the principles of the Declaration of Helsinki. |

### The Use of Digital Devices

In six of eight studies, the overall self-reported digital device usage in hours increased compared to pre-pandemic time. In two studies, there was no comparison between screen time before and during COVID-19 in hours, but they both stated that the spread of COVID-19 had increased the use of digital devices.

The study by Bahkir and Grandee (2020) was conducted during a worldwide lockdown in India for people over 18 who used digital devices. They aimed to evaluate the effect of lockdown on the use of digital devices and thus on the ocular surface health implications and circadian rhythm disorders related to digital eye strain. Their study had 407 respondents, of which 44.5% were females, and 55.5% were males. 93.6% of respondents marked an increase in digital device usage after a lockdown was initiated in India due to COVID-19. The average increase in hours was 4.8 ± 2.8 h per day, raising the total digital device usage to 8.65 ± 3.74 h per day. In addition, the total use of digital devices increased from pre-lockdown for 5 hours or more by 51.1% of the respondents, of which 40.9% were students. A small part of respondents, 6.63%, reported no change in their screen time after lockdown. This group consisted of homemakers and students who had logged a screen time of 6 to 7 hours before lockdown. 32.4% of respondents marked 9 to 11 hours of screen time per day after lockdown, followed by 26.5% marking 6 to 8 hours. The highest reported screen time, although marked only by 2% of respondents, was as high as > 18h per day. (Bahkir and Grandee 2020.)

The study by Alabdulkader (2021) in Saudi Arabia aimed to assess the impact of COVID-19 isolation on digital device usage by comparing hours of use before and during a curfew while evaluating the symptoms associated with DES. The study was made for Saudi Arabian residents over 18 years of age and consisted of 1939 valid questionnaire responses; of those, 72% were answered by females and 28% by males. The mean age of respondents was 33 ± 12.2 years (range 18-81 years). All study participants reported an increase in smartphone and overall digital device usage compared to pre-curfew usage. The median screen time in all digital devices during curfew was 10.2 h. Pre-curfew time was not reported. The median hours of smartphone usage were 5.6 h before curfew and raised to 7.1 h during curfew. (Alabdulkader 2021.)

Also, in the study by Ganne et al. (2021), the average daily screen time increased during the pandemic compared to pre-pandemic time. In their research conducted in India, there were 941 respondents, of which 48.9% were females and 51.1% were males. The mean age of respondents was 23.4 ± 8.2 years (range 18-79 years). The study aimed to estimate the prevalence of digital eye strain (DES), describe the ways of using gadgets, and analyze risk factors for DES during the COVID-19 pandemic. The proportion of participants exposed to screen time of six or more hours was more significant during the pandemic than before, rising from 10.9% to 57.01%. 184 from 941 participants (19.55%) reported an average screen time after the outbreak of COVID-19 to be more than 10 h, 353 (37.62%) 6-10 h, 264 (28.06%) 4-6 h, 118 (12.54%) 2-4 h, and 22 (2.34%) less than 2 h. Before the pandemic, the numbers were whole different: 224 participants (23.80%) reported that the average screen time had been less than 2 h, 398 (42.30%) 2-4 h, 216 (22.95%) 4-6 h, 85 (9.03%) 6-10 h, and only 18 (1.91%) more than 10 h. All in all, younger people tended to spend more time with digital devices than older people. (Ganne et al. 2021.)

Wang, Wei and Deng (2021) had a different income angle. They aimed to compare the prevalence of computer vision syndrome in university students of different teaching modes during the SARS-CoV-2 outbreak, comparing online lectures and classroom lectures. Chinese medical students took classroom lectures at the same time as the same grade international students from the Bachelor of Medicine and Bachelor of Surgery (MBBS) program took online lessons with similar schedules. In this study, there were 137 responses, 63 from Chinese students and 74 from MBBS students. 33.33% of Chinese students and 47.30% of MBBS were female. The overall digital screen time ranged from less than 2 h to more than 12 h. The difference in screen time between these two groups was understandably very different as one group studied via digital lectures. The most common reported digital screen time was 7-9 h (43.24%) for MBBS students and 2-4 h (46.03%) for Chinese students. The percentage of responders who marked less than 5 hours of digital screen time per day was only 5.41% for MBBS students but 50.79% for Chinese students. From another point of view, the percentage of heavy users of digital devices who had screen time of more than 10 h per day was 28.38% for MBBS students and only 6.35% for Chinese students. Among both groups, the most used device was a phone. (Wang, Wei and Deng 2021.)

Galindo-Romero et al. (2021) evaluated the computer vision syndrome-related eye symptoms due to the use of electronic devices during the COVID-19 lockdown in Spain in 2020, with their questionnaire filled in by participants older than 18 years. In their study, there were 730 respondents, and the average age of the participants was 36 ± 14 years (range 18-73 years). 65.3% of the respondents were female, and 34.7% were male. Their study found that daily use of electronic devices increased by an average of 3.1 ± 2.2 hours during the lockdown. The increase was significantly higher in participants between 18 and 45 years of age. Of all electronic devices, computer use increased the most. The total daily usage of electronic devices during the lockdown was 11.1 ± 4.5 h. The study included television among electronic devices together with smartphones, tablets, and computers. The smartphone was the most used electronic device (99.9%) with an average daily use of 4.3 ± 2.3 h. (Galindo-Romero et al. 2021.)

The study by Basnet et al. (2022), conducted in Nepal, aimed to determine the prevalence of digital eye strain among adults in a tertiary care hospital in the era of the COVID-19 pandemic with a semi-structured questionnaire. The study had a sample size of 318, consisting of patients of the Ophthalmology Outpatient Department of a tertiary hospital over 20 years of age. 54.4% of respondents were female, and 45.6% were male. As for the use of digital devices, there were results of average hours spent on the computer daily during the pandemic. The majority (34%) of participants spent 2-4 h on the digital screen, and 29.2% spent 1-2 h, 22.6% spent 4-6 h, 7.5% spent 6-8 h, 4.4% spent 8-10 h, and 2.2% over 10 h per day. There was no comparison in screen time before and during COVID-19, but it was noted that the spread of COVID-19 had increased the use of digital devices. (Basnet et al. 2022.)

Hundekari, Sisodiya and Kot (2021) had yet another point of view on the subject as they aimed in their study to investigate the impact of online classes on the development of digital eye syndrome, e.g., computer vision syndrome, among undergraduate medical students after they had been attending online classes regularly for five months in India. The study included 280 medical students, with a mean age of 20.36 ± 1.30 years (range 18-25 years). 135 (48.21%) were female, and 145 (51.79%) were male, all students selected from the same institute. 219 students used smartphones to read and attend online classes, and 61 used large screens. Out of 280 participants, 75 (26.79%) were exposed to screens for 1-3 h, 144 (51.43%) for 3-5 h, and 61 (21.79%) for more than 5 h. In this study, there was no comparison in hours between the time before the online lectures began and after the five months, but it was stated in the study that due to the COVID-19 pandemic, students had been forced to attend classes through online mode which has increased screen time additionally compared to already disturbing levels of pre-pandemic digital device use. (Hundekari, Sisodiya and Kot 2021.)

The study made in Chile by Salinas-Toro et al. (2021) aimed to evaluate visual display terminal (VDT)-related digital eye strain (ES) and dry eye disease (DED) symptoms in individuals whose work transitioned to teleworking (TW) during the coronavirus pandemic. This study had a sample of 1797 participants from all over the country, the mean age being 40.5 (SD 11.1) years, from whom 69.9% were female and 30.1% were male. When responding to the questionnaire, the mean number of TW weeks for the participants was 10.2 (SD 3.0), and 73.8% of the respondents had more than 10 weeks of TW. 88.3% were full-time TW workers, 4.1% were part-time TW, and 7.6% had alternating TW and office work. When comparing time pre-pandemic to pandemic teleworking time, the mean VDT total hours increased from 7.4 h (SD 3.3) to 9.5 h (SD 3.3). Divided into two parts, hours of concentration activities increased from 4.9 h (SD 3.1) to 6.0 h (SD3.4) and hours concerning leisure activities from 2.5 h (SD 1.8) to 2.9 h (SD 2.1). No differences in terms of genders were found, as total VDT hours increased in women from 7.2 h (SD 3.3) to 9.6 h (SD 3.3) and in men from 7.97 h (SD 3.25) to 9.5 h (SD 3.5). Although 66.9% of respondents reported an increase in total VDT hours, 22.2% reported the same time before and during the pandemic, and 10.9% reported a decrease in their VDT time. (Salinas-Toro et al. 2021.)

### The Prevalence and Symptoms of Digital Eye Strain

Bahkir and Grandee (2020) included sixteen symptoms related to digital eye strain in their questionnaire. 90.42% of the respondents experienced at least one out of sixteen symptoms. 56.5% reported that these symptoms had increased in frequency and intensity since the lockdown was announced. Females were more affected than males as females reported 3.5 ± 2.78

symptoms and males 2.81 ± 2.54. The seven most common symptoms experienced by the respondents were headache (43.5%), eye pain (29%), heavy eyelids (23.8%), redness of eyes (23.1%), watering of the eyes (23.1%), burning (22.9%), and dryness of eyes (22.4%). The least experienced symptoms were colored rings around bright objects (4.9%) and double vision (5.7%). (Bahkir and Grandee 2020.)

Incidence of DES was found to be 78% by the study by Alabdulkader (2021), with participants reporting one or more of DES- related symptoms out of 15 symptoms. The seven most reported symptoms experienced more than before COVID-19 was eye strain (51%), headache (37%), dryness (37%), difficulty focusing (30%), itchiness (28%), excessive blinking (28%), burning sensation (27%), and blurred vision (27%). The least experienced symptoms were diplopia (11%) and foreign body sensation (13%). (Alabdulkader 2021.)

Ganne et al. (2021) estimated the level of DES symptoms in their study with a pre-validated computer vision syndrome questionnaire designed by Seguí et al. (2015). The intensity and frequency of 16 symptoms were used to estimate the grading of DES. DES score ≥ 6 was an indication of digital eye strain. As a result, the highest DES score was among students attending online classes (median score 7, IQR 6.87-7.7), secondly came teachers of online classes (median score 5, IQR 4.37-7.23), followed by the rest of the public (median score 4, IQR 4.64-6.18). All in all, they noted that students studying online had a higher prevalence of eye strain (50.6%) compared to the rest of the public (33.2%). The symptoms of DES were not revealed in the study individually. (Ganne et al. 2021.)

Wang, Wei and Deng (2021) found out in their study that the prevalence of computer vision syndrome among Chinese students studying mainly in classrooms was 50.79%, and for the MBBS students taking exclusively online courses, 74.32%. Also, their CVS-Q questionnaire included 16 computer vision syndrome symptoms, including frequency and intensity of the symptoms. DES score ≥ 6 indicated computer vision syndrome, e.g., digital eye strain. The percentage of respondents with grades of computer vision syndrome ≥ 10 was 7.94% for Chinese and 13.51% for MBBS students. Chinese students' average grade was 5.00 ± 2.71 symptoms, and for the MBBS students, 5.91 ± 1.9. The seven most reported symptoms of the Chinese students were heavy eyelids (53.97%), dryness (50.79%), feeling of a foreign body (46.03%), headache (42.86%), eye pain (41.27%), blurred vision (39.68%), and tearing (34.92%). For the MBBS students, in comparison, the most reported symptoms were dryness (72.97%), feeling of a foreign body

(62.16%), heavy eyelids (58.11%), eye pain (48.65%), headache (45.95%), difficulty focusing for near vision (43.24%), and excessive blinking (40.54%). The least experienced symptom for both groups was colored halos around objects which were 7.94% for Chinese and 2.7% for MBBS students. The second least experienced symptom for Chinese students was double vision (9.52%) and increased sensitivity to light (14.86%) for MBBS students. (Wang, Wei and Deng 2021.)

In the study by Galindo-Romero et al. (2021), 66.6% of the respondents had experienced at least one visual symptom during the lockdown. Their questionnaire consisted of 11 digital device-related symptoms. They divided the symptoms into external, e.g., ocular symptoms (irritation, grittiness, burning, dryness, and tearing), and internal, e.g., visual symptoms (blurred vision, eye strain, ocular pain, headache, diplopia, and sensitivity to light). Of all the symptoms, the seven most experienced were headache (36.7%), eye strain (32.5%), dryness (31.1%), irritation (24.1%), blurred vision (21.2%), sensitivity to light (17.8%), and ocular pain (14.9%), five of them being internal and two externals. The least experienced symptoms were diplopia (2.6%) and grittiness (8.2%). Participants between 18 and 30 years were more likely to experience both ocular and visual symptoms when compared to participants > 45 years of age, especially headache, ocular pain, and sensitivity to light. (Galindo-Romero et al. 2021.)

Basnet et al. (2022) got in their study a result of 94.3% for the prevalence of symptoms (one or more) of digital eye strain. The seven most experienced symptoms were eye strain (irritation, heaviness) (62.6%), tiredness of eyes (50.9%), headache (44%), discomfort (31.8%), watering of eyes (28%), blurring of vision (25.5%), and dry eye (20.1%). The least experienced eye-related symptoms were double vision (5.7%) and redness of the eyes (14.5%). They also included backache, neck pain, and shoulder pain in their symptoms, but all three were less experienced than all other eye-related symptoms except double vision, which came last. (Basnet et al. 2022.)

Hundekari, Sisodiya and Kot (2021) included nine different symptoms in their questionnaire regarding digital vision syndrome (DVS), e.g., digital eye strain. The symptoms were divided into five accommodative symptoms (blurring, eye strained, eyes feeling heavy, tiredness, and headache) and four ocular surface-related symptoms (redness in the eyes, burning sensation, watery eyes, and ocular pain) scored as never =1, rarely =2, occasionally =3, frequently =4 and always =5. Including all the symptoms, 75% of the total students' scores ranged between occasionally and always, indicating that most students got DVS. Out of all symptoms, the most experienced were tiredness (mean points 3.72), eyes feeling heavy (3.69), headache (3.28), eyes strained (3.18), watery eyes (2.83), ocular pain (2.78), and redness in the eyes (2.68). The least experienced symptoms were blurring (2.46) and burning sensation (2.63). (Hundekari, Sisodiya and Kot 2021.)

Salinas-Toro et al. (2021) compared eye strain symptoms before and during the pandemic. Their questionnaire included eight symptoms (soreness, pain, foreign body sensation, redness, itchiness, visual fatigue, dryness, and blurred vision). They also included a separate DEQ-5 questionnaire to independently evaluate the dry eye symptoms. Individually, when assessing each of the eight symptoms variations, they all had an increase compared to pre-pandemic time. The symptoms presenting the most deviation from the pre-pandemic time were visual fatigue (increased in 37.8% of the subjects), soreness (increased in 28.5%), and dryness (increased in 26.6%). The most experienced symptoms were visual fatigue and blurred vision. The least experienced symptoms were pain and foreign body sensation. (Salinas-Toro et al. 2021.)

**The Risk Factors for Digital Eye Strain**

Seven studies out of eight reported a correlation between increased screen time and digital eye strain. In the study by Basnet et al. (2022), the correlation was not reported directly. Still, they noted that 60.4% of participants experienced the symptoms of digital eye strain after 1-2 hours of digital screen use. There were some differences in the studies by how strong the correlation between digital eye strain and hours of usage was and what other things affected the symptoms of digital eye strain in each study.

In the study by Bahkir and Grandee (2020), the correlation between the increase in screen time and the number of symptoms was found to be statistically significant (P=0.001). As screen time increased, there was also a statistically significant increase in both frequency (P=0.028) and intensity of symptoms (P=0.005). Sleep disturbances were also increasingly reported by people with more screen time (P=0.001). 90.42% of the respondents experienced at least one of sixteen digital eye strain symptoms, and 56.5% reported that these symptoms had increased in frequency and intensity since the lockdown was announced. This group averaged 9.3 ± 3.5 hours of digital device usage and consisted primarily of the student community (60%). During the pandemic, the student population was more symptomatic than the working population despite having the same comparable total screen time (8.8±3.6h for students and 9.3±3.4h for adults) as students reported 3.9±2.2 symptoms and the working population 3.4±2 symptoms. (Bahkir and Grandee 2020.)

In the study by Alabdulkader (2021), the association between the number of hours spent on digital devices per day and the complaints of symptoms were calculated by chi-squared tests, and results revealed that participants who used digital devices for more than 6 hours a day were at significantly higher risk of developing DES symptoms. Also, the association between the engagement level of digital device use and the number of hours spent on all devices was calculated. All symptoms showed a significant difference, where highly engaged individuals were more likely to suffer from symptoms associated with DES. The risk factor affecting DES the most was the number of devices used. This factor was more substantial than, for example, age, gender, level of engagement with digital devices, or even total usage time. (Alabdulkader 2021.)

Also, in the study by Ganne et al. (2021), digital eye strain was directly proportional to the increase in hours using digital devices. In addition, they observed that median DES scores were higher for those whose screen time jumped more during the pandemic. For example, people who used digital devices for 2-4h per day before the pandemic showed a steep increase in the median DES scores from 5 when using gadgets for 4-6h during the pandemic to 10 when using >10h during the pandemic. In their study, DES scores were not related to the number of devices used in a day, as in the study by Alabdulkader (2021). Instead, DES scores were higher in those with higher screen time per day, with pre-existing eye diseases, decreased screen distance < 20cm, using digital devices in the dark, and infrequent or no breaks. Also, younger age was associated with increased DES, i.e., age inversely correlated with DES scores as the device usage duration decreased. (Ganne et al. 2021.)

Wang, Wei and Deng (2021) analyzed the correlation between digital screen time and different symptoms of computer vision syndrome by univariate correlations. The digital screen time had a positive correlation with the feeling of a foreign body (p=0.010), heavy eyelids (p=0.016), and dryness (p=0.007). With other symptoms, the correlation was not significant. Additionally, the sum grades of CVS showed a moderate positive correlation with digital screen time (p<0.001). The overall prevalence of CVS was higher among MBBS students who studied exclusively online compared to Chinese students who received lectures in classrooms (74.32% vs. 50.79%). Due to the online classes, MBBS students spent a much longer time on digital devices compared with Chinese students. As these two groups spent similar time on common lectures during the semester when the survey was conducted, the study suggested that online studying may contribute to the prevalence of CVS among students. (Wang, Wei and Deng 2021.)

In the study by Galindo-Romero et al. (2021), the total symptom score was significantly influenced by the daily hours of electronic device use. The increased use of electronic devices was associated with an increased tendency to report visual symptoms (p=0.05). Respondents who reported a higher increase in daily digital device use during the lockdown were more likely to have a higher total symptom score. Also, participants who spent more time using electronic devices and less time outdoors reported more eye symptoms related to computer vision syndrome. Participants aged 18 to 30 were more likely to experience ocular and visual symptoms than those aged 45 and over, especially headaches, ocular pain, and sensitivity to light. A higher symptom score was reported when there was a higher use of a computer (p=0.001) or a smartphone (p=0.03) in hours. However, hours spent on a tablet (p=0.36) or television (p=0.20) or independently viewing distance of a smartphone (p=0.20) were not significantly associated with the total symptom score. 32.2% of the participants reported worsened visual symptoms compared to the time before lockdown, which also correlated with an increase in the median total symptom score. When comparing primary activities, studying from home and remote working showed a similar median total symptom score, significantly higher than the other activities (p=0.001). (Galindo-Romero et al. 2021.)

Basnet et al. (2022) solely reported that 60.4% of participants experienced the symptoms of digital eye strain after 1-2 hours of digital screen use. The most common preventive measure for relieving symptoms of digital eye strain was taking breaks between the use of the computer, which was reported by 76.6% of respondents. 98.1% of the participants were aware that long-term use of digital screens has a harmful effect on the eyes. (Basnet et al. 2022.)

Hundekari, Sisodiya and Kot (2021) also noted that effects on the eyes increased as the duration of digital device use increased. The study revealed that both the accommodative and ocular mechanisms responsible for developing digital device syndrome were significantly affected as the duration of exposure to digital devices increased. They also reported that students who kept less than arm or forearm length distance to the screen are at higher risk of digital device syndrome development. In addition, small screens have a more significant effect on the eyes than larger screens when looking at the development of digital device syndrome. (Hundekari, Sisodiya and Kot 2021.)

Salinas-Toro et al. (2021) reported that the number of VDT hours seems to be an essential factor in eye strain and the development of dry eye disease. The younger participants had higher hours of digital device use and were more exposed to the effects than the older group. But even though the frequency of ES symptoms increased in all age groups, the most senior group presented less discomfort intensification compared to the young population, which according to the study, could indicate that the number of VDT hours has a more significant effect on the eye strain and dry eye disease symptoms than age. According to the results, teachers and students were more affected than the other working sectors of teleworking after the outbreak of COVID-19. The ocular symptom index (OSI) rose from pre-pandemic to the pandemic time in all age groups. On average, including all age groups, the OSI raised from 15.0 (SD 5.2) to 17.3 (SD 6.4). 56.4% of respondents had an increase in the score, 22.48% maintained the same, and the OSI value decreased by 21.09%. For those whose score remained the same or reduced, the OSI was 15.8 (SD 6.3); for those whose score increased, the OSI was higher, 18.4 (SD 6.3). (Salinas-Toro et al. 2021.)

*Table 6. The summary of the results*

| No. | Title and authors | The use of digital devices | The prevalence of digital eye strain | The most prevalent symptoms | The risk factors of digital eye strain |
|---|---|---|---|---|---|
| 1 | Impact of the COVID-19 lockdown on digital device-related ocular health (2020)<br><br>Fayiqa Ahamed Bahkir, Srinivasan Subramanian Grandee | The average increase in hours per day was 4.8 ± 2.8 h.<br><br>The total digital device usage to 8.65 ± 3.74 h per day. | 90.42% of the respondents experienced at least one out of sixteen symptoms.<br><br>56.5% said that the frequency and intensity of these symptoms had increased since the lockdown was declared. | **1.** headache (43.5%)<br>**2.** eye pain (29%)<br>**3.** heavy eyelids (23.8%)<br>**4.** redness of eyes (23.1%)<br>**5.** watering of the eyes (23.1%)<br>**6.** burning (22.9%)<br>**7.** dryness of eyes (22.4%) | The correlation between the increase in screen time and the number of symptoms was statistically significant (P=0.001). As screen time increased, there was also a statistically significant increase in both frequency (P=0.028) and intensity of symptoms (P=0.005). |
| 2 | Effect of digital device use during COVID-19 on digital eye strain. (2021)<br><br>Balsam Alabdulkader | All study participants reported an increase in overall digital device usage compared to pre-curfew usage, but it was not noted in hours.<br><br>The median screen time in all digital devices during curfew was 10.2 h.<br><br>The median hours of smartphone usage were 5.6 h before curfew and raised to 7.1 h during curfew | The incidence of DES was 78%, with participants reporting one or more DES-related symptoms out of 15. | **1.** eye strain (51%)<br>**2.** headache (37%)<br>**3.** dryness (37%)<br>**4.** difficulty focusing (30%)<br>**5.** itchiness (28%)<br>**6.** excessive blinking (28%)<br>**7.** burning sensation (27%) and blurred vision (27%). | The risk factor affecting DES the most was the number of devices used.<br><br>Participants who used digital devices for more than 6 hours a day were at significantly higher risk of developing DES symptoms.<br><br>Highly engaged individuals were more likely to suffer from symptoms associated with DES. |
| 3 | Digital Eye Strain Epidemic amid COVID-19 Pandemic - A Cross-sectional Survey (2021)<br><br>Pratyusha Ganne, Shaista Najeeb, Ganne Chaitanya, Aditya Sharma, | Before the pandemic, for 23.80%, the average screen time had been less than 2 h,<br>for 42.30% 2-4 h, for 22.95% 4-6 h, for 9.03% 6-10 h, and only for 1.91% more than 10 h. | The intensity and frequency of 16 symptoms were used to estimate the grading of DES. DES score ≥ 6 indication of digital eye strain. The highest DES score was among students attending online classes (median score 7, IQR 6.87-7.7), secondly came teachers of online | Symptoms were not stated. | Digital eye strain was directly proportional to the increase in the number of hours of digital device usage.<br>In addition, they observed that median DES scores were higher for those whose screen time jumped more during the pandemic.<br><br>DES scores were higher in those with higher screen time |

| | | | | | |
|---|---|---|---|---|---|
| | Nagesha C Krishnappa | After the outbreak of COVID-19 19.55% reported an average screen time of more than 10 h, 37.62% 6-10h, 28.06% 4-6 h, 12.54% 2-4 h, and 2.34% less than 2 h. | classes (median score 5, IQR 4.37-7.23), followed by the rest of the general public (median score 4, IQR 4.64-6.18) | | per day, with pre-existing eye diseases, decreased screen distance < 20cm, using digital devices in the dark, and infrequent or no breaks.<br><br>Younger age was associated with increased DES, i.e., age inversely correlated with DES scores as the device usage duration decreased. |
| 4 | Computer Vision Syndrome During SARS-CoV-2 Outbreak in University Students: A Comparison Between Online Courses and Classroom Lectures (2021)<br><br>Lixiang Wang, Xin Wei, Yingping Deng | The most common reported digital screen time was 7-9 h (43.24%) for MBBS students (online lectures) and 2-4 h (46.03%) for Chinese students (classroom lectures). Less than 5 h of screen time per day was 5.41% for MBBS students but 50.79% for Chinese students.<br><br>More than 10 h per day, 28.38% for MBBS students and 6.35% for Chinese students. | For the MBBS (exclusively online courses), 74.32%. Among Chinese students (mainly in classrooms), 50.79%.<br><br>Their CVS-Q questionnaire included 16 computer vision syndrome symptoms, including frequency and intensity of the symptoms. DES score ≥ 6 indicated computer digital eye strain. The percentage of respondents with grades of computer vision syndrome ≥ 10 was 7.94% for Chinese and 13.51% for MBBS students. Chinese students' average grade was 5.00 ± 2.71 symptoms, and for the MBBS students, 5.91 ± 1.9. | MBBS students:<br>**1.** dryness (72.97%)<br>**2.** feeling of a foreign body (62.16%)<br>**3.** heavy eyelids (58.11%)<br>**4.** eye pain (48.65%)<br>**5.** headache (45.95%)<br>**6.** difficulty focusing for near vision (43.24%)<br>**7.** excessive blinking (40.54%)<br><br>Chinese students:<br>**1.** heavy eyelids (53.97%)<br>**2.** dryness (50.79%)<br>**3.** feeling of a foreign body (46.03%)<br>**4.** headache (42.86%)<br>**5.** eye pain (41.27%)<br>**6.** blurred vision (39.68%)<br>**7.** tearing (34.92%) | The sum grades of CVS showed a moderate positive correlation with digital screen time (p<0.001).<br><br>The overall prevalence of CVS was higher among MBBS students who studied exclusively online compared to Chinese students who received lectures in classrooms (74.32% vs. 50.79%)<br><br>The digital screen time had a positive correlation with the feeling of a foreign body (p=0.010), heavy eyelids (p=0.016), and dryness (p=0.007). With other symptoms, the correlation was not significant. |
| 5 | Computer Vision Syndrome in the Spanish Population during the COVID-19 Lockdown (2021)<br><br>Caridad Galindo-Romero, Alberto Ruiz-Porras 1, Diego García-Ayuso, Johnny Di Pierdomenico, Paloma Sobrado-Calvo, Francisco J Valiente-Soriano | The daily use of electronic devices increased by an average of 3.1 ± 2.2 h during the lockdown.<br><br>The total daily usage of electronic devices during the lockdown was 11.1 ± 4.5 h.<br><br>The smartphone was the most used electronic device (99.9%) with an average daily use of 4.3 ± 2.3 h. | 66.6% of the respondents had experienced at least one visual symptom during the lockdown.<br><br>Their questionnaire consisted of 11 digital device-related symptoms. | **1.** headache (36.7%)<br>**2.** eye strain (32.5%)<br>**3.** dryness (31.1%)<br>**4.** irritation (24.1%)<br>**5.** blurred vision (21.2%)<br>**6.** sensitivity to light (17.8%)<br>**7.** ocular pain (14.9%) | A higher symptom score was reported when there was a higher use of a computer (p=0.001) or a smartphone (p=0.03) in hours.<br><br>32.2% of the participants reported worsened visual symptoms compared to the time before lockdown, which also correlated with an increase in the median total symptom score.<br><br>Participants who spent more time using electronic devices and less time outdoors reported more eye symptoms related to computer vision syndrome.<br><br>Participants aged 18 to 30 were more likely to experience ocular and visual symptoms than those aged 45 and over, especially headaches, ocular pain, and sensitivity to light. |
| 6 | Digital Eye Strain among Adults Presenting to Tertiary Care Hospital in the Era of COVID-19 Pandemic: A Descriptive | Pre-COVID screen time was not reported.<br><br>During the pandemic 34% of participants spent 2-4 h on the digital | 94.3% for the prevalence of digital eye strain symptoms (one or more). | **1.** eye strain (irritation, heaviness) (62.6%)<br>**2.** tiredness of eyes (50.9%)<br>**3.** headache (44%)<br>**4.** discomfort (31.8%) | 60.4% of participants experienced the symptoms of digital eye strain after 1-2 hours of digital screen use. |

| | | | | | |
|---|---|---|---|---|---|
| | Cross-sectional Study (2022)<br><br>Anjila Basnet, Samyam Bickram Pathak, Anurag Marasini, Rohit Pandit, Amita Pradhan | screen, 29.2% 1-2 h, 22.6% 4-6 h, 7.5% 6-8 h, 4.4% 8-10 h, and 2.2% over 10 h per day. | | **5.** watering of eyes (28%)<br>**6.** blurring of vision (25.5%)<br>**7.** dry eye (20.1%) | |
| 7 | Smartphone Vision Syndrome Associated with Prolonged Use of Digital Screen for Attending Online Classes during COVID-19 Pandemic among Medical Students: A Cross-sectional Study (2021)<br><br>Hundekari Jagdish, Sisodiya Rishendra, Kot Lokendra | Pre-COVID screen time was not reported.<br><br>During the pandemic, 26.79% were exposed to screens for 1-3 h, 51.43% for 3-5 h, and 21.79% for more than 5 h. | Including all the symptoms, 75% of the total students' scores ranged between occasionally and always indicating DES | **1.** tiredness (mean points 3.72)<br>**2**. eyes feeling heavy (3.69)<br>**3.** headache (3.28)<br>**4.** eyes strained (3.18)<br>**5.** watery eyes (2.83)<br>**6.** ocular pain (2.78)<br>**7.** redness in the eyes (2.68) | Effects on the eyes increased as the duration of digital device use increased.<br><br>Both the accommodative and ocular mechanisms responsible for developing digital device syndrome were significantly affected as the duration of exposure to digital devices increased.<br><br>Students who kept less than arm or forearm distance to the screen are at higher risk of developing digital device syndrome.<br><br>Small screens have a more significant effect on the eyes than larger screens when looking at the development of digital device syndrome. |
| 8 | High frequency of digital eye strain and dry eye disease in teleworkers during the coronavirus disease (2019) pandemic (2021)<br><br>Daniela Salinas-Toro, Cristian Cartes, Christian Segovia, Maria Jesus Alonso, Begoña Soberon, Maritza Sepulveda, Claudia Zapata, Patricio Yañez, Leonidas Traipe, Claudia Goya, Patricia Flores, Daniela Lopez, Remigio Lopez | VDT total hours increased from 7.4 h to 9.5 h. Divided into two parts, hours of concentration activities increased from 4.9 h to 6.0 h and hours concerning leisure activities from 2.5 h to 2.9 h.<br><br>66.9% of respondents reported an increase in total VDT hours, 22.2% reported the same time before and during the pandemic, and 10.9% reported a decrease in their VDT time. | Prevalence was not noted.<br><br>The ocular symptom index (OSI) rose from pre-pandemic to the pandemic time in all age groups. The OSI average increased from 15.0 (SD 5.2) to 17.3 (SD 6.4).<br><br>56.4% of respondents had an increase in the score, 22.48% maintained the same, and the OSI value decreased by 21.09%.<br><br>For those whose score remained the same or reduced, the OSI was 15.8 (SD 6.3); for those whose score increased, the OSI was higher, 18.4 (SD 6.3) | The two most experienced symptoms out of eight:<br><br>**1.** visual fatigue and<br>**2.** blurred vision<br><br>The symptoms presenting the most deviation from the pre-pandemic time were:<br><br>**1.** visual fatigue (increased in 37.8% of the subjects)<br>**2.** soreness (increased in 28.5% of the subjects)<br>**3.** dryness (increased in 26.6% of the subjects) | The number of VDT hours seems to be an essential factor in eye strain and the development of dry eye disease.<br><br>Even though the frequency of ES symptoms increased in all age groups, the most senior group presented less discomfort intensification compared to the young population, which according to the study, could indicate that the number of VDT hours has a more significant effect on the eye strain and dry eye disease symptoms than age. |

### 4.5.2 Synthesis of the Results

In six of eight studies, a comparison was made between screentime hours before and during COVID-19, and in all studies, results showed an increase in digital device usage. In two studies, there was no comparison between screen time before and during COVID-19 in hours, but they both stated that the spread of COVID-19 had increased the use of digital devices. The reported average increase in screen time ranged between 2.1h – 4.8 ± 2.8h and was reported by hours by Bahkir and Grandee (2020), Galindo-Romero et al. (2021), and Salinas-Toro et al. (2021). The total screen time during the pandemic per day on average was reported in those same three studies and also by Alabdulkader (2021). The total screen time of all digital devices ranged between 8.65 ± 3,74h - 11.1 ± 4.5. According to these results, the highest screen time in average usage hours was as high as 15.6h per day. As an individual marking, there was even an amount of daily usage of >18 h reported by 2% of respondents in the study by Bahkir and Grandee (2020).

In studies by Wang, Wei and Deng (2021), Basnet et al. (2022), Hundekari, Sisodiya and Kot (2021), the average screen time during the pandemic was reported according to the answer options. In the study by Wang, Wei and Deng (2021), the most common answer for MBBS students studying remotely was screen hours of 7-9h. In the study by Basnet et al. (2022) the average time was lower than in other studies as the majority (34%) marked response of 2-4h and 22.6% of 4-6h. In a study by Hundekari, Sisodiya and Kot (2021), 51.4% marked 3-5h and 21.79% more than five.

Overall, as expected, based on the prevailing situation of the pandemic, there was quite a rise in average screen time after the outbreak of COVID-19, even though the screen time was already relatively high before the pandemic. When compared to the studies from pre-covid time, according to Sheppard and Wolffsohn (2018), in 2016, in the UK, it was estimated that adults spent 4h45min per day using digital media and, according to Coles-Brennan, Sulley and Young (2019), that same year, 2016, adult Americans viewed digital media for an average of 5,6h per day. However, already in 2018, reports showed an amount of 60 hours per week.

Alongside the steady growth of the total screen time, according to results, there has been an enormous instant growth in screen time due to working and studying from home. The massive use of digital devices has become significantly more common after the outbreak of COVID-19. In the study by Bahkir and Grandee (2020), the total use of digital devices increased from pre-lockdown for 5 hours or more by 51.1% of the respondents, of which 40.9% were students. Additionally, 32.4% of respondents marked 9 to 11 hours of screen time per day after lockdown, followed by 26.5% marking 6 to 8 hours. In the study by Ganne et al. (2021), the proportion of participants exposed to screen for six or more hours was more significant during the pandemic than before, rising from 10.9% to 57.01%. 19.55% of participants reported an average screen time after the outbreak of COVID-19 to be more than 10 h, and 37.62% to 6-10 h. Before the pandemic, the percentages were whole different as 9.03% reported 6-10 h of screen time, and only 1.91% more than 10 h. In the study by Wang, Wei and Deng (2021), only 5.41% of MBBS students studying remotely marked less than 5h of screen time, and in the study by Salinas-Toro et al. (2021) all in all 66.9% of respondents reported an increase in total screen hours.

The prevalence of DES was studied in four different ways. In studies by Bahkir and Grandee (2020), Alabdulkader (2021),Galindo-Romero et al. (2021), and Basnet et al. (2022), the prevalence was reported when experiencing at least one symptom of digital eye strain. The prevalence in these studies varied from 66.6% to 94.3%. In the studies by Ganne et al. (2021) and Wang, Wei and Deng (2021), the prevalence was reported by CVS-Q DES scores ≥ 6, and the prevalence was between 50.6%-74.32%. In the study by Hundekari, Sisodiya and Kot (2021), it was reported that 75% of the respondents marked experiencing DES symptoms between occasionally and always, thus, most of the students got digital vision syndrome. In the study by Salinas-Toro et al. (2021), the prevalence was not reported generally; instead, there was a comparison in the ocular symptom index (OSI), and the index increased in 56.4% of participants compared to the time before the pandemic.

As there are different ways to study the prevalence of DES, the results are not fully comparable, but the general picture can be seen. Compared to studies before the pandemic, the prevalence of DES remained quite the same in percentages compared to pre-pandemic time, when reported mostly between 64% and 90%. In 2018, according to Sheppard and Wolffsohn (2018), the prevalence of DES was 50% or more. But in various previous studies, the prevalence of digital eye strain has already risen for high as 90%-93%, as reported by Rosenfield (2011), Coles-Brennan, Sulley and Young (2019) in their systematic reviews. As the prevalence of DES has been detected to be as high as 93% already before the pandemic, there was not much higher it could have risen, respectively. Although Ranasinghe et al. (2016) noted that a lower prevalence of eyestrain among computer users had been observed in previous studies in Italy (31.9%), India (46.3%), Australia (63.4%), and Spain (68.5%). However, some of these studies have been made with a limited number of participants and conducted within a single institution. But all in all, from these numbers, India has had quite a leap in the prevalence of eye strain compared to current findings of 90.42% by Bahkir and Grandee (2020). One factor in this massive change in the situation in India can be that the Indian sub-continent has experienced rapid socio-economic and technological development during the last few decades, and screen time has increased rapidly, as mentioned by

Ranasinghe et al. (2016). The outbreak of COVID-19 has since accelerated this growth even further.

Rather than the general prevalence of digital eye strain, the attention in the results is more drawn to the risk factors and their effects. Seven studies out of eight reported a correlation between increased screen time and digital eye strain, and the time spent on digital devices was the most reported risk factor for DES. The correlation between the increase in screen time and the number of symptoms was stated to be statistically significant in studies by Bahkir and Grandee (2020) P=0.001, Galindo-Romero et al. (2021), Hundekari, Sisodiya and Kot (2021), and Salinas-Toro et al. (2021). A study by Wang, Wei and Deng (2021) reported a moderate correlation between screen time and DES symptoms. Ganne et al. (2021) and Salinas-Toro et al. (2021) reported that digital eye strain was directly proportional to the increase in hours of digital device usage and an essential factor in eye strain.

Only in the study by Basnet et al. (2022) the correlation was not reported directly. Still, they noted that 60.4% of participants experienced the symptoms of digital eye strain after 1-2 hours of digital screen use. The study by Alabdulkader (2021) reported that participants who used digital devices for more than 6 hours a day were at a significantly higher risk of developing DES. These findings are similar to the pre-pandemic time. For example, according to American Optometric Association, people who spend at least two continuous hours in front of a computer or use a digital screen daily are at the highest risk of developing computer vision syndrome. (American Optometric Association 2022). According to Seguí et al. (2015), it has been estimated that 90% of the 70 million workers in the United States who use a computer more than 3 hours per day experience eye-related symptoms. Jaiswal et al. (2019) reported in their review that by several studies, even one hour of tablet or smartphone use has shown an increase in eye strain and blur in young adults.

A noticeable and interesting emergent result that seems to be linked to the outbreak of COVID-19 due to the rapidly increased massive screen time hours is that students and overall young adults appear to be at high risk of DES with more intensive and frequent symptoms than before. It has already been detected in previous studies that students develop computer vision syndrome with a high prevalence of 71.6%-94.5% due to the heavy use of digital devices, as can be seen, for example, in studies by Kharel Sitaula and Khatri (2018), Logaraj, Madhupriya and Hegde (2014), and Gammoh (2021).

The result of young adults or students being at high risk of getting DES was found in the studies of this review by Bahkir and Grandee (2020) Ganne et al. (2021), Wang, Wei and Deng (2021), Galindo-Romero et al. (2021), Hundekari, Sisodiya and Kot (2021), and Salinas-Toro et al. (2021). An interesting remark was that during the pandemic, the student population was more symptomatic than the working population despite having the same comparable total screen time as found by Bahkir and Grandee (2020). They reflected in their discussion that the difference could be due to the sudden increase in students' screen time when moving from classrooms to online lectures. The same conclusion of the strong influence of sudden change from face-to-face classes to online studying via screen all day was made by Salinas-Toro et al. (2021) when they found out that teachers, as well as students, were more affected than the other working sectors of teleworking after the outbreak of COVID-19.

Research results support this observation as Ganne et al. (2021) observed that median DES scores were higher for those whose screen time jumped more during the pandemic. Also, Galindo-Romero et al. (2021) found that participants who reported a higher increase in the number of hours during the lockdown were more likely to have a higher symptom score. They also found out that participants aged 18 to 30 were more likely to experience ocular and visual symptoms than participants aged 45 and over, especially headache, ocular pain, and sensitivity to light. The younger population was more symptomatic in their study, although studying from home and remote working showed a similar total symptom score. As both Wang, Wei and Deng (2021) and Hundekari, Sisodiya and Kot (2021) studied exclusively young students, they had no comparison to older people, but their studies showed that as screen time grew due to attending online lectures, students became significantly more symptomatic.

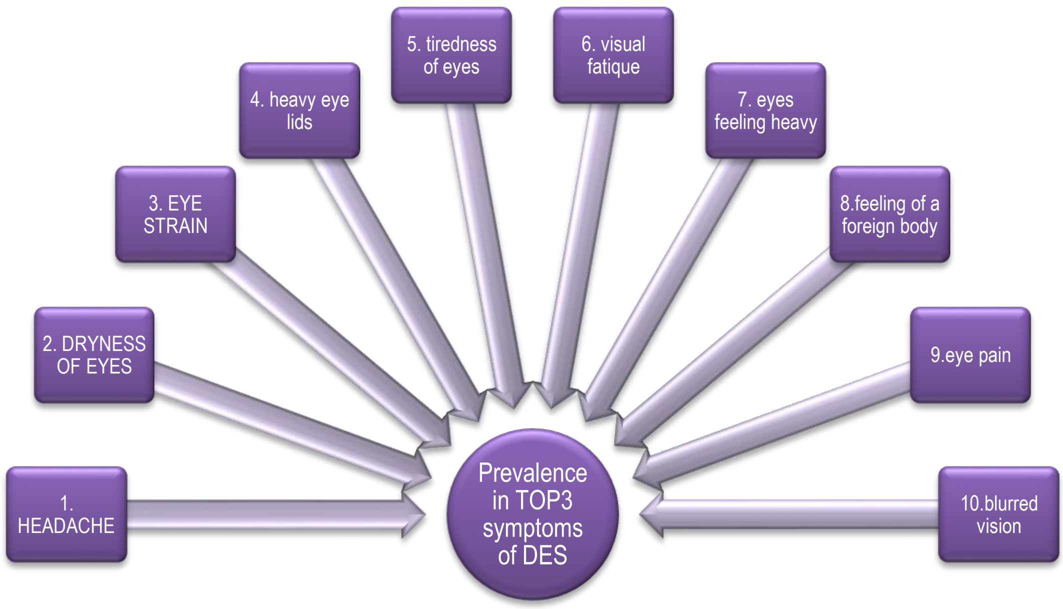
Relatively older age and female gender has traditionally been considered risk factors for DES. This might be partly due to dry eye disease (DED) being more prevalent in women and becoming more prevalent while aging. (Stapleton et al. 2017.) As Salinas-Toro et al. (2021) also studied dry eye symptoms separately, they resulted in higher DED symptoms in the younger population compared to the older. The number of screen hours differed by age conversely, as the highest hours of use was detected in the younger and lowest in the older population. Even though the frequency of eye strain increased in all age groups, the oldest group was less symptomatic than the younger population. Based on these results, the high screen time in hours might have an even more significant effect on digital eye strain and dry eye disease than age.

Overall, the frequency and intensity of symptoms became more severe, and the total symptom score rose while total screen time increased. In the study by Bahkir and Grandee (2020), 56.5% of the participants reported that the frequency and intensity of the DES symptoms had increased since the lockdown started. As screen time increased, there was also a statistically significant increase in both frequency (P=0.028) and intensity of symptoms (P=0.005). Also linked to this, as mentioned before, Ganne et al. (2021) observed that median DES scores were higher for those whose screen time jumped more during the pandemic. Galindo-Romero et al. (2021) also noted that total symptom score was significantly influenced by the daily hours of electronic device use, and participants who reported a higher increase in the number of hours were more likely to have higher symptom scores in all age groups. They mentioned that the percentages of participants reporting symptoms were not higher than in previous studies conducted under normal office work conditions. However, their study showed that participants perceived a worsening of ocular and visual symptoms during the lockdown, as 32.2% of the participants reported worsened visual symptoms compared to the pre-pandemic time. Hundekari, Sisodiya and Kot (2021) also noted that effects on the eyes increased as the duration of digital device use increased.

Other reported risk factors were the number of used devices, viewing distance, age, gender, level of engagement, refractive errors, pre-existing eye diseases, using digital devices in the dark, and infrequent or no breaks. Only in the study by Alabdulkader (2021) the most affecting risk factor of DES was the number of devices used, which exceeded, for example, age, gender, level of engagement with digital devices, or even total usage time a risk factor. Sheppard and Wolffsohn (2018) mentioned in their review that DES was more often reported by people who used two or more devices at the same time compared to those who used only one, with a prevalence of 75% vs. 53%. However, it was not mentioned if it was affecting more or less than, for example, total screen time spent on devices. But, for example, in the study by Ganne et al. (2021), DES scores were not related to the number of devices used in a day. Instead, DES scores were higher in those with higher screen time per day, with pre-existing eye diseases, decreased screen distance < 20cm, using digital devices in the dark, and infrequent or no breaks. Leaning to this, as mentioned by Jaiswal et al. (2019), further research is required in account for the diversity in the use of digital devices as there is a trend of dual or triple screening, where users concurrently use multiple devices such as a tablet, mobile phone, and computer. They point out that it is still poorly understood how using multiple devices affects the visual system, ocular surface, accommodation, and vergence when switching views between screens.

The most common symptoms were studied in seven out of the eight studies. Of the three most common symptoms of these studies, the most experienced symptom was a headache, reported in the TOP 3 of five studies, followed by dryness and eye strain, both reported in the TOP 3 of three studies. Heavy eyelids were reported in the TOP 3 of two studies, tiredness of eyes in two, visual fatigue in one, and eyes feeling heavy in one study. Also, feeling of a foreign body, eye pain, and blurred vision each were in the TOP 3 of one study individually. From another point of view, if the symptoms consisting of heavy eyelids, tiredness of eyes, visual fatigue, and eyes feeling heavy are combined as one group of being an indication of eye fatigue, they appear in one way or another in the TOP 3 of five studies out of seven. From this perspective, eye fatigue can be considered the most common symptom, along with headache. The study by Salinas-Toro et al. (2021) also reported three symptoms that increased the most during the pandemic. These symptoms were visual fatigue, soreness, and dryness. Two of these symptoms, visual fatigue and dryness, one or another, were reported in the TOP3 symptoms of all seven studies. Also, as mentioned before, Galindo-Romero et al. (2021) found that participants aged 18 to 30 were more likely to experience ocular and visual symptoms than participants aged 45 and over, especially headache, ocular pain, and sensitivity to light.

*Figure 3. Prevalence of individual symptoms in TOP3 symptoms of DES*




These findings are consistent with preceding results, as according to Coles-Brennan, Sulley and Young (2019), in numerous previous studies of the student population, the headache was found to be one of the most common digital eye strain symptoms followed by a burning sensation and tired eyes as other common symptoms. Also, according to American Optometric Association, the most common eye-related symptoms of DES are eyestrain, headaches, blurred vision, and dry eyes. (American Optometric Association 2022). Jaiswal et al. (2019) also bring out in their review that by the literature, also the use of smartphones and tablets shows increasing symptoms like headaches, eyestrain, dry eyes, and sore eyes, though they are not dissimilar to those reported with computer use.

Also, the least experienced symptoms, as well as the most experienced, were reported in seven studies out of eight. Double vision/diplopia was experienced the least, as reported in five of the studies among the two least experienced symptoms. Both colored rings around objects and foreign body sensation were reported in two studies among the least experienced symptoms. Other less common symptoms were grittiness, redness of the eyes, increased sensitivity to light, pain, and burning sensation. Interestingly by Hundekari, Sisodiya and Kot (2021), the least experienced symptom was blurring, which was by the study by Salinas-Toro et al. (2021) among the most experienced.

By Coles-Brennan, Sulley and Young (2019), various studies also showed that the prevalence of headaches increased with the duration of computer use and headaches were less common when the screen was viewed at a distance beyond 50cm. Similar findings were also noted in these recent studies as the increase in symptoms correlated with screen time and both Hundekari, Sisodiya and Kot (2021), as well as Ganne et al. (2021), mentioned viewing distance as a risk factor. Ganne et al. (2021) reported decreased screen distance < 20cm as a risk factor, and Hundekari, Sisodiya and Kot (2021) reported that students who kept less than arm or forearm length distance to the screen were at higher risk of digital device syndrome development. Small screens had a more significant effect on the eyes than larger screens when looking at the development of digital device syndrome. By contrast, in the study by Galindo-Romero et al. (2021), independently viewing distance of a smartphone was not significantly associated with the total symptom score of DES.

The most common preventive measure to relieve symptoms of digital eye strain reported by the participants themselves in the study by Basnet et al. (2022) was taking breaks in between the use of a computer (76.7%) followed by using fluorescent light in the room (58.8%) and keeping the screen at eye level (53.1%). The study by Ganne et al. (2021) gave recommendations based on their study results. Their recommendations are as follows: educational institutions should limit the total duration of online classes to less than 4 hours per day, provide sufficient breaks between lessons, and during those breaks, students should give their eyes an opportunity to look at distant objects (20-20-20 rule). Also, the ergonomic use of digital devices should be highlighted, and other screen-related activities should be reduced, if possible, to compensate the screen time spent on online classes or working from home. In this regard, parents are recommended to act as role models for their children. Also, other preventive measures as to avoiding glares and reflections, using anti-glare and blue-light filters in eyeglasses, maintaining the distance greater than 36 inches, placing the screen 20 degrees lower than eye level, and using night mode during the evening hours were recommended. It was also pointed out that it would be good to give eyes an adaptation time to gradually increase screen time instead of suddenly predisposing eyes to high hours of screen time when moved to studying or working remotely. (Ganne et al. 2021.) Alabdulkader (2021) also highlight that limiting screen time is the best approach, if possible, but if not, the 20-20-20 rule is worth trying, and rewetting drops should not be forgotten.

# 5 DEVELOPMENT PHASE

A master's thesis includes both a research phase and a development phase. The development phase should serve working life´s development needs and be implemented in the work field.

## 5.1 The Implementation of the Thesis for Working Life

The purpose and objectives of the development section of this thesis were to create up-to-date information for the work field about the effects of the outbreak of COVID-19 on the use of digital devices and, thereby, digital eye strain in adults and its impact on vision and eye health. As people are suffering from symptoms of DES to an increasing extent, optometrists should be prepared to detect the symptoms and comprise the growing problem of digital eye strain.

The development phase aims to turn the results and analysis of the data from the research phase into compiled information for optometrists in the working field and to introduce different possibilities to prevent and facilitate the symptoms of DES as it will be more and more encountered in eye exams.

The implementation will be done in cooperation with Instru Optiikka Oy as the author will be giving a lecture on a training day in November 2022 for the optometrists of Instru Optiikka Oy in Helsinki. The lecture will be prepared with PowerPoint and presented in front of a live audience. The training manager of Instru Optiikka Oy will participate in the process and be part of the implementation from the side of the firm.

## 5.2 Discussion and conclusions

COVID-19 forced the world to a worldwide social distancing and lockdowns at the beginning of 2020, thereby leading the world to a new era of digitalization as almost all communication began to take place via digital devices. Even though the pandemic might be in a better state in many countries for now, and people are being protected better against the most severe forms of the disease due to vaccinations, the use of digital devices has taken a leap during the worse moments of the pandemic and seems to be staying at high levels also in the future now that a hybrid model of working and studying has found its channels.

Three important aspects emerged when looking at how the outbreak of COVID-19 has impacted the use of digital devices and, thereby, digital eye strain in adults. Firstly, the average daily hours of digital device usage increased significantly, and the leap from lower usage times to massive hours was also detected. Secondly, this rapid increase in screen time instead of slow, steady growth seems to have affected especially young adults and students, as they were found to be even more symptomatic than relatively older people. This result came up despite young adults having had concerningly high screen hours, a high prevalence of DES, and a strong tendency of symptoms already before the pandemic. One reason might be the rapid, significant change of routine as they moved from classroom lectures to online studying and remote working almost overnight due to lockdowns. It seems that high hours of digital device usage might have already exceeded, for example, older age as a risk factor for DES, and DES has become increasingly common among young people as they tend to have higher average screen hours compared to the older population. All in all, it was detected that median DES scores were higher for those whose screen time jumped more during the pandemic. Thirdly, according to the results, the frequency and intensity of ocular and visual symptoms became more severe during the pandemic, and total symptom scores rose while total screen time increased.

These results are an alarming sign of how this new era of digitalization can lead to an epidemic worsening of digital eye strain and dry eye disease in the future, especially among young adults, all students, and remote workers if total screen time remains as high as reported in these recent studies, adequate breaks are not taken care of, and proper ergonomics are neglected. When it comes to the intensity or severity of symptoms, even though one digital device-related ocular or visual symptom per day might not seem like much, when experienced regularly for weeks or years, it should not be taken lightly, not to mention if one experiences several different symptoms or symptoms keeps worsening. This could lead to a chronic state of digital vision syndrome and dry eye disease.

When working remotely or studying from home, adequate breaks are often forgotten as there are no lunch breaks with colleagues or friends, and meetings are not in a conference room but instead moved to be held online. Due to missing breaks, a sufficient variation of viewing distance during the day is often lacking. Eyes keep focusing on computer screens or laptops at 50-70cm, and when starting a lunch break, people often change to look at smartphones from 40cm as there are no conversation partners to communicate with. When changed to an even shorter distance, eyes must work even harder during the lunch break to accommodate instead of having necessary relaxation by looking at distance. This can result in a situation where the eyes may stay in an accommodative state for hours continuously, leading to digital eye strain. Also, people might not be aware of the importance of regular breaks and how important variations in viewing distances is, though optometrists have an essential role as specialists to inform people about, for example, the 20-20-20 rule as well as other management strategies. It is also worth mentioning that sleep disturbances were also increasingly reported by people with more screen time and though people do not necessarily recover sufficiently from their working days.

When it comes to the most common symptoms of digital eye strain in these studies, the most experienced symptom was a headache, followed by dryness and eye strain. The symptoms increased both in severity and intensity during the pandemic. These symptoms can be influenced by rapid changes in digital device usage like increased usage hours, inadequate breaks, and poor ergonomics. But it is worth noting that there might also be other factors causing headaches and eye strain, like general stress induced by the pandemic.

As according to studies, the prevalence of digital eye strain remains extremely high, and the frequency and intensity of the symptoms seem to be worsening and becoming more common among students and young adults; it is expected that optometrists will be examining multiple patients with DES weekly if not daily in the future. These patients will be reasonably expecting a specialist's advice on managing their ocular and visual symptoms and preventing digital eye strain. Optometrists should be ready to face the challenges of this new era of digitalization when it comes to vision.

Excellent international studies have been made about the prevention and management of digital eye strain, like the study by Coles-Brennan, Sulley and Young (2019). Also, here in Finland, a study regarding this aspect has been made quite recently as Silber and Nieminen (2021) gathered information about the phenomenon of digital visual strain and made guidance for display terminal workers to help to identify visual strain caused by display terminal work and to find possible solutions for treating and preventing related symptoms (Silber and Nieminen 2021).

This scoping review only included studies regarding adults, but the effects of the rise of digital device usage in children's eyes are extremely concerning. Children are closely studied and should be followed up in the future as there is a possibility of increasing myopia resulting from prolonged hours of near work, in addition to other symptoms of digital eye strain (Huang, Chang and Wu 2015). Several studies have been made on the prevalence of digital eye strain and risk factor assessment in children during the COVID-19 pandemic. These studies were excluded from this scoping review because of the inclusion/exclusion criteria but can be detected from the table attached to the appendix.

Also, concerning this aspect, a recent study was made in Finland by Jansson, Iivari and Villanen (2022). Their study aimed to reveal the problems caused by digital devices and near work, emphasizing the vision of school-aged children. They also provided a guide of information to health nurses on how vision problems can be recognized, how young people can be advised regarding vision and ergonomics, and when should the young person be sent for further examinations. (Johansson, Iivari and Villanen, 2022.)

The increase in remote working has caused both positive and negative effects. For the firms, the positive effects include economic savings by reduced office fees and less need for traveling, not to mention the benefits for the nature of people being able to organize meetings thru digital devices without having to travel to the other side of the world. For the remote workers themselves, there are positive effects, such as being able to concentrate better and being more effective. In reverse, negative sides can be, as pointed out in this scoping review, an increase in digital eye strain, but also the impoverishment of social connections and, in some situations, even depression. Risk factors for DES in the future contain massive hours of digital device usage, continuous working without adequate breaks, lack of good ergonomics, and simultaneous use of multiple devices.

This scoping review consisted of eight studies from three continents and six countries: India, Saudi Arabia, China, Spain, Nepal, and Chile. Even though the scope of the review is reasonably small in terms of generalizability of the results, it can be considered in favor of this review that the studies are from different parts of the world, and the respondents who participated in the studies were quite varying in terms of both their age distribution and their digital device usage.

Regarding limitations of the studies included in this review, in all the studies, data were collected by questionnaires/surveys. Subjective assessment, as a frequently used questionnaire, is a commonly used method, even though it is known that it may include some reporting bias, for it relies on individual self-reporting. All in all, various studies have associated stress with computer work, and several methods have been tested and developed to estimate different kinds of stress in the work/study environment, of which self-reported stress is often considered a ground truth of stress. (Akbar et al. 2019.) Also, different questionnaires were used as there is no golden standard questionnaire to estimate DES. For this reason, results may vary depending on the questionnaire used, and the results are not entirely comparable.

Although there might have been some gathering or estimation bias in these studies due to self-evaluation, the sample sizes varied from 137 to 1939 and though gave a reasonable sampling of the matter. It should be remembered, though, that symptomatic patients may be more prone to participate in questionnaires. Also, when questionnaires are distributed solely via the internet, people who are more engaged with devices may be more likely to respond.

Because the studies were conducted during the pandemic, no ocular examinations were made, nor were refractions done. Still, due to the social distancing and lockdowns, this was the only possible way to study the effects of this unique snapshot of time. Uncorrected refractive errors and accommodative/binocular vision problems that also existed before the pandemic might have been exacerbated due to high hours of digital device usage during the pandemic causing additional headaches and eye strain. Also, mask-wearing-associated ocular dryness and irritation might have affected the entirety when it comes to the intensity and severity of the symptoms. The mask-wearing during the day in public areas might have caused additional ocular dryness, and combined with working with digital devices, might have worsened the equation.

In the future, as it seems like teleworking and studying online will stay as part of the picture and hours of digital device usage in massive dimensions, it would be exciting and valuable to have studies made on the topic, including visual and ocular examinations. It would also be important to study more what kind of an effect the use of multiple devices has on the visual system as it was pointed out in the review by Jaiswal et al. (2019), it is still poorly understood how using multiple devices affects the visual system, ocular surface, accommodation, and vergence when switching views between screens.

As a recommendation for future studies in Finland, it would be helpful to investigate how well the optometrists in Finland are aware of the prevalence of digital eye strain and their approaches and management of the matter. This kind of study was made recently by Moore, Wolffsohn and Sheppard (2021) to the optometrists in the UK and Ireland. Estimations of the prevalence of DES were found to be lower by optometrists when compared to the literature. But as a good thing, advising regular breaks (84%), use of lubricants (55.7%), and the right kind of environment set up (69.2%) were felt extremely or very important by most respondents. Advising on special lenses and blue filters were considered extremely or very important by much less (34.2% and 15.2%). Most of the respondents inquired about device usage in their routine case history always (60.6%) or frequently (21.9%) and asked follow-up questions, although 29.3% of the respondents only asked half of the time or less. Beyond this study, little is known about how optometrists comprise the growing problem of DES. (Moore, Wolffsohn and Sheppard 2021.)

The results of this scoping review give an alarming sign of how this new era of digitalization may lead to epidemic worsening or even chronic state of digital eye strain in the future, especially among young adults, all students, and remote workers, if total screen time remains as high as reported in recent studies, adequate breaks are not taken care of, and proper ergonomics are neglected.

# 6 REVIEW OF THE RELIABILITY OF THE THESIS

This scoping review was conducted and written by one author only. For the reliability of the thesis, the search process and critical appraisal of the studies were conducted in cooperation with an information specialist in the library of Oulu University of Applied Sciences and mentors of the thesis. Instructors and mentors guided the way throughout the process by sharing expertise and giving guidance as an important part of overall reliability.

An information specialist in the library of Oulu University of Applied Sciences was consulted to ensure the relevance and comprehensiveness of key search terms based on the research question and to determine which databases to include in the main search. A critical appraisal of the studies was made using the Centre for Evidence-Based Medicine - Oxford University Assessment Form of critical appraisal for qualitative studies (Centre for Evidence-Based Medicine (CEBM), accessed: 4 April 2022). The PRISMA Extension for Scoping Reviews (PRISMA-ScR) checklist was used throughout the writing process to ensure detailed, transparent, complete, and accurate reporting (Tricco et al. 2018).

As a limitation of this scoping review, the literature search was made only from databases, and no grey literature searches were done. Including only literature that has been published might be a concern and bias the study due to a risk of publication bias. There may be "hidden" evidence, often referred to as “grey literature” about the topic that is not published or generally in the public domain because it showed no effect.

Making a systematic literature review as a final thesis has developed my skills in identifying, appraising, and synthesizing research findings. It has also taught me to understand different research methods and how to read scientific texts more critically. It has been an instructive path of learning independent and self-directed work in cooperation with instructors and mentors.

# 7 REVIEW OF THE ETHICALITY OF THE THESIS

This scoping review was done within the accepted guidelines of Oulu University of Applied Sciences, following the responsible conduct of research (RCR) guidelines of responsible conduct of research and procedures for handling allegations of misconduct in Finland. These guidelines were drafted and published in 2012 by the Finnish National Board on Research Integrity (TENK) in cooperation with the Finnish research community. TENK is a board appointed by the Ministry of Education and Culture in Finland. (Finnish National Board on Research Integrity TENK 2021)

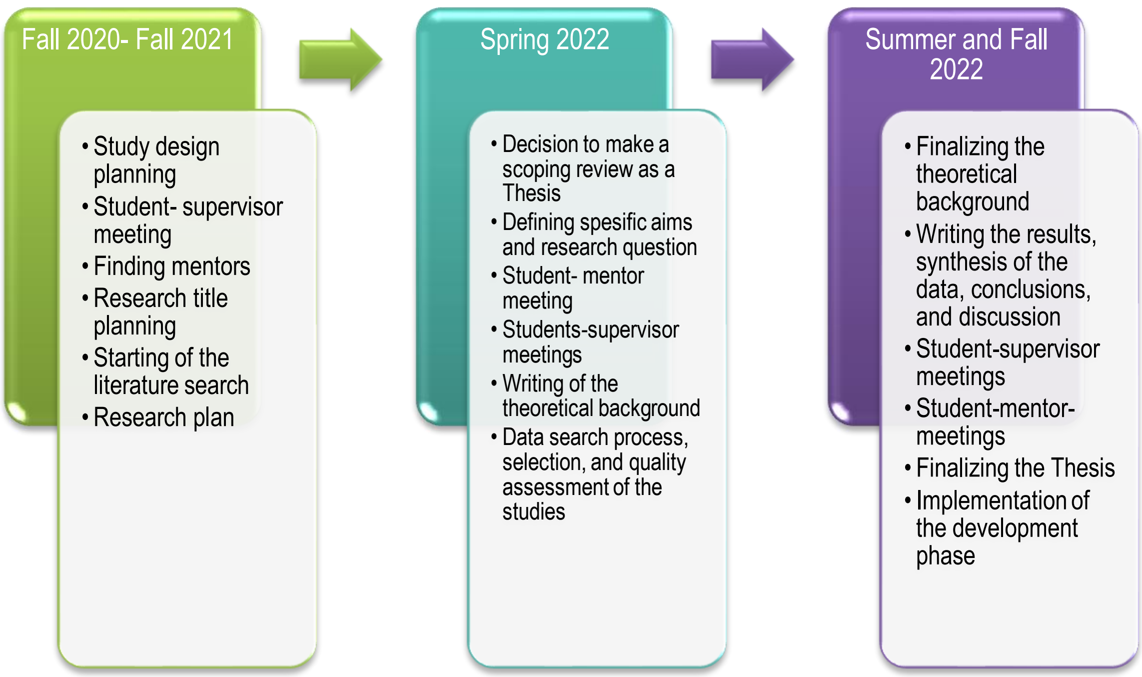
A separate Institutional Review Boards´ approval was not sought since a scoping review does not belong to the category of studies that require IRB approval.

# 8 TIMETABLE AND BUDGET

The Thesis was initially started in the fall of 2020 with the planning of the Thesis and search for literature. The main writing of the final Thesis began on February 2022. It was continued throughout the spring and summer of 2022 and finalized in the fall of 2022. The development phase of the Thesis will be conducted in November 2022 in cooperation with Instru Optiikka Oy.

This Thesis was conducted purely as a part of a Master´s Degree program in Clinical Optometry studies. Neither financial support nor funders or sponsors were included as part of the Thesis.

*Figure 4. The timetable*



# REFERENCES

Akbar, F., Mark, G., Pavlidis, I. and Gutierrez-Osuna, R. (2019) 'An Empirical Study Comparing Unobtrusive Physiological Sensors for Stress Detection in Computer Work', *Sensors (Basel, Switzerland)*, 19(17). Available at: https://doi.org/10.3390/s19173766.

Alabdulkader, B. (2021) 'Effect of digital device use during COVID-19 on digital eye strain', *Clinical and Experimental Optometry*, 104(6), pp. 698–704. Available at: https://doi.org/10.1080/08164622.2021.1878843.

Alghamdi, W.M. and Alrasheed, S.H. (2020) 'Impact of an educational intervention using the 20/20/20 rule on Computer Vision Syndrome', *African Vision and Eye Health*, 79(1). Available at: https://doi.org/10.4102/AVEH.V79I1.554.

Alsharif, W. and Qurashi, A. (2021) 'Effectiveness of COVID-19 diagnosis and management tools: A review', *Radiography*. Available at: https://doi.org/10.1016/j.radi.2020.09.010.

American Optometric Association (2022) *Computer vision syndrome*. Available at: Computer vision syndrome | AOA (Accessed: 27 July 2022).

Bahkir, F.A. and Grandee, S.S. (2020) 'Impact of the COVID-19 lockdown on digital device-related ocular health', *Indian Journal of Ophthalmology*, 68(11), pp. 2378–2383. Available at: https://doi.org/10.4103/ijo.IJO_2306_20.

Basnet, A., Bickram Pathak, S., Marasini, A., Pandit, R. and Pradhan, A. (2022) 'Digital Eye Strain among Adults Presenting to Tertiary Care Hospital in the Era of COVID-19 Pandemic: A Descriptive Cross-sectional Study', *Journal of the Nepal Medical Association*, 60(245). Available at: https://doi.org/10.31729/jnma.7092.

Booth, A., Sutton, A. and Papaioannou, D. (2016) *Systematic approaches to a successful literature review*. 2nd edn. SAGE Publications Ltd.

CDC – Centers for Disease Control and Prevention (2022a) *Long COVID or Post-COVID Conditions*. Available at: https://www.cdc.gov/coronavirus/2019-ncov/long-term-effects/ (Accessed: 15 July 2022).

CDC - Centers for Disease Control and Prevention (2022b) *What You Need to Know About Variants*. Available at: What You Need to Know About Variants | CDC https://stacks.cdc.gov/view/cdc/112202 (Accessed: 15 July 2022).

Centre for Evidence-Based Medicine (CEBM), U. of O. (2022) *Critical Appraisal tools*. Available at: https://www.cebm.ox.ac.uk/resources/ebm-tools/critical-appraisal-tools (Accessed: 4 April 2022).

Chetty, V., Munsamy, A., Cobbing, S., van Staden, D. and Naidoo, R. (2020) 'The emerging public health risk of extended electronic device use during the COVID-19 pandemic', *South African Journal of Science*, 116(8). Available at: https://doi.org/10.17159/sajs.2020/8530.

Coles-Brennan, C., Sulley, A. and Young, G. (2019) 'Management of digital eye strain', *Clinical & Experimental Optometry*, 102(1), pp. 18–29. Available at: https://doi.org/10.1111/cxo.12798.

Datareportal (2022) *Digital 2022: July Global Statshot Report*. Available at: https://datareportal.com/reports/digital-2022-july-global-statshot (Accessed: 12 September 2022).

Evans, B.J.W. (2007) *Pickwell´s Binocular Vision Anomalies*. 5th edn.

Finnish National Board on Research Integrity TENK (2021) *Responsible Conduct of Research (RCR)*. Available at: https://tenk.fi/en/research-misconduct/responsible-conduct-research-rcr (Accessed: 19 August 2022).

Galindo-Romero, C., Ruiz-Porras, A., García-Ayuso, D., Di Pierdomenico, J., Sobrado-Calvo, P. and Valiente-Soriano, F. (2021) 'Computer Vision Syndrome in the Spanish Population during the COVID-19 Lockdown', *Optometry and Vision Science*, 98(11), pp. 1255–1262. Available at: https://doi.org/10.1097/OPX.0000000000001794.

Gallagher, S., Clasing, J., Hall, E., Hammond, S., Howard, G., Mohrmann T. and Vaccaro, J.T. (2021) 'Eye Health, COVID-19, and the Occupational Health Professional: Round Table', *Workplace Health and Safety*, 69(8). Available at: https://doi.org/10.1177/21650799211022990.

Gammoh, Y. (2021) 'Digital Eye Strain and Its Risk Factors Among a University Student Population in Jordan: A Cross-Sectional Study', *Cureus* [Preprint]. Available at: https://doi.org/10.7759/cureus.13575.

Ganne, P., Najeeb, S., Chaitanya G., Sharma, A. and Krishnappa N.C.Ganne, P. (2021) 'Digital Eye Strain Epidemic amid COVID-19 Pandemic – A Cross-sectional Survey', *Ophthalmic Epidemiology*, 28(4), pp. 285–292. Available at: https://doi.org/10.1080/09286586.2020.1862243.

Heus, P., Verbeek, J.H. and Tikka, C. (2018) 'Optical correction of refractive error for preventing and treating eye symptoms in computer users', *Cochrane Database of Systematic Reviews*, 2018(4). Available at: https://doi.org/10.1002/14651858.CD009877.pub2.

Huang, H.M., Chang, D.S.T. and Wu, P.C. (2015) 'The association between near work activities and myopia in children - A systematic review and meta-analysis', *PLoS ONE*. Available at: https://doi.org/10.1371/journal.pone.0140419.

Hundekari, J., Sisodiya, R. and Kot, L. (2021) 'Smartphone Vision Syndrome Associated with Prolonged Use of Digital Screen for Attending Online Classes during COVID-19Pandemic among Medical Students:A Cross-sectional Study', *JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH* [Preprint]. Available at: https://doi.org/10.7860/jcdr/2021/46651.14399.

Jaiswal, S., Asper, L., Long, J., Lee, A., Harrison, K. and Golebiowski, B. (2019) 'Ocular and visual discomfort associated with smartphones, tablets and computers: what we do and do not know', *Clinical and Experimental Optometry*, 102(5), pp. 463–477. Available at: https://doi.org/10.1111/cxo.12851.

Johansson, A., Iivari, E. and Villanen, M. (2022) *Näetkö? Ser du? : kaksikielinen opas terveydenhoitajille digilaitteiden ja lähityön vaikutuksista nuorten näkemiseen*. Metropolia

Ammattikorkeakoulu. Available at: https://urn.fi/URN:NBN:fi:amk-202204245808 (Accessed: 27 July 2022).

Kal, E.C., Young, W.R. and Ellmers, T.J. (2020) 'Face masks, vision, and risk of falls', *The BMJ*. Available at: https://doi.org/10.1136/bmj.m4133.

Kharel Sitaula, R. and Khatri, A. (2018) 'Knowledge, Attitude and practice of Computer Vision Syndrome among medical students and its impact on ocular morbidity', *Journal of Nepal Health Research Council*, 16(3). Available at: https://doi.org/10.3126/jnhrc.v16i3.21426.

Lawrenson, J.G., Hull, C.C. and Downie, L.E. (2017) 'The effect of blue-light blocking spectacle lenses on visual performance, macular health and the sleep-wake cycle: a systematic review of the literature', *Ophthalmic & Physiological Optics: The Journal of the British College of Ophthalmic Opticians (Optometrists)*, 37(6), pp. 644–654. Available at: https://doi.org/10.1111/opo.12406.

Logaraj, M., Madhupriya, V. and Hegde, S. (2014) 'Computer vision syndrome and associated factors among medical and engineering students in Chennai', *Annals of Medical and Health Sciences Research*, 4(2). Available at: https://doi.org/10.4103/2141-9248.129028.

Moore, P.A., Wolffsohn, J.S. and Sheppard, A.L. (2021) 'Attitudes of optometrists in the UK and Ireland to Digital Eye Strain and approaches to assessment and management', *Ophthalmic and Physiological Optics*, 41(6), pp. 1165–1175. Available at: https://doi.org/10.1111/opo.12887.

Mork, R., Falkenberg, H.K., Fostervold, K.I. and Thorud H.M. (2018) 'Visual and psychological stress during computer work in healthy, young females-physiological responses', *International Archives of Occupational and Environmental Health*, 91(7), pp. 811–830. Available at: https://doi.org/10.1007/s00420-018-1324-5.

Moshirfar, M., West, W.B. and Marx, D.P. (2020) 'Face Mask-Associated Ocular Irritation and Dryness', *Ophthalmology and Therapy*. Available at: https://doi.org/10.1007/s40123-020-00282-6.

Napoli, P.E., Nioi, M. and Fossarello, M. (2021) 'The "quarantine dry eye": The lockdown for coronavirus disease 2019 and its implications for ocular surface health', *Risk Management and Healthcare Policy*, 14, pp. 1629–1636. Available at: https://doi.org/10.2147/RMHP.S277067.

Nelson, J.D., Craig, J.P., Akpek E.K., Azar, D.T., Belmonte C., Bron A.J., Clayton, J.A., Dogru, M., Dua, H.S., Foulks, G.N., Gomes, J.A.P., Hammit, K.M., Holopainen, J. Jones, L., Joo, C-K., Liu, Z., Nichols, J.J., Nichols K.K., Novack, G.D., Sangwan, W., Stapleton, F., Tomlinson, A., Tsubota, K., Willcox, M.D.P., Wolffsohn, J.S. and Sullivan, D.A. (2017) 'TFOS DEWS II Introduction', *Ocular Surface*. Available at: https://doi.org/10.1016/j.jtos.2017.05.005.

Pham, M.T., Rajic, A., Greig, J.D., Sargeant, J.M., Papadopoulos, A. and McEwen, S.A. (2014) 'A scoping review of scoping reviews: Advancing the approach and enhancing the consistency', *Research Synthesis Methods*, 5(4). Available at: https://doi.org/10.1002/jrsm.1123.

Portello, J.K., Rosenfield, M. and Chu, C.A. (2013) 'Blink Rate, Incomplete Blinks and Computer Vision Syndrome', *Optometry and Vision Science*, 90(5), pp. 482–487. Available at: https://doi.org/10.1097/OPX.0b013e31828f09a7.

Ranasinghe, P., Wathurapatha, W.S., Perera, Y.S., Lamabadusuriya, D.A., Kulatunga, S., Jayawardana, N. and Katulanda, P. (2016) 'Computer vision syndrome among computer office workers in a developing country: An evaluation of prevalence and risk factors', *BMC Research Notes*, 9(1). Available at: https://doi.org/10.1186/s13104-016-1962-1.

Regmi, A., Suresh, J. and Asokan, R. (2022) 'Changes in work patterns during COVID-19 lockdown and its impact on the eyes and body', *Clinical and Experimental Optometry*, pp. 1–7. Available at: https://doi.org/10.1080/08164622.2022.2029682.

Rosenfield, M. (2011) 'Computer vision syndrome: a review of ocular causes and potential treatments', *Ophthalmic and Physiological Optics*, 31(5), pp. 502–515. Available at: https://doi.org/10.1111/j.1475-1313.2011.00834.x.

Salinas-Toro, D., Cartes, C., Segovia, C., Alonso, M.J., Soberon, B., Sepulveda, M., Zapata, C., Yañes, P., Traipe, L., Goya, C., Flores, P., Lopez, D. and Lopez, R. (2021) 'High frequency of digital eye strain and dry eye disease in teleworkers during the coronavirus disease (2019) pandemic', *International Journal of Occupational Safety and Ergonomics* [Preprint]. Available at: https://doi.org/10.1080/10803548.2021.1936912.

Seguí, M. del M., Carbrero-García, J., Crespo, A., Verdú, J. and Ronda, E. (2015) 'A reliable and valid questionnaire was developed to measure computer vision syndrome at the workplace', *Journal of Clinical Epidemiology*, 68(6), pp. 662–673. Available at: https://doi.org/10.1016/j.jclinepi.2015.01.015.

Sheppard, A.L. and Wolffsohn, J.S. (2018) 'Digital eye strain: prevalence, measurement and amelioration', *BMJ open ophthalmology*, 3(1), p. e000146. Available at: https://doi.org/10.1136/bmjophth-2018-000146.

Silber, G. and Nieminen, E. (2021) *Stressaako näkö? : opas näyttöpäätetyöntekijöille digitaalisen näkörasituksen tunnistamiseen ja hoitoon*. Metropolia Ammattikorkeakoulu. Available at: https://urn.fi/URN:NBN:fi:amk-2021112521779 (Accessed: 24 July 2022).

Stapleton, F., Alves, M., Bunya, V.Y., Jalbert, I., Lekhanont, K., Malet, F., Na, K-S, Schaumberg, D., Uchino, M., Vehof, J., Viso, E., Vitale, S. and Jones, L. (2017) 'TFOS DEWS II Epidemiology Report', *Ocular Surface*. Available at: https://doi.org/10.1016/j.jtos.2017.05.003.

Sullivan, D.A., Rocha, E.M., Aragona, P., Clayton, J.A., Ding, J., Golebiowski, B., Hampel, U., McDermott, A.M., Schaumberg, D.A., Srinivasan, S., Versura, P. and Willcox, M.D.P. (2017) 'TFOS DEWS II Sex, Gender, and Hormones Report', *Ocular Surface*. Available at: https://doi.org/10.1016/j.jtos.2017.04.001.

Talic, S., Shah, S., Wild, H., Gasevic, D., Maharaj, A., Ademi, Z., Li, X., Xu, W., Mesa-Eguiagaray, I., Rostron, J., Theodoratou, E., Zhang, X., Motee, A., Liew, D. and Ilic, D. (2021) 'Effectiveness of public health measures in reducing the incidence of covid-19, SARS-CoV-2 transmission, and covid-19 mortality: Systematic review and meta-analysis', *The BMJ*. Available at: https://doi.org/10.1136/bmj-2021-068302.

Tricco, A.C., Lillie, E., Zarin, W., O´Brien, K.K., Colquhoun, H., Levac, D., Moher, D., Peters, M.D.J., Horsley, T., Weeks, L., Hempel, S., Akl, E.A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M.G., Garritty, C., Lewin, S., Godfrey, C.M., Macdonald, M.T., Langlois, E.V., Soares-Weiser, K., Moriarty, J., Clifford, T., Tunçalp, Ö. and Straus, S.E. (2018) 'PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation', *Annals of Internal Medicine*. Available at: https://doi.org/10.7326/M18-0850.

Usgaonkar, U., Shet Parkar, S. and Shetty, A. (2021) 'Impact of the use of digital devices on eyes during the lockdown period of COVID-19 pandemic', in *Indian Journal of Ophthalmology*. Wolters Kluwer Medknow Publications, pp. 1901–1906. Available at: https://doi.org/10.4103/ijo.IJO_3500_20.

Wang, B., Liu, Y., Qian, J. and Parker, S.K. (2021) 'Achieving Effective Remote Working During the COVID-19 Pandemic: A Work Design Perspective', *Applied Psychology*, 70(1), pp. 16–59. Available at: https://doi.org/10.1111/apps.12290.

Wang, L., Wei, X. and Deng, Y. (2021) 'Computer Vision Syndrome During SARS-CoV-2 Outbreak in University Students: A Comparison Between Online Courses and Classroom Lectures', *Frontiers in Public Health*, 9. Available at: https://doi.org/10.3389/fpubh.2021.696036.

Wangsan, K., Upaphong, P., Assavanopakun, P., Sapbamrer, R., Sirikul, W., Kitro, A., Sirimaharaj, N., Kuanprasert, S., Saenpo, M., Saetiao, S. and Khamphichai, T. (2022) 'Self-Reported Computer Vision Syndrome among Thai University Students in Virtual Classrooms during the COVID-19 Pandemic: Prevalence and Associated Factors', *International Journal of Environmental Research and Public Health*, 19(7). Available at: https://doi.org/10.3390/ijerph19073996.

World Health Organization (2022a) *Coronavirus disease (COVID-19)*. Available at: https://www.who.int/health-topics/coronavirus#tab=tab_1Coronavirus (Accessed: 15 July 2022).

World Health Organization (2022b) *COVID-19 vaccines*. Available at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/covid-19-vaccines (Accessed: 15 July 2022).

World Health Organization (2022c) *COVID-19 weekly epidemiological update*. Available at: https://www.who.int/publications/m/item/weekly-epidemiological-update-on-covid-19---6-july-2022 (Accessed: 12 July 2022).

World Health Organization (2022d) *Tracking SARS-CoV-2 variants*. Available at: https://www.who.int/activities/tracking-SARS-CoV-2-variants/ (Accessed: 15 July 2022).

Yammouni, R. and Evans, B.J. (2020) ‘An investigation of low power convex lenses (adds) for eyestrain in the digital age (CLEDA)’, *Journal of Optometry*, 13(3). Available at: https://doi.org/10.1016/j.optom.2019.12.006.

Yang, L., Holtz D., Jaffe, S., Suri, S., Sinha, S., Weston, J., Joyce, C., Shah, N., Sherman, K., Hecht, B. and Teevan, J. (2022) ‘The effects of remote work on collaboration among information workers’, *Nature Human Behaviour*, 6(1), pp. 43–54. Available at: https://doi.org/10.1038/s41562-021-01196-4.

Zetterberg, C., Forsman, M. and Richter, H.O. (2017) ‘Neck/shoulder discomfort due to visually demanding experimental near work is influenced by previous neck pain, task duration, astigmatism, internal eye discomfort and accommodation’, *PLoS ONE*, 12(8). Available at: https://doi.org/10.1371/journal.pone.0182439.

## ALL IDENTIFIED RECORDS EXCLUDED FROM THE REVIEW APPENDIX 1

| No. | Title | Publication | Authors | Reason for exclusion |
|---|---|---|---|---|
| 1 | Computer vision syndrome in the time of COVID-19: Is blue-blocking lens a panacea for digital eye strain? | Indian Journal of Ophthalmology, 2021 | Viswanathan Sivaraman, Jothi Balaji Janarthanam | A non-scientific study, letter to the editor. Fully opened, no abstract available |
| 2 | Prevalence and risk factor assessment of digital eye strain among children using online e-learning during the COVID-19 pandemic: Digital eye strain among kids (DESK study-1) | Indian Journal of Ophthalmology, 2021 | Amit Mohan, Pradhnya Sen, Chintan Shah, Elesh Jain, Swapnil Jain | Excluded by title, study regarding children |
| 3 | Digital eye strain in the era of COVID-19 pandemic: An emerging public health threat | Indian Journal of Ophthalmology, 2020 | Sudip Bhattacharya, Sheikh Mohd Saleem, Amarjeet Singh | A non-scientific study, letter to the editor. Fully opened, no abstract available |
| 4 | Managing the myopia epidemic and digital eye strain post COVID-19 pandemic - What eye care practitioners need to know and implement? | Indian Journal of Ophthalmology, 2020 | Jameel Rizwana Hussaindeen, Aparna Gopalakrishnan, Viswanathan Sivaraman, and Meenakshi Swaminathan | A non-scientific study, letter to the editor. Fully opened, no abstract available |
| 5 | A Peer-to-Peer Live-Streaming Intervention for Children During COVID-19 Homeschooling to Promote Physical Activity and Reduce Anxiety and Eye Strain: Cluster Randomized Controlled Trial | Journal of Medical Internet Research, 2021 | Yingfeng Zheng, Wei Wang, Yuxin Zhong, Fengchun, Zhuoting Zhu, Yih-Chung Tham, Ecosse Lamoureux, Liang Xiao, Erta Zhu, Haoning Liu, Ling Jin, Linyi Liang, Lixia Luo, Mingguang He, Ian Morgan, Nathan Congdon, Yizhi Liu | Excluded by title, study regarding children |
| 6 | COVID-19 and the increased risk of myopia and digital eye strain | Einstein (São Paulo), 2021 | Lorenzo Ferro Desideri and Marcos Roberto Tovani-Palone | A non-scientific study, letter to the editor. Fully opened, no abstract available |
| 7 | Binocular Accommodation and Vergence Dysfunction in Children Attending Online Classes During the COVID-19 | Journal of Pediatric Ophthalmology and Strabismus, 2021 | Amit Mohan, Pradhnya Sen, Chintan Shah, Krashan Datt, Elesh Jain | Excluded by title, study regarding children |

| | | | | |
|---|---|---|---|---|
| | Pandemic: Digital Eye Strain in Kids (DESK) Study-2 | | | |
| 8 | Eye Health, COVID-19, and the Occupational Health Professional: Round Table | Workplace Health and Safety, 2021 | Susan Gallagher, Jay Clasing, Edward Hall, Stephanie Hammond, Gayle Howard, Todd Mohrmann, Jayme Taormina Vaccaro | Excluded by abstract screening. Round table discussion, not answering the review question. |
| 9 | Prevalence of Self-Reported Symptoms of Computer Vision Syndrome and Associated Risk Factors among School Students in China during the COVID-19 Pandemic | Ophthalmic Epidemiology, 2021 | Rui Li 1, Bowen Ying, Yingxiao Qian, Danni Chen, Xiaoxiao Li, Hui Zhu, Hu Liu | Excluded by abstract screening, study regarding children |
| 10 | Knowledge, Attitude, and Practice Patterns Related to Digital Eye Strain Among Parents of Children Attending Online Classes in the COVID-19 Era: A Cross-sectional Study | Journal of Pediatric Ophthalmology and Strabismus, 2021 | Kirandeep Kaur, Veena Kannusamy, Bharat Gurnani, Fredrick Mouttapa, Logesh Balakrishnan | Excluded by title, study regarding children |
| 11 | Digital eye strain and its associated factors in children during the COVID-19 pandemic | Indian Journal of Ophthalmology, 2022 | Bengi Demirayak, Büşra Yılmaz Tugan, Muge Toprak, Ruken Çinik | Excluded by title, study regarding children |
| 12 | Series of cases of acute acquired comitant esotropia in children associated with excessive online classes on a smartphone during COVID-19 pandemic; digital eye strain among kids (DESK) study-3 | Strabismus, 2021 | Amit Mohan, Pradhnya Sen, Deepti Mujumdar, Chintan Shah, Elesh Jain | Excluded by title, study regarding children |
| 13 | Impact of E-Schooling on Digital Eye Strain in Coronavirus Disease Era: A Survey of 654 Students | Journal of Current Ophthalmology, 2021 | Richa Gupta, Lokesh Chauhan, Abhishek Varshney | Excluded by abstract screening, study regarding children |
| 14 | Commentary: Impact of the COVID-19 pandemic on digital eye strain in children | Indian Journal of Ophthalmology, 2020 | Chaitra Jayadev, Puja Sarbajna, Anand Vinekar | Excluded by title, commentary regarding children |
| 15 | Impact of online classes and home confinement on myopia progression in children during COVID-19 pandemic: Digital eye strain among kids (DESK) study 4 | Indian Journal of Ophthalmology, 2022 | Amit Mohan, Pradhnya Sen, Parimal Peeush, Chintan Shah, Elesh Jain | Excluded by title, study regarding children |
| 16 | Contribution of Total Screen/Online-Course Time to Asthenopia in Children During COVID-19 Pandemic via Influencing Psychological Stress | Frontiers in Public Health, 2021 | Lin Li, Jing Zhang, Moxin Chen, Xue Li, Qiao Chu, Run Jiang, Zhihao Liu, Lili Zhang, Jun Shi, Yi Wang, Weizhong | Excluded by title, study regarding children |

| | | | | |
|---|---|---|---|---|
| | | | Zhu, Jian Chen, Pengcheng Xun, Jibo Zhou | |
| 17 | Teleconsultation at a tertiary care government medical university during COVID-19 Lockdown in India - A pilot study | Indian Journal of Ophthalmology, 2020 | Nitika Pandey, Rajat M Srivastava, Gaurav Kumar, Vishal Katiyar, Siddharth Agrawal | Excluded by abstract screening, the study does not answer the review question |
| 18 | Commentary: Not just COVID-19 pandemic, it is a pandemic of digital eye strain among children | Indian Journal of Ophthalmology, 2022 | Jai Kelkar, Aditya Kelkar, Priyanka Singhvi | Excluded by title, commentary regarding children |
| 19 | The 17-Item Computer Vision Symptom Scale Questionnaire (CVSS17): Translation, Validation and Reliability of the Italian Version | International Journal of Environmental Research and Public health, 2022 | Gemma Caterina Maria Rossi, Federica Bettio, Mariano González-Pérez, Aba Briola, Gemma Ludovica Maria Pasinetti, Luigia Scudeller | Excluded by abstract screening, the study does not answer the review question |
| 20 | Association of screen time, quality of sleep and dry eye in college-going women of Northern India | Indian Journal of Ophthalmology, 2022 | Parul Chawla Gupta, Minakshi Rana, Mamta Ratti, Mona Duggal, Aniruddha Agarwal, Surbhi Khurana, Deepak Jugran, Nisha Bhargava, Jagat Ram | Excluded by abstract screening, the study does not answer the review question. |
| 21 | Commentary: Impact of COVID-19 on ocular surface health | Indian Journal of Ophthalmology, 2022 | Singh Aastha, Acharya Manisha, Sangwan Virender, Sangwan Virender S | Excluded by title, a non-scientific study, commentary |
| 22 | Computer Vision Syndrome (CVS) and its Associated Risk Factors among Undergraduate Medical Students in Midst of COVID-19. | Pakistan Journal of Ophthalmology, 2021 | Noreen Khola, Ali Kashif, Aftab Kausar, Umar Muhammad | Excluded by abstract screening, the study also regards adolescents |
| 23 | Digital devices; a boon or bane: Ocular and musculoskeletal manifestations during lockdown in COVID-19 pandemic among general population of North India. | Indian Journal of Health Sciences & Biomedical Research, 2021 | Kumari Sneha, Ranjan Pankaj, Singh Mitasha | Excluded by abstract screening, the study regards the population of all age groups; also regards children. Opened fully to make sure. |
| 24 | Commentary: Digital toxicity: Another side effect of COVID-19 pandemic. | Indian Journal of Ophthalmology, 2021 | Akkara John, Kuriakose Anju, Akkara John Davis | Excluded by title, a non-scientific study, commentary |
| 25 | A review exploring convergence insufficiency in | African Vision & Eye Health, 2021 | Pillay Renaishia, Munsamy Alvin J. | Excluded by abstract screening, study |

| | | | | |
|---|---|---|---|---|
| | younger populations and e-devices in the digital era. | | | regarding children |
| 26 | Changes in work patterns during COVID-19 lockdown and its impact on the eyes and body | Clinical & Experimental Optometry, 2022 | Alisha Regmi, Janani Suresh, Rashima Asokan | Full text opened and read, the study also regarding adolescents |
| | | | | |