University of South-Eastern Norway

Faculty of Health and Social Sciences

Master in Optometry and Visual Science

Master's thesis MPRO5001

Spring 2024

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Association between headache disorders and visual anomalies: A literature review

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This thesis is worth 30 study points

Acknowledgements

I would like to thank University of South-Eastern Norway, campus Kongsberg, and the supervisors Hanne-Mari Schiøtz Thorud and Helle Kristine Falkenberg for their help with this thesis. Also, a big thank you to my fiancé Simon Behrendsen Lien for all the love and support throughout working and writing this thesis.

Summary (English)

Background: Visual anomalies in form of uncorrected refractive errors, binocular anomalies, and computer vision syndrome, are common in the general population, and especially myopia and computer vision syndrome are increasing due to more modern, digitalised lifestyles. Headache disorders are also common, and symptoms of headache may be exacerbated due to visual disturbance.

Purpose: The aim of this literature review is to summarize studies performed on headache disorders and visual anomalies, and investigate the prevalence of headache amongst patients that are uncorrected or mis-corrected. The goal is also to see if severity and frequency of headache can be lessened with optimal optical correction, orthoptic exercise and correction with filter lenses.

Methods: The search for scientific studies was performed last quarter of 2023 in multiple databases, such as MEDLINE, EBSCO, CINAHL, and Scopus. Most of the studies were of cross-sectional, retrospective, and prospective design, and were published between 2002 and 2023. The scientific quality of the studies was assessed by using Kanalregister, Helsebiblioteket, and The Strengthening the Reporting of Observational studies.

Results: The search yielded 387 articles, of which 14 were eligible for this review. The scientific quality of assessed studies was graded fair (5) and good (9). Eight studies investigated if optimal correction, orthoptic exercises or filter lenses could ease frequency and/or severity of headaches, or eliminate headache symptoms completely. When compared to control groups, a significant number of subjects experienced relief after intervention. Six studies found that headache symptoms are often commonly prevalent in patients with ametropia, binocular vision problems, and prolonged digital screen use. Several studies showed that most frequent ametropia associated with headache was low astigmatism and hyperopia.

Conclusion: Optimal optical correction and/or orthoptic exercises are advised in subjects with headache symptoms, as it may reduce frequency and/or severity of headache complaints.

Keywords: Refractive error, binocular anomaly, eye strain, computer vision syndrome, headache, headache disorders.

Summary (Norwegian)

Bakgrunn: Synsforstyrrelser som ukorrigerte brytningsfeil, samsynsproblemer, og skjermtrøtte øyne (computer vision syndrome), er vanlige i den generelle befolkningen, og tilstander som nærsynthet (myopi) og skjermtrøtte øyne øker på grunn av mer moderne, digitalisert livsstil. Hodepinelidelser er også vanlig blant befolkningen, og synsforstyrrelser kan forverre symptomer på hodepine.

Formål: Målet med denne litteraturstudien er å oppsummere forskning utført på hodepinelidelser og synsforstyrrelser, samt undersøke forekomsten av hodepine blant de som er under- eller feilkorrigert. Det er også et mål å se om frekvens og alvorlighetsgrad av hodepine kan minskes med optimal optisk korreksjon, synstrening, og bruk av filterbriller.

Metoder: Et litteratursøk ble gjennomført siste kvartalet av 2023 i nettbaserte databaser som MEDLINE, EBSCO, CINAHL og Scopus. Artiklene som er utvalgt for denne litteraturstudien ble publisert mellom 2002 og 2023, og flesteparten er av typen tverrsnitt-, prospektive- og retrospektive studier. Kritisk vurdering av forskningsartiklene ble utført ved bruk av Kanalregister, Helsebiblioteket, og Strengthening the Reporting of Observational studies.

Resultater: Litteratursøket resulterte i 387 artikler, hvorav 14 ble utvalgt for denne litteraturstudien. Vitenskapskvaliteten på studiene var gradert til middels (5) og god (9). Åtte av studiene undersøkte om optisk korreksjon, synstrening og filterbriller kunne minske eller eliminere hodepineplager fullstendig. Sammenlignet med kontrollgrupper, var det et signifikant antall subjekter som opplevde lindring etter intervensjon. Seks av studiene fant sammenheng mellom hodepineplager og ukorrigerte synsfeil, samsynsproblemer, og langvarig skjermbruk. Flere studier viste at vanlig synsfeil assosiert med hodepineplager var lav astigmatisme (skjeve hornhinner) og hypermetropi (langsynthet).

Konklusjon: Optimal synskorrigering og/eller synstrening er anbefalt hos individer som lider av hodepine, da det kan redusere hyppighet og/eller alvorlighetsgrad av hodepineplager.

Nøkkelord: Refraktive feil, binokulære synsfeil, øyetretthet, computer vision syndrome, hodepine, hodepine lidelser.

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Foreword

This thesis assumes some knowledge of optometry regarding refractive errors, binocular vision, computer vision syndrome (CVS) and eye strain. There are many headache disorders, and they are often caused by many different factors or a combination of different factors, including visual disturbances. Yet, refractive errors and other eye conditions such as binocular vision anomalies, eye strain induced by digital screen use, and others, are still somewhat overlooked in Norway regarding headache complaints. From personal experience working as an optometrist for more than 7 years, and experience from fellow colleagues, it seems that headache disorders associated with visual anomalies are more frequent than ICHD-3 portrays. Patients with severe headache complaints can be so affected and debilitated that it affects their performance in school, workplace, and personal life. This thesis presents a review of studies that researched visual anomalies in patients in relation to various headache disorders. The purpose of this review is to look at recommended clinical guidelines and studies, the prevalence of visual anomalies in headache patients, as well as the association between these conditions, the different examination techniques, limitations of studies, and make an overview of available knowledge to hopefully make it more manageable to treat or help lessen severity of pain in such patients, and help direct future research and further change and/or creation of clinical guidelines.

Skien, April 2024

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1 Introduction

Visual anomalies are disorders of the visual system, such as refractive errors in the form of myopia (nearsightedness), hypermetropia or hyperopia (farsightedness), astigmatism, binocular vision dysfunctions, and more (Rabbetts, 2007). If the visual system is not working appropriately and increases the difficulty of visual tasks at distance and near, it may lead to squinting, frowning, closing one eye and more, which in turn may lead to symptoms of eyestrain and headache (Nunes & Hammond, 2020). As there are many different headache disorders, some of them may be caused by or have increased severity and/or frequency of pain, due to visual disturbance (Elliott, 2014).

According to The International Classification of Headache Disorders (ICHD), refractive errors are much less commonly a cause for headache than generally believed ("11.3.2 Headache attributed to refractive error,"), yet some studies show that prevalence of ametropia is relatively high, and a significant percentage of these patients experience symptoms of headache that may be avoided with prescription eye wear (Gunes et al., 2016; Harle & Evans, 2006) and/or orthoptic exercise (Nguyen et al., 2021). Search results on PubMed for headache yields 52,039 results. As soon as any of the eye conditions relevant for this review are added (refractive error, binocular vision, computer vision syndrome), search results drop down to 57-80, indicating there is not an overwhelming amount of research on this topic.

Parts of this literature review has been presented in the project protocol, as the final exam in MRES019 Research methods (D. Naumenok, 2023) at USN (unpublished).

2 Background

Headache, HIT-6 & VAS

One of the most common disorders of the nervous system are headaches. Headache is experienced by many occasionally, but repeated symptoms of pain are called headache disorder (WHO, 2014). The medical term for headache is cephalgia, and it includes any type of pain affecting the head, face, or neck. According to World Health Organization (WHO), it is estimated that the prevalence of headache disorders globally in adults aged 18-65 is 50 – 75% (symptomatic at least once within the last year), and 30% or more have reported migraines. It is more prevalent in females than males, and can be mild to very severe and disabling. Patients suffering from chronic headaches (experiencing cephalgia 15 or more days every month) are estimated to 1,7 – 4% of the world's adult population (Pietrasik & WHO, 2016).

It is often advised for sufferers from different kind of headaches to keep track by using a form of diary (either an application on the phone or tablet, or a physical diary to take notes in), especially for chronic sufferers. Another way to see how headache disorders affects individuals' lives, is to use the Headache Impact Test (HIT-6). This tool is used to measure the functionality of an individual suffering from headache, and the impact on daily life regarding school, work, private and social life. This test has 6 questions, and the answers make up a score that indicates the severity state. The scores range from 36 to 78, where higher score indicates higher impact (Kosinski et al., 2003).

Visual Analogue Scale (VAS) is a visual scale that can be used to rate pain, effect of mediation, symptoms and more. It is a scale that can be presented in different ways, including numerical scale and graphic rating scale. It is an easy and widely used scale that can be found in more than 25 000 articles on PubMed (Faiz, 2014).

ICHD-3

The Classification Committee of The International Headache Society has been working for 30 years to systematically classify headache disorders with explicit diagnostic criteria for each disorder. The 3rd edition for the ICHD has been available online for everybody since 2018. ICHD-3 has sorted cephalgia into three main groups, **part 1: The primary headaches** (consisting of migraine, tension-type headache, trigeminal autonomic cephalalgias, and other primary headache disorders), **part 2: The secondary headaches** (consisting of headache attributed to trauma or injury, headache attributed to cranial or cervical vascular disorder, headache attributed to non-vascular intracranial disorder, headache attributed to substance or withdrawal, infection, or psychiatric disorder, and headache or facial pain attributed to disorder of cranium, neck, eyes, ears, nose or other facial cervical structure), and lastly

part 3: Neuropathies & Facial Pains and other headaches (including painful lesions of the cranial nerves and other facial pain, and other headache disorders) (International Headache Society, 2018).

Part 2, chapter 11 in ICDH-3's classification: *Headache or facial pain attributed to disorder of the cranium, neck, eyes, ears, nose, sinuses, teeth, mouth or other facial or cervical structure,* contains a section regarding refractive errors and headache (11.3.2). It states that most patients with headache attributed to refractive error will seek advice from an ophthalmologist, and that "While refractive error is much less commonly a cause of headache than is generally believe, there is some evidence for it in children, as well as a number of supportive cases in adults" (Olesen et al., 2018).

The diagnostic criteria for 11.3.2 Headache attributed to refractive error (HARE), are pictured below.

Figure 1

A. Any headache fulfilling criterion C
B. Uncorrected or miscorrected refractive error(s) in one or both eyes
C. Evidence of causation demonstrated by at least two of the following:
   1. headache has developed and/or significantly worsened in temporal relation to the onset or worsening of the refractive error(s)
   2. headache has significantly improved after correction of the refractive error(s)
   3. headache is aggravated by prolonged visual tasks at an angle or distance at which vision is impaired
   4. headache significantly improves when the visual task is discontinued
D. Not better accounted for by another ICHD-3 diagnosis.

Figure 1: Diagnostic criteria have been saved as a picture from https://ichd-3.org/11-headache-or-facial-pain-attributed-to-disorder-of-the-cranium-neck-eyes-ears-nose-sinuses-teeth-mouth-or-other-facial-or-cervical-structure/11-3-headache-attributed-to-disorder-of-the-eyes/11-3-2-headache-attributed-to-refractive-error/

In Norway, ophthalmologists diagnose and treat eye diseases and perform screenings for diabetes, glaucoma, tumours, and other eye conditions. They can also evaluate patients for surgery and surgeons who have appropriate training, perform eye surgeries as well. Usually, ophthalmologists in Norway seldom perform refractive examinations, as they usually have opticians and/or orthoptist performing them (Utdanning.no & Norsk Oftalmologisk Forening, 2019). Opticians/optometrists in Norway perform eye examinations and diagnose and treat refractive errors, binocular anomalies and more (USN, 2019). The biggest difference here is that opticians/optometrists cannot diagnose eye conditions other than refractive errors, and they cannot treat with medication and/or surgery, as well as the refractive examination is usually performed by non-doctors. More on this in chapter 5: Discussion, "*Eye examination in a clinical setting",* page 39.

Social and economic burden of headache on society

According to WHO, 1/3 of all neurological consultations in United Kingdom were due to symptoms of headache, meaning that cephalgia is high among reasons for consulting medical practitioners. WHO has also reported that approximately 25 million working hours or school days are lost each year due to migraine alone in United Kingdom (Pietrasik & WHO, 2016). Some headache disorders may be so impairing and debilitating that it can affect performance in school, at work, in social and personal life (Thorud et al., 2024). Many sufferers also live with constant fear of next cephalgia attack, which in return puts a restriction on their lifestyle. The type of headaches that often cause the most absence from work and school are migraine, tension-type headaches, and cluster headache (Baigi & Stewart, 2015; Rasmussen, 1999).

In Norway, it is estimated that over 700 000 people suffer from migraines. Most of these er under the age of 50, and women are affected two-three times more than men. The societal costs are estimated to be approximately 53 billion Norwegian kroners (NOK) yearly (Oslo Economics, 2023).

Many individuals who suffer from headache disorders may also never get diagnosed or treated properly due to various reasons, one of them being economy. Not having necessary funds and/or resources to cope with and treat such disorders, may lead to more health issues in the future, and less opportunities to recover and stay a contributing and active member of the society (Mennini & Gitto, 2015).

Studies show that sufferers of chronic headache also have more increased risk of depression, anxiety, diabetes, heart disease, stroke and obesity to name a few, which in return can lead to more stress and impact lifestyle even more negatively (Caponnetto et al., 2021; Dresler et al., 2019). These comorbidities can often lead to temporary absence due to sickness, but also long-term sickness absence. Both temporary and long-term sickness absence can lead to disruption at work in form of reduced effectiveness, lost income for both the employer and employee (e.g. if sick leave is not paid by the employer or the government, or the work is based on commission), and impact the social life at work and private in a negative way (e.g. bullying, difficulties with making friends) (Kivimäki et al., 2000; Livanos & Zangelidis, 2010). Absence from school may also have an impact on social and personal life, as well as performance and grades (Pijl et al., 2021).

It is a vicious cycle that affects many aspects of life and can have a strong, negative impact on quality of life.

Refractive errors and other visual anomalies

As mentioned in Introduction, refractive errors, or ametropia, are eye conditions such as myopia, hypermetropia and astigmatism. The higher the ametropia, usually the lower is the visual acuity (VA). Children and young adults with good accommodation can still maintain sufficient VA, despite low, medium, and high hyperopia. Common symptoms of ametropia can be blurred vision, asthenopia (eyestrain), headache and diplopia (Elliott, 2014).

Binocular vision is the fusion between two eyes that is achieved through a well-developed and coordinated oculo-motor and neural system. The binocular vision may be impaired if one or both eyes are not functioning properly and is out of focus due to e.g. ametropia, anisometropia, malfunctioning accommodation, convergence and/or vergence problems and more. Similarly to regular refractive errors, symptoms of binocular anomalies are blurred vision, headaches, asthenopia and diplopia, and also unnatural head tilt or turn, fluctuations in distance vision, poor reading ability and poor school progress (Elliott, 2014; Rabbetts, 2007).

Prolonged work in front of a computer video display terminal (VDT) may lead to the experience of CVS. This may lead to a series of symptoms and complaints in the eyes that are related to digital screen use. The cause of symptoms associated with this condition can be categorized into four groups: Refractive error(s), binocular vision, ocular and systematic health, and ergonomic (Scheiman & Wick, 2014).

Symptoms due to visual related computer use problems (refractive and binocular anomalies) are usually eyestrain, headache, blurred vision, diplopia, difficulties with concentration on reading material, a pulling sensation around the eyes and movement of the print. Eye strain, also known as asthenopia, is a condition that is often described as eye fatigue, discomfort, or pain inside or around the eyes (Grosvenor, 2007). Symptoms due to ocular and systemic health are dry eyes (due to decreased blinking frequency) that can often be aggravated by dry environment, and some systemic conditions can increase the chance and severity of dry eye disease. When it comes to ergonomics, there are many different factors that can affect someone working in front of a screen. These factors are lighting conditions and glare, seating position, and type of computer monitor and its position to the user. Usually, the symptoms can increase with the demand of the task in front of the digital screen (Blehm et al., 2005).

There is a rapid increase in myopia worldwide, and it is projected to affect approximately 50% of the world population by 2050. This is caused by many different factors, mainly due to lifestyle factors, as daily prolonged digital screen use is becoming more normal, especially in children (Sankaridurg et al., 2022). High myopia's problematic nature extends beyond the necessity of optical correction most of the time. It is also one of the leading causes of blindness worldwide, this due to the increased prevalence of eye conditions such as myopic macular degeneration, macular hole, glaucoma, cataract, retinal tears, retinal detachment, and more (Kanski & Bowling, 2011). Many of these conditions can lead to irreversible vision impairment and blindness.

Other eye conditions that can cause headaches

It is important to mention that there are also other eye conditions that can cause headache symptoms. Not all eye conditions usually lead to permanent damage, but eye conditions that can are glaucoma, uveitis, and others. These conditions may require treatment and usually need follow-up with an ophthalmologist (Raymond, 2022). Other conditions that also can cause headache symptoms but can resolve on their own, are optic neuritis and keratitis (Kanski & Bowling, 2011).

Clinical guidelines for opticians/optometrists in Norway

The title optician is protected in Norway and have the same educational qualifications as optometrists internationally. An optician in Norway has at least a three-year bachelor's degree in optometry and is a healthcare professional who provides primary vision care. Opposed to international standards, opticians/optometrists in Norway cannot prescribe medication to patients, though have access to diagnostic drugs such as Cyclopentolate, Tropicamide, Atropine, local anaesthesia and Epinephrine (EpiPen) (Optikeres rett til rekvirering, 2022). Some opticians with higher degree of education prefer to use the term optometrist.

The Norwegian association of opticians in Norway, Norges Optikerforbund (NOF), is a type of union for opticians and optometrists. The goal of the organization is to assist their members in providing the best possible care for patients, help with academic development, and safeguarding professional and political interest (Klæboe & Olsen, 2024). The organization has developed clinical guidelines which are still being updated regularly, based on evidence-based practice. A committee is responsible for keeping the guidelines revised and updated before they are presented and admitted by the board. It is important to note that the guidelines do not override laws, regulations, and other public provisions (Klæboe, 2024). The guidelines for routine examination mention that a thorough anamnesis should be performed, including questions about symptoms, occurrence and frequency of headache (Ágústsdóttir et al., 2005).

NOF's clinical guidelines recommends to perform cycloplegic refraction on children aged 5-18 years at first eye examination (Jeber & Vinjevoll, 2005). Cyclopentolate is a drug used for partial or total paralysis of accommodation, and is often used, especially in children, to avoid accommodative fluctuations that can lead to under- or overestimation of refractive errors (Elliott, 2014). Atropine is another drug that has similar qualities, but can last up to 7-10 days, while Cyclopentolate usually lasts up to 24 hours (Bausch + Lomb, 2022, 2023). For the purpose of performing cycloplegic refraction, research suggests that Cyclopentolate 1% has sufficiently similar cycloplegic effect as Atropine 1%, with lesser adverse effects (Elliott, 2014; Singh et al., 2023).

European clinical guidelines

As of now, spring 2024, there are no official clinical guidelines for Norway or Scandinavia regarding diagnosing, treating and follow-up for headache disorders. Most health institutions in Norway have clinical guidelines based on European recommendations from European Headache Federation (EHF), ICHD-3 and evidence-based guidelines available through UpToDate and BMJ Best Practice that can be obtained on Helsebiblioteket.

The database NevroNEL for neurologists in Norway has developed some clinical guidelines regarding headache, them being guidelines for Botox treatment for chronic migraine, medication treatment during pregnancy and breastfeeding, and guidelines for pain treatment in Norway, where it is mentioned that one should be careful to treat headache with weak opioids due to risk of developing medication overuse headache (Bell et al., 2003).

Aim and hypotheses

The aim for this literature review is investigate the prevalence of refractive errors, binocular vision anomalies and computer vision syndrome in individual with headache disorders, and review existing research on the relationship between visual anomalies and headache symptoms, in children and adults.

Hypotheses that were developed for this literature review:

• May visual anomalies increase frequency and/or severity of existing headaches, or be the main cause of headache symptoms?

• May headache complaints be reduced or fully eliminated by correcting visual anomalies with optical correction (prescription glasses and/or contact lenses), and/or orthoptic exercise, and/or filter lenses?

3 Methods

This literature review is written as final exam for Master in Optometry and Visual Science, Faculty of Health and Social Sciences at University of South-Eastern Norway.

Search strategy

The search strategy for this thesis was to search for relevant studies in four different electronic databases, accessed through USN library. The engines used were Medline, Academic Search Premier (EBSCO), Cumulative Index to Nursing and Allied Health (CINAHL), and Scopus. The electronic databases were chosen after guidance from USN library, and supervisor Thorud.

The search keywords that were used were refractive errors (exploded) and headache (exploded). The final step was to perform a final search where both exploded search words were included.

The term *explode* is a command that makes it possible for the database to search for all related terms for the initial search, and allows for a broader or more specific search, as it also makes it possible to include or exclude relevant keywords in the search ("Step Three, Exploding and/or Focusing A Subject Heading,").

Additional records were identified through supervisors Falkenberg and Thorud.

There was not set a restriction on publication date, and last search was performed start of January 2024. All relevant studies were imported into EndNote (a citation and reference management tool (EndNote, 2023)) and Rayyan (a web-based tool for screening and storage of literature (Rayyan, 2024)), and duplicates were removed.

Inclusion and exclusion criteria

The inclusion criteria for the studies were participants of all ages and all genders. Studies also had to include participants with any headache disorders *and* visual anomalies (e.g. refractive errors, binocular vision anomalies, computer vision syndrome and others). Another criterion was that the articles must be full-length and either in English language or Scandinavian languages, and that the original studies must have been published in peer-reviewed journals.

The studies must also use appropriate statistics according to their study design, and statistical significance must be set at $p = 0.05$ or less (two-tailed).

In the selection process, studies were reviewed through Norwegian Register (Kanalregister), which is an online register of scientific publication channels and scientific literature. The register is run by The National Board of Scholarly Publishing (NPU) and Norwegian Directorate for Higher Education and Skills. Only studies of level 1 and 2 have been included in this review.

As search results were few, there were really no exclusion criteria set other than that study design must not be case study, and that quality of the studies needs to be rated above low quality.

Study selection

The relevant studies were imported into Rayyan. After reviewing the studies, a final decision on what articles were going to be included and excluded from the thesis was made, and several of them were reviewed together with supervisor Thorud.

Quality assessment

Randomized controlled- and cross-sectional studies were assessed for quality using guidelines by Helsebiblioteket (Dysthe et al., 2021), which is an online library that provides free access to guidelines, encyclopaedias, and other knowledge resources for health personnel in Norway. The instructions for quality assessment of randomized controlled studies were available in Norwegian language, while instructions for assessment of cross-sectional studies was available in English.

Some of the assessment required to explore if criteria for inclusion was well defined, clear description of study objects, if exposure was measured in a valid and reliable way, identifying confounding factors, valid and reliable measurements, and an evaluation of the statistical analysis for cross-sectional studies. For randomized controlled study, an evaluation of clear research question(s), satisfactory random distribution of participants, equal treatment of groups, comprehensive report of effects of measurement(s), if benefits of intervention outweigh side effects and costs, and possibility of transfer of results to own practice, was important.

Retrospective and observational studies were assessed for quality using The Strengthening the Reporting of Observational studies in Epidemiology guidelines (STROBE)(Limaye et al., 2018), found on equator network. STROBE are guidelines for epidemiologists, methodologists, statisticians, researchers and journal editors that are involved in conduct and dissemination of observational studies (Uhlig et al., 2007). Decision to assess retrospective studies with STROBE guidelines was decided due to them being performed in the past and have similar methodology with observational studies.

Quality assessment of these studies required among other things to consider if hypotheses were clearly defined, details about eligibility criteria, location and period of recruitment and methods, description of statistical methods and summary of key results and limitations.

4 Results

The overall search across all chosen databases yielded a result of 378 studies, of which 42 were eligible for this review. But due to articles no longer being accessible online for free, and not retrievable through the library of USN, only 14 of these articles were included in this review. A PRISMA flow chart have been created with an overview of search strategy and selection of studies (see Figure 2).

Figure 2

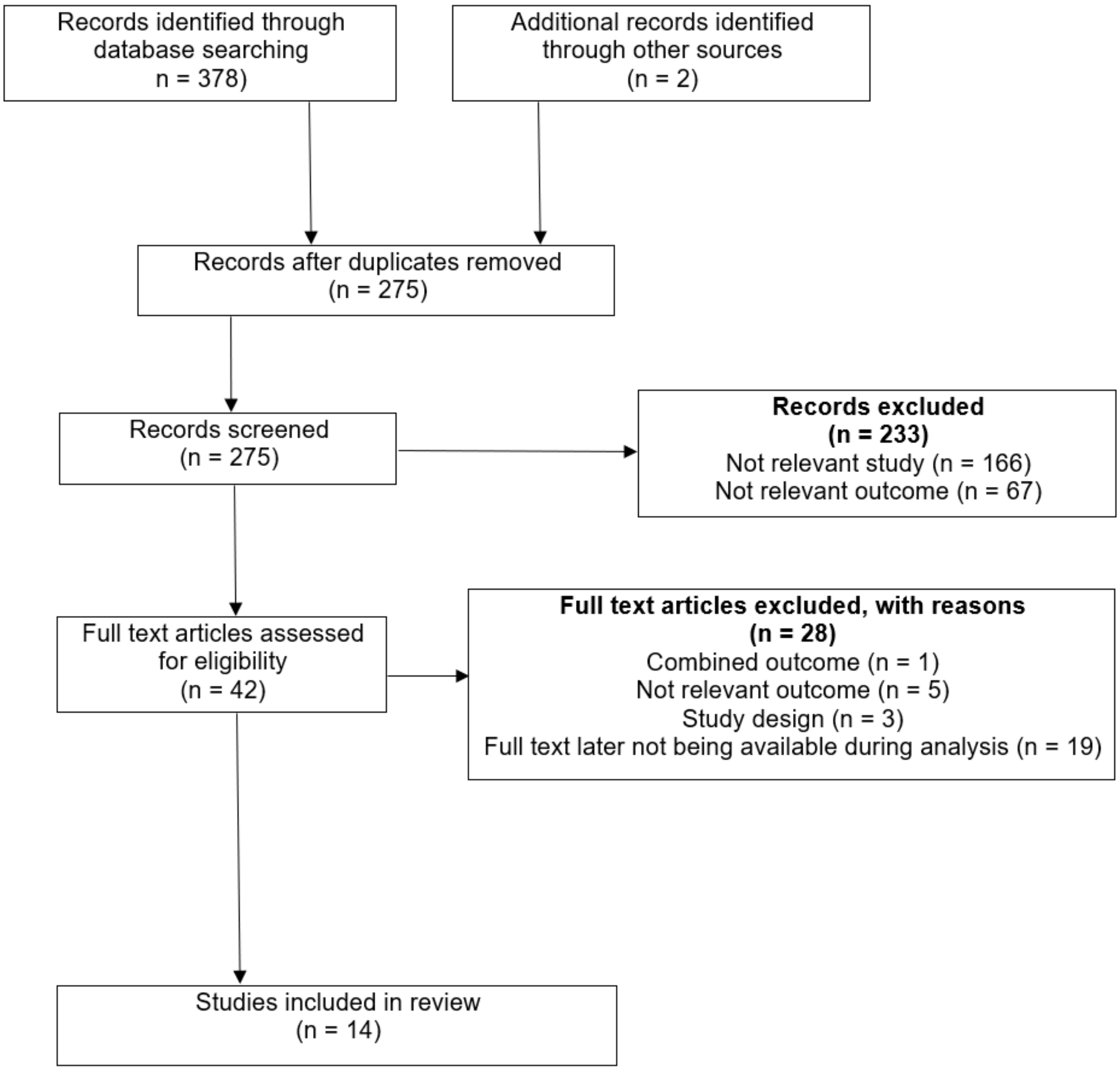

Figure 2: PRISMA flow chart. Not relevant study: Studies included keywords like headache and a visual anomaly, but were investigating something irrelevant for this review. Not relevant outcome (screened records): Studies' outcome was based on irrelevant measurements. Combined outcome: One study combined optical correction with medication and exercise regime. Not relevant outcome (full text records assessed for eligibility): One study investigated what eye conditions (irrelevant conditions for this review) were mostly seen in subjects with headache. Four studies investigated visual symptoms without addressing headache symptoms properly. Study design: Three studies were case-control studies with 1 – 3 participants. Full text later not being available during analysis: After the turn of the year, articles chosen in 2023 were no longer available online for free, and neither retrievable through USN library.

Study quality

As described in Methods (main chapter 3, page 14), quality of the studies were assessed using Kanalregister where all studies had approval level of 1 or 2 (Linge, 2016). With the help of guidelines from Helsebiblioteket (Dysthe et al., 2021), quality assessment was performed on selected studies that can be seen in Table 1. The appraisal of the studies is based on traffic light rating system (Fehlings, 2014).

Table 1

Authors	Study name	Appraisal
(Abdul-Kabir et al., 2023)	Fixation disparity and refractive error among first-year optometry students	Green
(Akinci et al., 2008)	The correlation between headache and refractive errors	Green
(Alrasheed et al., 2023)	Clinical features of Sudanese patients presenting with binocular vision anomalies: A hospital-based study	Green
(Dotan et al., 2014)	Uncorrected ametropia among children hospitalized for headache evaluation: a clinical descriptive study	Green
(Evans et al., 2002)	Optometric function in visually sensitive migraine before and after treatment with tinted spectacles	Yellow
(Gil-Gouveia & Martins, 2002)	Headaches associated with refractive errors: myth or reality?	Yellow
(Gunes et al., 2016)	Refractive errors in patients with migraine headache	Yellow
(Iqbal et al., 2021)	Visual Sequelae of Computer Vision Syndrome: A Cross-Sectional Case-Control Study	Yellow
(Lajmi et al., 2021)	Headache associated with refractive errors: Characteristics and risk factors	Green
(Marasini et al., 2012)	Ocular morbidity on headache ruled out of systemic causes — A prevalence study carried out at a community-based hospital in Nepal	Green
(Mehboob et al., 2019)	Ametropia in children with headache	Green
(Neena et al., 2023)	Impact of online classes on eye health of children and young adults in the setting of COVID-19 pandemic: A hospital-based survey	Green
(Wajuihian, 2015)	Frequency of asthenopia and its association with refractive errors	Green
(Wajuihian, 2022)	Characterizing Refractive Errors, Near Accommodative and Vergence Anomalies and Symptoms in an Optometry Clinic	Yellow
Final assessment	Green: 9 / Yellow: 5	Red: 0

Table 1: The overall appraisal is colour coded in green, yellow and red. Green indicates good quality, yellow represents fair, and red is poor quality. Most of the studies are considered to be of good scientific quality, meaning they have few or none flaws. The studies considered to be of fair quality have moderate flaws but are still considered to be above poor quality. There are no studies of poor quality, as they have already been eliminated in the study selection process.

As there were two studies performed by Wajuihian, the studies will be referred to as: Study by Wajuihian (2015) and Wajuihian (2022) to avoid confusion. All studies were published between 2002 and 2023.

Study characteristics

Of the 14 studies, four of them were performed on adults only (where one of them were categorized young adults), four on children only, and six studies included both adults and children (where one study included children and young adults). One study had participants aged 17-54, and since most of the subjects were above 18 years of age, the population groups is considered adult. Another study had subjects between the ages of 17 and 27, which is also considered adult due to the majority of the participants being above 18 years of age. One study had nonstandard age grouping as participants were between the ages 6 and 19, which in this review are considered children due to the majority of participants being younger than 18 years of age.

The 14 studies were performed in 12 different countries, where majority of them are from African and Asian descent. Only two of the studies were performed in Europe, one in England and one in Portugal. Most of the studies were various types of cross-sectional studies. Some studies were retrospective, a few prospective, one observational, and one not specified. Some of these studies were a mixture of cross-sectional and another kind.

The study by Gil-Gouveia & Martins did not specify what kind of study they were performing. The quality assessment of said study is based on guidelines for cross-sectional study, as not all patients had equal follow up. If they did, it would have been a cohort study.

All studies are available in English language.

A quick overview of the characteristics of the studies (in alphabetical order), including their purpose and research questions, and their outcome, can be found in table 2.

Table 2

Authors	Study	Population	Participants	Purpose/Research question(s)	Outcome
(Abdul-Kabir et al., 2023)	Analytical cross-sectional study No control group	Adults in Ghana (17-27 years)	85	Determine the fixation disparity and refractive error of first-year optometry student to ascertain any relationship between them, also identify any association between fixation disparity and visual symptoms at near	Refractive error has no significant effect on fixation disparity. Headache is significantly associated with exo fixation disparity at near
(Akinci et al., 2008)	Retrospective study Control group	Children in Turkey (7-18 years)	1153 (310 in study group and 843 in control group)	Compare prevalence of refractive errors in patients with headache and a control group	In patients with headache, compound and mixed types of astigmatism, anisometropia and mis-correction of refractive error were found more often than in control group

(Alrasheed et al., 2023)	Retrospective study No control group	Children and adults in Sudan (2-39 years)	304	Report clinical characteristics of Sudanese patients with binocular vision disorders who attended orthoptic clinic at hospital	Most common type of binocular vision anomaly was exophoria, with convergence weakness exophoria and convergence insufficiency (CI) being predominant anomalies. Headache was common among participants with binocular vision problems
(Dotan et al., 2014)	Retrospective study No control group	Children in Israel (8-18 years)	917	Determine the frequencies of refractive error, near accommodative and vergence anomalies, and their associations with symptoms of asthenopia	Accommodation anomalies are more frequent than refractive error and vergence anomalies. Accommodation anomalies are also the most symptomatic (40,9% of participants complained of headache). There is a need to diagnose visual symptoms and coexisting anomalies, and a need for establishment of validated study protocols for all accommodative and vergence anomalies
(Evans et al., 2002)	Randomized controlled study Control group	Adults in England (17-54 years)	32 (21 in study group and 11 in control group)	Migraine patients may be hypersensitive to visual stimuli. May prescription of coloured filters be effective treatment to reduce symptoms from such stimuli?	The frequency of headaches in subjects was significantly lower with optimal tint when compared with control
(Gil-Gouveia & Martins, 2002)	Not specified Control group	Adults and children in Portugal (Not specified, 16-55?)	176 (105 in study group and 71 in control group)	Compare overall headache frequency and HARE frequency in healthy subjects with uncorrected or mis-corrected refractive errors versus a control group	HARE is rarely identified in individuals with refractive error. In those with chronic headache, proper correction of refractive error significantly improved headache complaints and decreased frequency of headache episodes
(Gunes et al., 2016)*	Prospective case-control study Control group	Adults in Turkey (19-50)	148 (77 in study group and 71 in control group)	Evaluate refractive errors in patients with migraine headache and compare with healthy subjects	Migraine patients may have higher degrees of astigmatism, spherical equivalent (SE) ametropia, and anisometropia. Regular examinations are recommended to ensure refractive errors are appropriately controlled
(Iqbal et al., 2021)	Cross-sectional case-control study Control group	Young adults in Egypt (20-23 years)	733 (557 in study group and 176 in control group)	Assess the visual, ocular, extraocular and multifocal electroretinography (mfERG) outcomes of CVS among medical students	Among CVS patients, 87,9% had one or more ocular and/or extraocular complaints. The most common extraocular symptom was headache (46,8%). All complaints worsened with prolonged screen hours
(Lajmi et al., 2021)	Cross-sectional, retrospective, comparative study Control group	Children and adults in Tunisia (13-36)	90 (50 in study group and 40 in control group)	Study characteristics of HARE, and to search for the correlation between headaches characteristics and some risk factors. Also assess the impact of these headaches on the quality of life of patients	HARE may influence quality of life, and it needs appropriate treatment based on risk factor management. Appropriate optical correction was prescribed to all participants. There was a report of improvement of headache in 86% of participants

(Marasini et al., 2012)*	Descriptive cross-sectional study No control group	Children and adults in Nepal (<17 - >40 years)	100	Investigate association between ophthalmic anomalies and headache	Ocular anomalies co-exist with headache complaints very frequently (44%). Most headache complaints are overall from non-presbyopic females. Refractive errors and binocular vision anomalies need to be largely investigated in all headache patients
(Mehboob et al., 2019)	Cross-sectional study No control group	Children in Pakistan (5-12 years)	262	Measure frequency of uncorrected ametropia in children with 2-8 weeks of persistent headache, referred to outpatient department for evaluation	Significant proportion of children with ametropia have initial symptoms of headache (21,4%). Any child with unexplained headache must undergo ophthalmic evaluation to diagnose refractive errors, if there are any
(Neena et al., 2023)	Observational study No control group	Children and young adults in India (5-23 years)	496	Analyse the impact of online classes on eye health of children and young adults during the COVID-19 pandemic	Increased screen time, inadequate light setting, and excessive application of near vision can produce undesirable effects, including digital eye strain (DES), worsening or development of new refractive errors and squint
(Wajuihian, 2015)	Retrospective cross-sectional study No control group	Children in South Africa (6-19 years)	1109	Study prevalence of asthenopia and any association with refractive errors in a clinical setting	Most frequent complaint was headache. Females and high school students were most likely to complain of such symptom. Astigmatism was most frequent cause of asthenopia. Further studies to relate binocular vision to asthenopia are needed to enhance understanding of the relationship between binocular vision anomalies and asthenopia
(Wajuihian, 2022)	Prospective cross-sectional study No control group	Children and adults in South Africa (10-40 years)	254	Determine the frequencies of refractive error, near accommodative and vergence anomalies, and their associations with symptoms of asthenopia	Accommodation anomalies are more frequent than refractive error and vergence anomalies. Accommodation anomalies are also the most symptomatic (40,9% of participants complained of headache). There is a need to diagnose visual symptoms and coexisting anomalies, and a need for establishment of validated study protocols for all accommodative and vergence anomalies

Table 2: This is an overall, short, summary of the chosen literature in this review, including authors names, type of study, possession of control group, type of population and geographic location, number of participants, and research question(s) and study outcome. The study by Gil-Gouveia & Martins did not mention span of age amongst participants, only mean age, which was 37,6 in study group and 34,8 in control group. Looking at subjects with HARE, their age span from 16 (youngest) and 55 (oldest). Marasini et al. grouped their subjects into three groups: Younger than 17 years (<17), younger than 40 years (<40), and older than 40 years (>40), and did not mention age span of subjects.

The youngest subjects in all studies were two years old, and the oldest subject were 55, or older, as two studies were not specific about age of participants (study by Marasini et al. and Gil-Gouveia & Martins).

The four studies that were performed on children were the studies by Akinci et al., Dotan et al., Mehboob et al., and Wajuihian (2015). The studies by Akinci et al. and Mehboob et al., were investigating uncorrected refractive errors in children with headache, comparing the results to a control group. The studies by Wajuihian (2015) and Dotan et al. were investigating refractive errors and binocular vision anomalies and the association with asthenopia symptoms. Both studies did not have control groups.

Adult subjects were researched in studies of Abdul-Kabir et al., Evans et al., Gunes et al., and Iqbal et al. The study by Gunes et al. investigated refractive errors in subjects with migraine and comparing to healthy subjects, while the study Evans et al. investigated if coloured filter lenses could effectively be used as treatment to reduce symptoms of visual hypersensitivity in migraine subjects. Both studies compared results to a control group.

The study by Iqbal et al. was investigating visual, ocular, extraocular and mfERG reactions in subjects with CVS, and comparing results with a control group. The study by Abdul-Kabir et al. only investigated the relationship between refractive errors and fixation disparity, and their association to symptoms at near, and had no control group.

The remaining six studies had research that included all ages (children, young adults, and adults). Studies by Gil-Gouveia & Martins and Lajmi et al. investigated characteristics and prevalence of HARE, where Lajmi et al. also focused on quality of life impacted by headache symptoms. Both studies had control groups.

The studies by Alrasheed et al. and Wajuihian (2022) looked at frequency of refractive errors and binocular vision anomalies, and their association with asthenopia. None of them had control groups in their studies.

Marasini et al. researched the relationship between headache and ophthalmic anomalies, while Neena et al. analysed the impact of digital (online) classes on ocular health of students during lockdown of COVID-19 pandemic. Neither of these studies had control groups.

Summary of results

The summarization of relevant results from all studies can be found in Table 3. Irrelevant measurements have not been included in this summary, as it has no significance for this thesis. All studies in this literature review had set their significance of p-value at 0.05. Results that were not significant and have a p-value of more than 0.05, are not presented in the summary text with numeric values.

Table 3

Authors	Summary of relevant results
(Abdul-Kabir et al., 2023) No follow-up Diagnostic criteria for refractive errors Emmetropia: 0.00 D Ametropia: ±0.25 D SE	58,8% females and 41,2% males. All subjects had normal binocular vision. 32,9% of subjects reported symptoms of headache during or after reading, and 30,6% reported symptoms of eye strain during or after reading (with optical correction). Of all subjects, 31,8% were emmetropes, 40% myopes, and 28,2% hyperopes. 61,2% of all subjects with ametropia had no optical correction. Fixation disparity was better in myopes and hyperopes with optical correction than without, but not statistically significant. There was no statistical correlation between refractive error and fixation disparity with and without optical correction. Subjects who experienced headache during or after reading (with optical correction), had significantly higher fixation disparity measurements in exo and ortho direction, opposed to subjects who did not experience headache during or after reading (**p=0,032**). No significant correlation between subjects who experienced eye strain during or after reading, and those who did not, as well as no correlation between subjects who experienced headache and phoria in eso direction.
(Akinci et al., 2008) No follow-up Diagnostic criteria for refractive errors Myopia: ≤-0.50 D SE Hyperopia: ≥+2.00 D SE Astigmatism: ≥1.00 D Anisometropia: ≥2.00 D SE	Study group (headache): 52,9% females and 47,1% males. Control group (no headache): 52,4% females and 47,6% males. Study group contained subjects with headache of unknown origin, and they had been referred to ophthalmology after being evaluated by paediatric neurology and otorhinolaryngology. All subjects wound up at ophthalmology due to systemic disease such as diabetes mellitus, primary hypertension, and juvenile rheumatoid arthritis. Subjects' headache could not be clearly categorized, and fit diagnosis criteria B and C of *11.2.3 Headache attributed to refractive error*. Prevalence of refractive errors in study group was higher than in control group (**p=0,002**), where compound and mixed astigmatism was significantly more common in subjects with headache, as well as severe myopia and severe hypermetropia, and severe and moderate astigmatism. Anisometropia statistically significantly more prevalent in study group (19,7%) than control (2,5% **p=0,0001**). Mis-correction of refractive errors was also more prevalent in study group (16,5%) than in control group (2%).
(Alrasheed et al., 2023) No follow-up Diagnostic criteria for refractive errors Myopia: ≤-0.50 D Hyperopia: ≥+1.00 D Astigmatism: SE + final spherical power	70,7% females and 29,3% males. All subjects had binocular vision anomalies. The association between age (years) and binocular vision problems was statistically highly significant (**p=0,001**), as the distribution of binocular vision anomalies was distributed in three groups: <6 years of age: 5,9%, 6-17 years of age: 51,6%, and >17 years of age: 42,4%. The relationship between ocular symptoms and binocular vision anomalies was also highly significant (**p=0,001**), where headache during reading/fixation was most prevalent (37,8%). VA and refractive errors varied by type of binocular vision problems and were both statistically significant (VA **p=0,001** and refractive errors **p=0,001**).

	Measurements such as near point convergency (NPC) and positive fusional vergence (PFV) also varied by type of binocular vision problem, and both statistically significant (NPC **p=0,001** and PFV **p=0,001**). The most common binocular vision disorder was convergence weakness (45,39%), and it was more prevalent in children 6-17 years of age (51%) and adults >17 years of age (44,2%). Unilateral esotropia was more prevalent among children <6 years of age (38,9%).
(Dotan et al., 2014) Follow-up (Mean 15 months) Diagnostic criteria for refractive errors Myopia: ≤-0.50 D SE Hyperopia: ≥+2.00 D SE Astigmatism: ≤1.00 D Anisometropia: ≤1.00 D SE	43,7% females and 56,3% males. Out of all subjects, only 1,7% (16) had uncorrected ametropia. 62,5% (10) of these children did not report any visual difficulties. After ophthalmological examination and prescription of optimal optical correction, 87,5% (14) of subjects had complete resolution of headache symptoms after one month. VA was statistically significantly improved compared to pre-intervention (**p=0,001**). Anisometropia (10), myopia (10), hypermetropia (6) and astigmatism (3) were the refractive errors that were measured in all subjects. Diagnostic criteria for refractive errors in this study was based on criteria set by Akinci et al. (2008).
(Evans et al., 2002) Follow-up (14-17 weeks) Diagnostic criteria for refractive errors was not defined	Study group (migraine): 86% females and 14% males. Control group (no migraine): Subjects in study group were asked to bring a friend of same gender and similar age. 11 subjects in total. No information about age and gender provided. All subjects went through same measurements, except for one (binocular vision measurements were excluded due to monovision caused by contact lens use). Only statistically significant measurements were divergent fusional reserves (DFR) at distance, as blur (**p=0,032**), break (**p=0,047**) ad recovery (**p=0,019**) was lower for study group. Sheard's value at near was statistically significant (**p=0,032**), suggesting that decompensated heterophoria at near may be a feature of migraine in this sample. Study group experienced more pattern glare than control group (**p=0,004**). Subjects selected their active tint with Intuitive Colorimeter, as well as they got corrected with a control tint (similar saturation but different chromaticity). Subjects were unaware of the identity of active and control tint. At follow-up, subjects got tested again, but with preferred tint, control tint and no tint (hereby addressed as conditions). Measurements that were worse with preferred and control tint: DFR at distance (**p=0,002**), convergent fusional reserves (CFR) (**p=0,033**), increase in degrees of visual perceptual distortion (**p=0,001**). The standard deviation at near for dissociated heterophoria varied statistically significantly between study and control group, with under all three conditions (**p=0,002**), and it varied significantly more with preferred tint than control (**p=0,004**). There was no report of pattern glare under all three conditions. Subjects reported experience of significantly lower frequency of headaches when wearing optimal tint, compared to control tint.
(Gil-Gouveia & Martins, 2002) Follow-up (10 months) Diagnostic criteria for refractive errors was not defined	Study group (ametropia): 49,5% females and 50,5% males. Control group (no ametropia): 52,5% females and 46,5% males. Both groups were similar in presence of headache symptoms. There was no significant difference in pain duration, pain intensity, frequency or photophobia, or aggravation of pain by visual stimuli in different types of headaches (migraine, tension-type, and other primary headache disorders). Subjects in study group were more likely to report pain relief after closing their eyes.

	HARE was found in 6,6% of all subjects. There was no statistically significant association between headache frequency and type of visual error, but there was a significant association between HARE and hypermetropia (**p=0,03**). Subjects that had under- or mis-corrected refractive errors, were corrected with optimal optical correction. Only 38,1% (40) subjects in study group were re-examined after intervention (time of first re-examination not provided). Of them, only 34,4% (36) used optical correction as prescribed. 72,5% of subjects reported improvement of headache symptoms, while remaining 27,5% experienced no change in their headache. Later, within 10 months, 37,5% of all subjects in study group had ceased to suffer from headache after using optimal correction. Subjects who continued to suffer from headache, reported significant reduction in frequency (days) with headache, but no change in duration or intensity.
(Gunes et al., 2016) No follow-up Diagnostic criteria for refractive errors was not defined	Study group (migraine): 88,3% females and 11,7% males. 77 Control group (no migraine): 83% females and 17% males. 71 Subjects in study group had higher prevalence of astigmatism (**p=0,01**), spherical equivalent (**p=0,03**), and anisometropia (**p=0,02**). 45,5% of subjects in study group used optical correction, similarly to study group (42,2%). There was no significant difference in subjects with migraine with aura, and migraine without aura regarding spherical refractive error, spherical equivalent, astigmatism, and anisometropia.
(Iqbal et al., 2021) No follow-up Diagnostic criteria for refractive errors was not defined, but exclusion criteria for refractive errors was defined Myopia: >6.00 D Hyperopia: >4.00 D Astigmatism: >4.00 D	Study group (CVS): 61% females and 39% males. Control group (no CVS): 50% females and 50% males. 87,9% of all subjects had one or more ocular and/or extraocular complaint, though only 70,8% of them associated it with digital screen use. The most common ocular complaint was blurred vision (40,9%) and most common extraocular symptoms was headache (46,8%). Participants reported that all ocular and extraocular symptoms worsened with prolonged screen use (hours). The complaints were also worse at nighttime, and severity and frequency of ocular symptoms increased with number of years using digital screen, except for eye- strain and redness. The most used digital screen device was smartphone, and second most used device was laptop. Ocular and extraocular symptoms were significantly higher in subjects who used smartphones versus laptops and desktop computer. Of them, desktop users had lowest risk of developing CVS complaints. Screen level brightness and screen mode (interrupted or continuous use) had no significant implication on experience of symptoms. The most common factors associated with CVS were close distance from eyes to screen (42,6%), watching the screen in the dark (33,7%), improper gaze angle as screen edge was above/at eye level (28,2%), small sized font (23,9%), and improper lighting conditions (20,9%). Due to mean number of attacks (experience of symptoms) per month (3,6 ± 2,9 (ranging 0-15 attacks/month), it is suggested that CVS may be responsible for chronic complaints in some cases. 78% of all subjects reported repeated attacks monthly. 56,5% of subjects had refractive errors and had statistically significantly higher percentage of most CVS ocular and extraocular symptoms. Mean sphere, cylinder and spherical equivalent were significantly higher in study group opposed to control group (**p<0,0001**), suggesting refractive errors are risk factors in occurrence of CVS. Subjects in control group had significantly better corrected and uncorrected VA (**p=0,001**). Subjects in study group had significantly reduced tear break-up time (TBUT) and Schirmer results when compared to control group (**p=0,0001**) mfERG was only measured in on 40 left eyes (out of 1466 eyes) by random selection. This due to high expenses associated with such testing. Results in control group were considered normal, while 85% of subjects in study group had reduced foveal response.
(Lajmi et al., 2021) Follow-up (1-4 months)	Study group (uncorrected ametropia and headache): Sex ratio 1: 50% females and 50% males. Control group (uncorrected ametropia, no headache): Sex ratio 1,1 (no more information provided).

Diagnostic criteria for refractive errors Myopia: ≤-0.50 D SE Hyperopia: ≥+0.50 D SE Astigmatism: ≤0.50 D Anisometropia: ≥3.00 D in myopia ≥1.00 D in hyperopia ≥1.00 D in astigmatism	92% in study group and 87,1% in control group reported prolonged near visual tasks during professional activity, especially students and administrative staff. 82% of subjects in study group reported suffering from daily and chronic headaches (20,9 ± 15,76 months). Most of the subjects suffered from frontal pain (60%) and 52% had multiple locations of pain. The mean score of intensity on VAS was 4, as most subjects had moderate pain (64%), and only 30% experienced severe pain. The rest of subjects had mild and very severe pain. 58% of subjects in study group reported prolonged digital screen use, and 54% of them reported prolonged reading time triggered headache. In 26% of them, resolution was spontaneous, while the rest had to relieve their symptoms with rest, sleep, and analgesic treatment. In control group, 27,5% of subjects reported prolonged digital screen use and prolonged reading. In study group, 76% of subjects had combined ametropia (spherical ametropia and astigmatism), and 24% had single ametropia. Only 22,5% of subjects in control group had combined ametropia, while the rest (77,5%) had simple ametropia. Orthoptic assessment was abnormal in 50% of cases in study group (exophoria, esophoria and CI), while it was normal in all subjects in control group. The difference between the two groups was statistically significant (**p=0,001**). Univariate analysis showed that prolonged exposure to digital screens, prolonged reading, combined ametropia, moderate myopia, moderate and severe hypermetropia, moderate astigmatism, CI, and esophoria, were statistically significantly linked to HARE. Multivariate analysis identified four independent risk factors related to headache: Prolonged digital screen use (**p=0,013**), combined ametropia (**p=0,001**), moderate hypermetropia (**p=0,01**), and moderate astigmatism (**p=0,03**). The mean value of HIT-6 test score was 54,54 ± 5,8 with a median of 55. High myopia was identified as a risk factor for at least a substantial impact on quality of life (**p=0,014**). All subjects in need were prescribed with optical correction, prism correction, and had orthoptic rehabilitation. 86% of subjects in study group reported headache improvements at follow-up. The univariate analysis showed that conditions such as anisometropia, severe myopia, moderate hypermetropia, and exotropia were significantly linked to headache symptoms.
(Marasini et al., 2012) No follow-up Diagnostic criteria for refractive errors Emmetropia: -0.25 D - +0.25 D SE Myopia: ≤-0.50 D SE Hyperopia: ≥+0.50 D SE Astigmatism: ≥0.50 D	All subjects were divided into three age groups. <17 years of age: 9% females and 11% males (20 subjects). <40 years of age: 42% females and 18% males (60 subjects). >40 years of age: 12% females and 8% males (20 subjects). In total: 63% females and 37% males. Subjects were then divided into occupations students, housewives and others. The most common headache reported was frontal headache (49%, more common in students and housewives). 44% of all subjects had uncorrected refractive errors, where 63,6% were astigmatic, 27,3% were hyperopic, and 9,1% were myopic. Uncorrected refractive errors were observed to be a risk factor for frontal headaches. Binocular vision assessment was performed on non-presbyopic subjects (80). Of them, 16,3% had CI, 11,3% poor fusional vergence and 1,3% intermittent exotropia. 5% of subjects suffered from CVS.
(Mehboob et al., 2019) Follow-up (4-8 weeks) Diagnostic criteria for refractive errors was not defined	53,6% females and 46,4% males. 21,4% of all subjects had uncorrected refractive errors, where 42,8% were astigmatic, 35,7% were myopic and 21,5% were hypermetropic. Mean duration of headache was 4.94 ± 1.84. After intervention (correction of refractive errors), 62,5% of subjects reported alleviation of headache after four weeks, and 75% reported alleviation of headache after eight weeks.

(Neena et al., 2023) No follow-up Diagnostic criteria for refractive errors was not defined	52,8% females and 47,2% males. All subjects were divided into four groups regarding duration of online classes. 1-2 hours: 51,8% 2-3 hours: 20,8% 3-4 hours: 12,1% More than 4 hours: 14,7% 42,5% of subjects used a tablet for their online classes from home and 76,2% had ambient light setting. After online classes, 95,6% of subjects continued to use their electronic gadgets, where 28,6% of them used it more than two hours a day, mainly for entertainment (surfing and gaming). Eye complaints were seen in 50,8% of all subjects, where headache and eye ache were most common (30%). There was a statistically significant association between duration of online classes and amount of eye complaints (**p=0,001**). Univariate analysis showed that eye complaints increased 2,55 times with more than two hours of online classes, while likelihood of eye complaints increased 3,28 times with more than four hours of online classes. The likelihood of headache/eye ache increased 2,13 times with more than two hours of online classes, while it increased 3,19 times with more than four hours of online classes. Children below the age of 10 years with more than two hours of online classes, had 2,06 times increased risk of developing DES, while children above the age of 10 years with more than four hours of online classes, had 2,04 increased risk of developing DES. Preexisting refractive errors were observed in 72% of subjects, and majority of them were compound myopic astigmatic. Preexisting cases of strabismus was observed in 22,8% of subjects. During the study, worsening of refractive errors were seen in 52% of subjects, and worsening of strabismus was seen in 10,1%. New refractive errors were discovered in 15,3% of all participants, and new strabismus was discovered in 12,4%. The newly detected refractive errors were mostly myopia and compound myopic astigmatism. 81,3% of subjects with newly detected strabismus were symptomatic, and had more than four hours of screen time.
(Wajuihian, 2015) No follow-up Diagnostic criteria for refractive errors Myopia: ≤-0.50 D Hyperopia: ≥+0.50 D Astigmatism: ≥-0.75 D	61,5% females and 38,5% males. All subjects were divided into two age groups. 6-12 years of age: 29,7% (329 subjects). 13-19 years of age: 70,3% (780 subjects). Only the right eye measurements were reported. 48,5% of subjects had ametropia, whereas 19,7% were myopic, 15,4% were astigmatic, and 13,4% were hyperopic. 77,5% of subjects had unaided VA of 6/6 or better, while 22,5% had unaided VA worse than 6/9. After optical correction, 96,6% of all subjects had corrected VA of 6/6 or better, while 3,1% were considered visually impaired (no improvement). The most frequent symptom was headache, and it was experienced by 40,8% of subjects. Headache was categorized into temporal (15,7%), frontal (11,5%), general (9,8%), and occipital (3%) headache. Females in general experienced more frequent symptoms, but only headache (**p=0,0003**) and photophobia (**p=0,006**) that were statistically significant more prevalent than in males. Frequency of all types of headaches were also more prevalent in females (**p=0,003**) and occurred more often in age group 13-19 (**p=0,001**). An association between frontal headache and low astigmatism was found to be significant (**p=0,001**), as well between frontal and general headache and compound astigmatism (**p=0,001**). Subjects with low and moderate astigmatism had higher prevalence of headache, compared to emmetropic, high astigmatic and low hypermetropic subjects.

(Wajuihian, 2022) No follow-up Diagnostic criteria for refractive errors was not defined	63% females and 37% males. All subjects were divided into two age groups. Children (10-18 years of age): 33% (84 subjects). Adults (19-40 years of age): 67% (170 subjects). Uncorrected refractive errors were found in 61,2% of all subjects, whereas 30% were hyperopic, 19,6% were myopic and 11,6% were astigmatic, and 3,6% had anisometropia. For single measures, most frequent vergence anomaly was reduced negative fusional vergence (NFV) (17,2%), while the most frequent accommodative anomaly was reduced NPC (30,4%). Children had statistically higher frequency of receded NPC (**p=0,001**), lag of accommodation (**p=0,001**), reduced negative relative accommodation (NRA) and positive relative accommodation (PRA) (**p=0,001**), and accommodative infacility (AIF) (**p=0,001**). For single measure anomalies, accommodative and vergence anomalies, and refractive errors and accommodative anomalies, coexisted somewhat more than refractive errors and vergence anomalies. For syndromes, refractive errors and accommodative anomalies, and refractive errors and vergence anomalies coexisted more than accommodative anomalies and vergence anomalies. 70,9% of all subjects reported they were symptomatic, and the most frequent symptom was headache (41,1%). The most common type of headache was temporal (18,5%). Subjects that had most frequent symptoms of headache, were low astigmatic (44,1%), emmetropic (18,8%), and hypermetropic (11,2%). Subjects that were most symptomatic, had reduced NRA (30%), PRA (22%), and NFV (13,6%), while subjects with moderate to high astigmatism were least symptomatic. Symptoms of asthenopia was significantly more frequent in adults (**p=0,01**).

Table 3: This table contains summary of results, and their significant p-values (when provided) are highlighted in bold. Studies varied on how many measurements were performed, and how widely they described the results. Measurements that were not relevant for this review have not been added to avoid unnecessary information.

The studies that looked primarily at refractive errors and its association with headache symptoms, were studies by Akinci et al., Dotan et al., Mehboob et al. and Gunes et al. More studies were looking at both refractive errors and binocular vision anomalies in association with headache symptoms, such as Abdul-Kabir et al., Alrasheed et al., Evans et al., Marasini et al., Wajuihian (2015) and Wajuihian (2022). One article (Neena et al.) studied the impact of digital online classes on eye health, where the ophthalmic examination included both refraction and binocular vision assessment. Two of the studies investigated the frequency of HARE, where the study by Gil-Gouveia & Martins included refractive measurements and a questionnaire, while the study by Lajmi et al. investigated both refractive errors and binocular vision anomalies, as well as the impact of headache and ametropia on quality of life. Two studies looked at prevalence and impact of CVS on subjects in their study (Iqbal et al. and Marasini et al.).

There were two studies that looked primarily at subjects with migraine headaches (Gunes et al. and Evans et al.), while the rest looked at headaches in general, and headaches that could not be categorized properly. The most common types of headaches (when localization or type was mentioned) was frontal (Marasini et al. and Lajmi et al), temporal (Wajuihian 2015 and 2022) and migraine headache.

Some studies excluded migraine subjects, namely studies by Lajmi et al., Wajuihian (2022), and Mehboob et al, while the study by Marasini et al. excluded subjects with pregnancy induced migraine. Some of the studies also noted that they excluded subjects with ocular and systemic disease, but not all studies specified what kind of ocular and systemic diseases were excluded, namely studies by Alrasheed et al., Evans et al., Iqbal et al., and Gunes et al. One study did not mention exclusion of ocular and/or systemic diseases (Abdul-Kabir et al.). The rest of the articles had clear or semi-clear directions on what ocular and/or systemic diseases was excluded from their research.

Both studies by Wajuihian (2015 and 2022) included only Black African participants.

Seven of the studies had defined diagnostic criteria for refractive errors in their research, while six of the studies did not include what diagnostic criteria they were following. The study by Iqbal et al. did not have any clear diagnostic criteria for refractive errors other than what was maximum diopters allowed for their subjects (anything beyond got excluded).

Most of the studies had a slight, moderate, or high female preponderance amongst their participants. The only study that had an equal distribution of genders, were study by Lajmi et al. and the control group in study by Iqbal et al. The only two studies that had a slight male preponderance was the study by Dotan et al. and Gil-Gouveia & Martins (study group).

Cycloplegic refraction was performed in eight studies, where four of them had certain criteria. The study by Alrasheed et al. only performed cycloplegic refraction on children, while Akinci et al. only performed cycloplegic refraction on children below 10 years of age, and Wajuihian (2015) used cyclopentolate on children below 13 years of age. In the study by Marasini et al. there was certain criteria for cycloplegic refraction: It was performed on all children below 15 years of age, subjects with binocular vision anomalies, and in subjects where there was a fluctuating refractive status.

The studies that looked more at prevalence of visual anomalies and the association to ocular and extraocular symptoms, had no control groups to compare to. These studies were by Abdul-Kabir et al., Alrasheed et al., Dotan et al., Marasini et al., Mehboob et al., Neena et al., and both studies by Wajuihian. The rest of the studies had control groups to compare with.

Follow-up was performed in only 5 studies, namely studies by Evans et al., Mehboob et al., Dotan et al., Gil-Gouveia & Martins, and Lajmi et al. The rest of the research did not include follow-up for their participants, hence having no knowledge if intervention in their subjects would change the experience of their symptoms. Several of them did though mention it as their limitation.

After participants got their ametropia corrected with optimal optical correction, a significant percentage of subjects had improvements or complete resolution of their headache symptoms. This happened to subjects in study by Mehboob et al. were 75% of all participants experienced alleviation of their headache after 8 weeks after intervention. 87,5% of participants experienced also full alleviation of symptoms after 1 month in the study by

Dotan et al. In the study by Gil-Gouveia & Martins, improvement was noted in 72,5% of their subjects after intervention, where 37,5% experienced full alleviation of symptoms within 10 months after intervention. The rest of subjects (27,5%) had a significant reduction in frequency of headache attacks. The study by Lajmi et al. implemented correction of ametropia, prisms and orthoptic rehabilitation for subjects in need, and noted significant improvement in 86% of them. The study by Lajmi et al. had a mean follow-up time of 2,4 months.

The studies that found a statistically significantly higher prevalence of refractive errors and/or binocular vision anomalies in subjects with headache disorders, were studies by Abdul-Kabir et al., Alrasheed et al., Akinci et al., Gunes et al., Wajuihian (2015), and Wajuihian (2022).

The study by Marasini et al. suggests that there is evidence of a relationship between ocular morbidities and headache symptoms, but there are limitations to their study as they had neither a control group nor follow-up for their participants.

The studies that found statistically significant improvement in headache symptoms after correcting their ametropia with optical correction, prism correction, orthoptic rehabilitation, and filter lenses, were studies by Evans et al., Gil-Gouveia & Martins, Lajmi et al., and Mehboob et al.

Even though the study by Dotan et al. found a significant improvement in headache symptoms after optical correction, researchers did not have a study group to compare results with, hence they cannot determine if the prevalence of uncorrected ametropia in children with headache is any different than in children that were admitted for other reasons.

5 Discussion

In this literature review, 14 articles were reviewed regarding different visual conditions and their possible effect on subjects with headache symptoms. Most of the studies performed were cross-sectional, meaning that results came from observation of a population at a given time. Visual conditions that were explored were refractive errors, binocular vision anomalies, computer vision syndrome and the use of filter lenses. Several studies looked at more than one of the visual conditions mentioned beforehand.

Majority of the studies in this review found significant improvement in headache sufferers after correction of ametropia, heterophoria and/or orthoptic exercises. Many of these studies also found a statistically significant association between ametropia, and/or binocular vision anomalies in subjects with headache when compared to control groups. How significant and applicable these results are on the general population can be discussed, as several of these studies had limitations and varying differences such as study design, methods, and diagnostic criteria for refractive errors. As comparison of these studies is complicated, exercising discernment is advised when interpreting the findings. Other literature on similar topic have also noted such difficulties (Atowa et al., 2019; Harle & Evans, 2004).

A majority of the studies in this review came from countries that are still in development, whereas three of the studies, namely England, Portugal, and Israel, are from countries that are considered developed when it comes to standard of living and advanced economies (International Monetary Fund, 2023). It is unknown if more modern and developed countries take it for granted that headache sufferers will seek help from optometrists and ophthalmologists to rule out cephalgia induced or worsened by visual anomalies, or if it is assumed that there is enough knowledge on the topic, and that only a small percentage of headache complaints are partially or fully due to ophthalmic reasons. As it is mentioned in ICHD-3's paragraph 11.3.2 about HARE (Olesen et al., 2018), refractive errors are much less commonly cause for headache than it is generally believed, there is no mention of prevalence or estimation on how often or seldom it is the case. Therefore, it is somewhat difficult to argue if prevalence in a study is higher or lower when compared to ICHD-3's statements.

Female preponderance in studies

There was a notable gender imbalance, where three of the studies exceeded 70% female subjects. This may be caused by the fact that women are more prone to headache (Pascual et al., 2001; Rossi et al., 2022), and naturally more females than males joined studies regarding headache symptoms, or females with headache symptoms are easier to obtain than male subjects, alternatively, the observed phenomenon is caused by entirely different factors. What is certain, is that the numbers are consistently showing a female preponderance, and it is unlikely it is random.

Women in these studies also were often more significantly symptomatic than men regarding headache symptoms, which is consistent with previous research (Pietrasik & WHO, 2016).The reason why females are more prone to headaches is still somewhat unclear, but it is hypothesized that it may be due to hormones and environmental factors (Rossi et al., 2022).

Diagnostic criteria for ametropia

The was a variety in diagnostic criteria values between the studies, where six of them did not include which criteria for refractive errors they were following when assessing refraction results. The study by Iqbal et al. did not include values for diagnosing, but stated their exclusion criteria if spherical or cylindrical power exceeded a certain amount. Reason why was not provided. Most of the studies in this review found an association with headache and low refractive errors more often than between headache and high ametropia.

The study by Dotan et al. had based their diagnostic criteria set by the study of Akinci et al., except for Dotan et al. set criteria for anisometropia at ≤1.00 D SE, while Akinci et al. had it set at ≤2.00 D SE. Schieman & Wick suggest that a significant amount of anisometropia is 1.00 D, either sphere or cylinder (Scheiman & Wick, 2014), so one may argue anisometropia of less than 2.00 D may instigate some binocular vision problems. The study by Lajmi et al. set different criteria for anisometropia in myopes, hyperopes and astigmats. The anisometropia criteria for myopes was three times higher than for hyperopes and astigmats, this is probably due to the fact that myopic anisometropia up to 3 D usually does not cause amblyopia, while hyperopic anisometropia of 1-2 D may induce amblyopia (Gabai & Zeppieri, 2024). In regard of scientific research and finding association between headache symptoms and ametropia, it is also important to not set the criteria too low, as it may include subjects who are not likely to be prone to headache complaints due to their refractive errors. The study by Abdul-Kabir et al. set criteria for emmetropes at 0.00 D, meaning anything above or below is considered as an ametropia. When comparing the diagnostic criteria set by other studies and literature in general, one may argue that the diagnostic values set by Abdul-Kabir et al. are somewhat unspecific.

Headache associated with refractive errors

There were a few studies that looked at headache symptoms in accordance with refractive errors solemnly, such studies were by Akinci et al., Dotan et al., Gil-Gouveia & Martins, and Mehboob et al. All four studies had similar measurements such as uncorrected and corrected visual acuity, and refraction with and without use of Cyclopentolate. All studies except for the study by Dotan et al. mentioned the use of an autorefractor, and only Dotan et al., Gil-Gouveia & Martins, and Mehboob et al. mentioned they performed cycloplegic refraction. Three of these studies included examination of the anterior and posterior segment, probably to rule out other eye conditions that can lead to headache symptoms as well. The study by Mehboob et al. mentioned some examinations that were later not mentioned in results (cover test and stereopsis), leaving it open for interpretation if they were within normal limits, or if there were any indication that further testing is necessary.

The studies by Akinci et al. and Gil-Gouveia & Martins mentioned they excluded subjects with heterophoria (binocular vision anomaly), as they are known to cause headache issues (Scheiman & Wick, 2014). Which is reasonable to do when investigating the association between headache and refractive errors solemnly. The study by Mehboob et al. excluded children with previously known refractive errors from their study. Assuming this was done to avoid subjects whose headache will not benefit from optical correction, there are no mention if they were using proper correction, or any correction at all.

In the study by Dotan et al., participants with known refractive errors and in need of optical correction were excluded, without clarifying if optical correction was used or not. If many of these excluded subjects were aware of their refractive errors but were not using optical correction and had headache symptoms, it is arguable they could have been included in the study to see if their headache complaints lessened or resolved with proper optical correction.

These studies had a control group to compare results with, except for study by Dotan et al. and Mehboob et al. The study by Akinci et al. found a significantly higher prevalence of refractive errors such as astigmatism, severe myopia and hyperopia, and anisometropia and mis-correction in individuals with headache complaints compared to subjects without headache complaints. A possible theory as to why uncorrected ametropia can induce asthenopia leading to headache, in hyperopes and individuals with astigmatism it may be the prolonged contracture of ciliary muscles due to sustained use of accommodation, and inability to relax. In myopes, it is theorized that squinting of forehead and eyelids to create a small aperture for sharper vision, as a small aperture can minimize aberrations (Strauss & Azar, 2007). Something the study by Akinci et al. lacks is a follow-up to see if participants in their study could benefit from optical correction regarding their headache complaints.

There were more than twice as many participants in the control group as study group in the study by Akinci et al., leading to the possibility of results being interpreted in two ways: Either there is indeed a high significant prevalence of refractive errors in subjects with headache (as participants were retrospectively evaluated and not recruited, there is no recruitment bias) compared to controls (no headache), or, since the study group is more than twice as small, could there be randomly more subjects with headache in study group?

The study by Dotan et al. had a small study sample, as there were only 16 individuals with refractive errors in a group of 916 participants. Hence no control group, the authors of this study cannot determine whether their results prove there is a higher prevalence of uncorrected refractive errors in children with headache than children admitted for other reasons. As this was a retrospective study, missing data could not be obtained easily, and it is not known what the authors did in those cases. For instance, it is noted that not all children with headache complaints underwent a complete eye examination, hence there is a possibility that the prevalence of uncorrected ametropia in children with headache can be higher than assumed in this study. The authors concluded that uncorrected refractive errors may be a possible cause for headache symptoms among hospitalized children, and they believe that proper ophthalmic examination including refraction is important in such subjects.

Gil-Gouveia & Martins concluded that occurrence of HARE is rare in their subjects. Authors also suggest that individuals with refractive errors could benefit from optical correction without the presence of HARE, as 72,5% of subjects experienced improvement in their headache symptoms. Initially authors decided to follow-up 47 out of 105 subjects with ametropia and headache complaints, but only 36 (34,3%) of them completed the follow-up. It is unknown how high the total percentage would have been if all subjects in study group would have been followed up properly. This is one of the reasons why the quality of this study was categorized yellow, for fair.

After 8 weeks of intervention (optical correction), 75% of subjects reported alleviation of headache, while 25% still experienced headache, in the study by Mehboob et al. Others have also seen the possibility of refractive errors being a culprit of headache in schoolchildren (Hendricks et al., 2007).

These four studies had some limitations to them, as some were lacking a control group and/or follow-up of their participants. Akinci et al. had subjects recruited from a hospital in their study, thereby results may not be totally translatable to the general population. The study by Gil-Gouveia & Martins had a very small group of subjects that completed the follow-up opposed to the initial study group, thus, the real results may potentially deviate from current data. As not all subjects in the study by Dotan et al. underwent complete eye examination, calculated prevalence of ametropia may be incorrect. The sample size (especially study group) of study by Dotan et al. was very small. There are some limitations to the study by Mehboob et al. as well. One of them is believed to be the exclusion of children with known refractive errors (bearing in mind there is a possibility optical prescription is not used properly). Another is the confusion of not having a control group, but separating all included subjects into two groups, and only comparing age and duration of headache. This last study was also in a hospital-based setting, also making translation of result to the general population troubling.

Headache associated with binocular vision anomalies & refractive errors

There were more studies that looked at both refractive and binocular vision anomalies in association with headache, such as studies by Abdul-Kabir et al., Alrasheed et al., Lajmi et al., Marasini et al. and both studies by Wajuihian (2015 and 2022). Only the study by Lajmi et al. had a control group follow-up of their subjects, where a significant number of subjects reported headache improvement. Most of these studies excluded normal binocular vision and strabismus, lastly of unknown reasons. The study by Marasini et al. had excluded subjects with migraine, women with menstrual migraines and women taking oral contraceptive, lastly probably due to the risk medication induced headache (Loder et al., 2005). What these studies had in common were measurements such as VA, refraction (with and without use of Cyclopentolate), cover test, and a variation of binocular vision assessment. The studies that did not perform cycloplegic refraction noted they were fogging subjects with at least +2.00D lens, for accommodation control, while some studies used cyclopentolate only during certain criteria.

Cyclopentolate is a drug used for partial or total paralysis of accommodation, and is often used, especially in children, to avoid accommodative fluctuations that can lead to under- or overestimation of refractive errors (Bausch + Lomb, 2023). Cycloplegic refraction is usually recommended in all children due to over-focusing and difficulties with cooperation (Major et al., 2020). Atropine is another drug that has similar qualities, but can last up to 7-10 days (Bausch + Lomb, 2022), while Cyclopentolate usually lasts up to 24 hours. For the purpose of cycloplegic refraction, research suggests that Cyclopentolate 1% has sufficiently similar cycloplegic effect as Atropine 1%, with lesser adverse effects (Elliott, 2014). Subjects in the study by Lajmi et al. were using Atropine eight days prior to refraction. As the effect of mydriasis can be quite unpleasant, it is considered Atropine in this study setting unnecessary.

In scientific investigations, it is recommended to perform cycloplegic refraction to mitigate procedural imperfections and inaccurate results (Sun et al., 2019).

In the study by Abdul-Kabir et al., 62,1% of subjects with refractive errors did not use optical correction. 55,6% of these were hyperopes and 44,4% myopes. Even low degrees of myopia and hypermetropia may lead to headache symptoms (Jain et al., 2014; Thorud et al., 2021). Curiously, it is noteworthy that all these uncorrected subjects were 1st year optometry students. The authors do not provide information about severity of their refractive errors, and one may presume they are low hyperopes and do not feel the need for optical correction daily. It is important to note that unnecessary use of optical correction may also result in eyestrain and headache complaints (Robaei et al., 2006).

As one of the few studies in this review, Abdul-Kabir et al. did not find many strong correlations between visual anomalies and headache, except for an association between headache and exo fixation disparity at near.

Most binocular vision anomalies were found in subjects aged <6 years of age, and Alrasheed et al. found headache to be significantly prevalent among participants with abnormal binocular vision. This statement is supported by others (Hussaindeen et al., 2017; Scheiman & Wick, 2014). 74% of exophoric subjects complained of headache during reading, most likely due to the divergence of the eyes, increasing the need for muscle activity to compensate for the misalignment (Barden, 2021).

Almost half of all subjects in the study by Marasini et al. had refractive errors. The authors suggest there is a frequent prevalence of ocular anomalies in co-existence with headache symptoms. The same conclusion had study by Wajuihian (2015). The only studies that talked about quality of life were studies by Lajmi et al, Marasini et al., Mehboob et al., and Wajuihian (2015).

In the study by Lajmi et al. there were measurements of pain intensity with use of VAS and headache's impact on life with HIT-6, which had respective mean scores of 4 (VAS) and 55 (HIT-6), meaning the pain was moderate for most of the subjects. The score on HIT-6 of 50-55 indicates that headache was some impact on the quality of life, and a score of 56-59 indicates that headache has a significant impact on the quality of life (Kosinski et al., 2003). The mean score of 59 indicates most of the subjects experience close to significant impact on their quality of life. Research has shown that headache sufferers may have a higher prevalence of developing other comorbidities such as depression, anxiety, back pain and more, which in turn can have a big impact on life quality in a negative way. Treating headache disorders may improve quality of life as well as contribute positively towards reducing the impact of other high-burden conditions (Caponnetto et al., 2021). A large proportion of subjects in study by Lajmi et al. exhibited headache improvements after intervention of optical and prism correction, and orthoptic exercises. It was not mentioned if HIT-6 was performed after intervention, which is unfortunate as it could have given helpful insight of headache's impact on life after intervention.

The only two studies in this review that had any exclusion criteria regarding ethnicity, was both studies by Wajuihian, where only Black African population was included. The study from 2015 was primarily investigating prevalence of asthenopia and its association to ametropia, while the study from 2022 was on characterizing different visual anomalies in an optometry clinic. The most frequent symptom in 2015 study was headache, and females of the study experienced more frequent symptoms of headache than males. This is consistent with research that states women are more susceptible for cephalgia (Pascual et al., 2001). The ametropia that was mostly associated with asthenopia and headache symptoms, was (low) astigmatism in both studies by Wajuihian, which is also the case in another literature review (Harle & Evans, 2006). The study from 2022 also noted that asthenopia is significantly more frequent in adults, which is considered natural, as adults usually have more prolonged reading and use of digital screens (Howarth, 2023).

As with other studies, these had some limitations as well. Some of these studies were also lacking a control group and/or follow-up. It is assumed that correction of ametropia may have provided more knowledge and insight in how optimal prescription may affect subjects with ocular and extra-ocular complaints. A limitation of both studies by Wajuihian was the lack of the explanation behind the inclusion criteria of only subjects of Black African origin. The study from 2022 mentioned a relatively small sample size (especially when compared to the study from 2015). The study by Abdul-Kabir had a narrow variety of refractive errors in their sample, and a small sample as well. The studies by Alrasheed et al. and Marasini et al. were hospital-based, and as with the study of Akinci et al., outcomes of the studies may not be completely transferable to the general population. The study by Alrasheed et al. also lacks information about treatment and progress of subjects in the sample group. The study by Lajmi et al. had a narrow sample size.

Subjects that were diagnosed with headache of known etiology were excluded from the study by Marasini et al. It may have yielded interesting results if they were included and re-examined again after some time after intervention (optical correction), this to assess the potential effect of optical intervention in headache-related complaints.

Visual anomalies in migraine subjects

The two studies in this review that investigated migraine subjects were studies by Evans et al. and Gunes et al. While Gunes et al. researched the prevalence of refractive errors in their sample, Evans et al. investigated if tinted spectacles could improve migraine symptoms in their subjects.

The subjects in the study by Evan et al. were not entirely randomly selected, as authors of the paper asked neurologists, general practitioners, and optometrists to refer migraine patients to their study for research purposes. Out of 21 subjects in total, only 17 completed the trial (including follow-up) for unknown reasons. In this study and sample, there were border-line significance of correlation between migraine subjects and astigmatism. The study by Gunes et al. concluded that refractive errors such as astigmatism, anisometropia and SE may be more prevalent in subjects with migraine. They also saw a significant correlation between duration of attack and grade of astigmatism, suggesting ametropia may have an impact on duration of migraine attacks. Unfortunately, as there was no follow-up for said subjects, there is no evidence of improvement of headache complaints with treatment (optical correction). A literature review performed by Evans and Harle investigated literature on the association between migraine headache and refractive errors, and concluded that there seems indeed to be a higher prevalence of low astigmatism and anisometropia in such subjects (Harle & Evans, 2006).

The only study out of all in this review to include examination and measurements of anterior chamber depth (ACD), central corneal thickness (CCT), and axial length, was the study by Gunes et al. There are currently no studies that have investigated the sole association between headache and axial length, CCT and ACD. It is known that headache symptoms can occur in individuals with acute angle closure glaucoma (Kanski & Bowling, 2011), and factors such as ACD and CCT are important regarding diagnosing and further treatment of glaucoma. The motivation behind measurements of ACD and CCT and how they may impact subjects with migraine headaches, are unfortunately missing from the study.

It was observed that methodology section of the study by Gunes et al. was missing some steps and may be challenging to replicate. It was noted by the authors that refractive errors were analyzed with an autorefractometer, and since no more information is provided, one may assume that subjective refraction was not performed. The authors of this study had also mentioned that severity of headache was assessed with VAS, but score results could not be found in the study (except for calculated Pearson correlation coefficient). There was also no binocular vision assessment to rule out amblyopia, strabismus, or other abnormal binocular conditions.

Limitations of study by Evans et al. were that all subjects were pre-selected, and the study sample was small. As this was a randomized controlled study, and sample was not obtained randomly, the randomization of the study was subjects wearing two different filters (one selected after colorimetry assessment, and one that was assigned to them) without them knowing which filter is the active. The slight deterioration in the orthoptic status after use of colored overlays calls for a thorough investigation to elucidate the long-term ramifications, if any, in subjects involved (and future individuals).

Headache associated with CVS

The only two studies in this review that investigated CVS, were studies by Neena et al. and Iqbal et al. Only one of them had a control group (Iqbal et al.), but neither had follow-up of their participants. As the study by Neena et al. was observational, records of participants’ ophthalmological examinations were obtained from pediatric ophthalmology and strabismus department in India, meaning no actual ophthalmological examination was performed by the authors. Both studies had a CVS questionnaire and ophthalmological examinations such as VA, refraction, slit lamp examination, and fundus examination. What the studies did not have in common, was the study by Iqbal et al. performed subjective and cycloplegic refraction, while the study by Neena et al. only mentioned refraction, leaving it open for interpretation if it was done objective (autorefractor), and/or subjective. Subjects in the study by Neena et al. underwent binocular vision assessment, opposed to participants in study by Iqbal et al.

Both studies found headache complaints in their subject sample (30-46,8%). Study by Neena et al. found an increase in ametropia and strabismus in a substantial number of subjects, supporting the hypothesis about myopia increase in children with prolonged screen time (Lança & Saw, 2020). The study by Iqbal found a significantly higher prevalence of ametropia in subjects with CVS complaints, suggesting refractive errors may be a risk factor for CVS, whereas similar findings and theories may be observed in other studies (Peter et al., 2023).(Shrestha et al., 2020)

A review on computer vision syndrome concluded that a thorough anamnesis and ocular examination is important to identify ocular complaints in association with VDT usage, and a possible management of such symptoms consists of several factors: Improving the ergonomics of the workstation, optical correction (when needed), periodically scheduled breaks, and appropriate lighting (Blehm et al., 2005).

Eye examination in a clinical setting

The clinical guidelines for opticians and optometrists may vary in different clinics and countries, and may also vary depending on type of population, knowledge, and availability of instruments. There are no official guidelines for optometrists in Norway other than the recommended clinical guidelines developed by NOF (Klæboe, 2024). These guidelines are meant for everyday clinical work, and they are regularly updated for evidence-based practice. Yet not all practitioners in Norway follow these guidelines, and they may perhaps overlook or not discover significant findings.

Several of the studies in this review also pointed out the need for guidelines and protocols for patients suffering from headache and asthenopia. There are currently no official guidelines regarding diagnosing, treating and follow-up of headache patients in Norway and Scandinavia. Authors of studies in this thesis suggest creating guidance protocol and treatment and follow-up protocol for such patients, to make it easier for future clinicians, and provide more optimized care.

There was a substantial variety in methodology between studies in this review. All studies had included examination of uncorrected/corrected VA and refraction, but the rest of the tests varied widely. Some studies performed only objective refraction with an autorefractor, while others performed subjective refraction, with and without drugs. Possible complications with autorefractors are over- or underestimation of refractive errors, especially in children and young adults with poorly controlled accommodation, somewhat inaccurate estimation of high refractive errors, involuntary eye movements, such as nystagmus, conditions such as keratoconus may go unnoticed, and others (Gurnani & Kaur, 2024). For accurate measurements, it is recommended to perform subjective refraction (if the patient is cooperating), perhaps after retinoscopy and/or with use of cycloplegia (Elliott, 2014). Those who performed binocular vision assessment had great variety in both examinations and examination techniques. There is a plethora of different testing techniques, provided the methods are validated, choice of technique is up to the clinician.

There were several studies that included a questionnaire regarding headache, which also varied widely from one another. What characterizes a good questionnaire, is how well questions are made (open/closed), reliability, preciseness, and interest (Brosius et al., 2022). It is also important to note that subjects may exaggerate symptoms, frequency, and more when answering questionnaires, and if there are ocular examinations that can confirm or deny their claims, it is useful to perform both and compare the results. For instance, 87,9% of subjects in the study by Iqbal et al. self-reported CVS related symptoms through the questionnaire, while ophthalmic examinations revealed a prevalence of 76% that had CVS related symptoms in the same sample. In this case, the authors assumed that the ophthalmic examination was more accurate than the questionnaire.

Many of the studies in this review had eye examinations on subjects performed by an ophthalmologist, which may be the norm in their respective countries. There are less than 500 practicing ophthalmologists in Norway as of spring 2024 (Høvding, 2020). The education level of opticians and optometrists in Norway is high, and with the European Diploma specialization, which is the highest level of authorization for optometrists in Norway, they have the opportunity to practice in over 20 European countries (ECOO, 2021, 2022). The ratio of ophthalmologists to patients is disproportionately low, hence the wait time may be long, and there are few ophthalmologists that perform refractive examinations in Norway. Experienced opticians and optometrists in Norway are better positioned to assume the responsibility of easing the load and help such patients more rapidly. Due to this being current practice in Norway today, following only guidelines created by ICHD-3 lacks coherence, as they imply patients with HARE will seek advice from an ophthalmologist (Olesen et al., 2018). If there is suspicion of headache induced by visual anomalies, a patient may be referred to an ophthalmologist, but as long a refraction and assessment of binocular vision is not performed, that same patient must be referred to an optometrist for further evaluation, which can result in lost time and unnecessary costs for the individual and society.

ICHD-3's classification does not mention if existing headache may be aggravated by visual anomalies. There are yet no official classification of headache attributed by heterophoria or heterotropia, as it is pending more formal studies (Olesen et al., 2021).

Correction of visual anomalies as intervention

Visual anomalies are usually corrected with optical correction in the form of prescription spectacles, tinted filters that may be applied as an overlay over glasses, or as a coating applied on the lenses, contact lenses, and with the help of orthoptic exercises. In some cases, there may a need for surgical intervention. Spectacle correction and/or contact lenses are usually easy to fit and use and cause little to no side effects (with proper use), especially when compared to the economic burden of visiting one or several medical professionals and prescription medication. It is though important to bear in mind that pricing of optical correction varies, and affordability will depend on individual's funds.

It is not unusual for headache patients to undergo expensive testing like magnetic resonance imaging (MRI), and sometimes even a computer tomography (CT) and a sample of cerebrospinal fluid (CSF) may be needed (De Luca & Bartleson, 2010). These examinations are usually costly and may cause individuals discomfort and pain. Not all patients receive successfully a headache diagnosis, or necessarily correct diagnosis and treatment, which in turn can result in a failed management strategy, and in some cases lead to medication overuse (Davies et al., 2019). Eye examinations are usually pain-free and not invasive, and the wait time for an appointment with optometrist in Norway is also usually short. If there are no signs of serious illness or need for acute medical help (assessed by a medical professional like general practitioner), may individuals suffering from headache be referred to their local optician first? As optometrists are healthcare professionals trained in discovering certain eye and general health conditions, such as signs of papilledema, high intracranial pressure, hypertension, and other conditions that require further investigation, a discovery of such condition will result in need for further referral (ophthalmologist or general practitioner). If headache complaints persist or increase after visual correction, it is advised to seek professional medical care in the right place.

If current headache complaints are aggravated or caused by visual anomalies, visual correction may be a low-cost intervention that may save personal and societal funds, and unnecessary referral and wait time.

It is important to note that these are not direct recommendations for patients, and advice should be approached with critical discernment, as contextual relevance and limitations must be considered.

Final remarks

Older review that looked at research published between 1904 and 1995, concluded that it was not possible to support or reject the hypothesis of uncorrected refractive errors causing headache symptoms, and that further research is necessary (Gordon et al., 2001). This thesis shows a correlation between these factors, but with limitations.

As health care systems in different countries do not operate equally, following one set of clinical guidelines will not guarantee that protocol will or can be followed correctly. It is advised that guidelines are adjusted to each region, depending on available knowledge, population, funds, and other factors. Standardized guidelines and examination protocols for opticians is also needed, especially for vulnerable subjects with headache disorders. A study by Shah et al. discovered that there are substantial variations between clinicians regarding depth and accuracy of the examination of their patients (Shah et al., 2008). A standardized clinical examination routine can aid in discovery of findings that could have been missed and may help secure better-quality assessment of patients.

Some limitations to this review include many different study designs. The task of sourcing studies with similar study design covering a time span of 10-12 years proved challenging, even though publishing year was not limited in the academic search of this thesis. Another limitation was the lack of investigation of guidelines for optometrists from respecting countries, and discussion of their similarities and differences. The scientific quality of assessed articles may have been somewhat flexible.

As it was noted by several authors in this review, and as this thesis also reveals, there is indeed a need for more studies of high scientific quality (preferably using standardized methodology), sufficient sized samples, and preferably not hospital-based, as it may be trivial to translate results and prevalence for the general population. The fact that this topic has been somewhat researched throughout the years, indicates there are reasons behind the theories, unfortunately not all researchers agree completely.

6 Conclusion

The quality of clinical examination and sample sized varied greatly in reviewed studies, and their results and conclusions should be interpreted from a critical perspective. Overall results indicate there is an association between headache disorders and visual anomalies, and a thorough clinical eye examination is recommended for patients suffering from headaches. Optical correction, either with spectacles, filter lenses, and/or orthoptic exercises may reduce the frequency and severity of headaches, and in some cases lead to complete alleviation of symptoms.

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List of tables and figures

Annexes

Abbreviations

This is an overview of the abbreviations used in this thesis, in alphabetical order.

ACD = Anterior Chamber Depth
AIF = Accommodative Infacility
CCT = Central Corneal Thickness
CFR = Convergent Fusional Reserves
CI = Convergence Insufficiency
CINAHL = Cumulative Index to Nursing and Allied Health
CSF = Cerebrospinal Fluid
CT = Computer Tomography
CVS = Computer Vision Syndrome
DES = Digital Eye Strain
DED = Dry Eye Disease
DFR = Divergent Fusional Reserves
EBSCO = Academic Search Premier
EHF = European Headache Federation
HARE = Headache Associated with Refractive Error
HIT = Headache Impact Test
ICHD = International Classification of Headache Disorders
mfERG = Multifocal Electroretinography
MRI = Magnetic Resonance Imaging
NFV = Negative Fusional Vergence
NOF = Norges Optikerforbund
NPC = Near Point of Convergency
NPU = National Board of Scholarly Publishing
NRA = Negative Relative Accommodation
PFV = Positive Fusional Vergence
PRA = Positive Relative Accommodation
SE = Spherical equivalent
STROBE = The Strengthening the Reporting of Observational studies in Epidemiology
TBUT = Tear Break-up Time
USN = University of South-east Norway
VA = Visual Acuity
VAS = Visual Analogue Scale
VDT = Video display terminal
WHO = World Health Organization